Agency and the Pace of Adoption of New Techniques

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1 Introduction

This paper is an exploration of how financial contracting can determine the pace of technical change in modern, developed economies. An important characteristic of such economies is that most economic activity takes place within large, complex organizations where the interests of the individuals who make them up are very often in conflict with one another. One of the most important of such misalignments of interests results from the separation of ownership and control, identified long ago by Berle and Means (1932) and subsequently extensively studied in corporate finance following the seminal paper on agency cost by Jensen and Meckling (1976).[1]

In this paper we adopt a dynamic, agency theoretic model to examine the pace of technological advance when firms are owned by outside investors but are run by professional managers. Because perfect monitoring is difficult to achieve, once a manager is in charge he has some latitude to make decisions that favor his interests in opposition to those of outside shareholders. There are limits to how much an incumbent manager can exploit his advantage as a firm insider because he faces the threat of being replaced with another outside manager with similar skills. However, if it is anticipated that the potential replacement manager would also exploit his

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[1] For a recent survey emphasizing the incomplete contracts approach to modeling corporate finance see Oliver Hart's monograph (1996). We adopt the incomplete contracts approach in the model presented here.

advantage as insider to some degree, the incumbent's rent extraction will be curbed but not eliminated altogether. Thus owners of firms will tend to tolerate some degree of organizational slack in the operation of assets under the prevailing technology.

The interests of shareholders and managers may come into conflict as well when it comes to the issue of whether or not to adopt a new technique that has become available. Often incumbent management has a vested interest in seeing the firm keep the existing technology. New technologies may require new skills which incumbents do not have. Thus if the new technique is adopted incumbents may be forced to retrain themselves, may find that they are less productive relative to potential rivals, and could face the loss of their jobs. The way that organizations deal with this potential opposition by insiders will be an important determinant of both their profitability and their ability to grow.

We argue that the structure of the firm's financial contracts can be an important determinant of the performance of the firm and of the economy as a whole. In particular, we show that they can affect the speed with which technological advances are adopted once they are available, the degree to which productive investment opportunities are foregone, and the incentives to create future growth opportunities (R&D).

The remainder of the paper is organized as follows. Section 2 presents the framework of our dynamic analysis which we analyze recursively in succeeding sections. Section 3 considers the behavior of managers once a new technique has been put into place. Section 4 is devoted to the critical stage for the firm when a new technique has become available but it has not yet been adopted by the firm. It describes two possible reactions of incumbents confronted by a potential technological improvement, each of which engenders a specific sort of inefficiency. One, "entrenchment" will delay the adoption of the new technique, possibly forever. The other, "maximum rent extraction", may temporarily reduce shareholders' earnings in advance of implementing the new technique, but it may also lead to liquidation. Section 5 studies the firm in the earlier stage when the firm is operating and the new technique has not been announced but is nevertheless recognized as a potentiality. Section 6 considers the incentives to invest in the firm. Section 7 concludes by discussing the relation of our results to the literature on financial development.

2 The Model

The model is adapted from the two-stage model of firm growth introduced by Anderson and Nyborg (2001a). The firm is owned by outside shareholders and has access to an existing technology (the "old technique") which generates an infinite stream of cash flows in the future. The firm must be

operated by a manager who is hired from an infinitely deep pool of managers with identical skills. Once appointed, a manager is able to divert some or all of the current period's cash flows for his own consumption of perquisites. Since cash flows are non-contractible[2], shareholders are unable to prevent this from occurring, but they are aware that it has occurred. If they are unwilling to tolerate this rent extraction by the incumbent manager they may replace him. Alternatively, they may liquidate the firm and obtain its value as scrap. While the firm operates under the old technique, there is the possibility that a discovery will be made that will make available a new, improved technology (the "new technique") which will generate a higher level of operating cash flows if it is adopted instead of the old technique. There is a waiting/transition period (the "minimal time to adoption") between the time the new technique is announced and its earliest possible adoption date. However, the effective time to adoption will exceed this if shareholders find it advantageous to delay its introduction. The new technique requires new skills so that its adoption would require replacing the old management with a new manager also recruited from an infinitely deep pool of identical managers but with different skills than the old vintage of managers.

We use the following notation.

- π_1, the cash flow per period under the old technique (non-contractible);
- π_2, the cash flow per period under the new technique (non-contractible);
- y_{it}, the payout ratio at date t ; i.e., the fraction of cash flow that a manager of type i reports to investors ($i = 1$ for "old managers" and $i = 2$ for "new managers");
- L, the liquidation value of the firm;
- r, the discount rate per period;
- p, the probability that a new technology will be announced given that none has been announced previously;
- N, the length of the transition period, i.e., the number of periods between the announcement of a new technology and its earliest possible introduction.

At each date t, the following stage game is repeated until the firm is liquidated (which may be never) : First, shareholders choose whether to *retain* the incumbent manager, *replace* the incumbent manager and continue with a new manager, or *liquidate* the firm. In case of liquidation, the game ends, shareholders receive the liquidation value L, and managers receive nothing. Second, if the firm is kept alive, the cash flow π_i is produced with $i = 1$ if the manager is of the old type and $i = 2$ if he is of the new type, $\pi_2 > \pi_1$. The manager who is in charge decides the payout ratio, $y_{it} \in [0, 1]$. Shareholders receive a total dividend of $y_{it}\pi_i$ and the current manager receives $(1 - y_{it})\pi_i$.

[2] As with other incomplete contracts models we assume that the non-contractible variable (here taken to be cash flows) is "observable but not verifiable". This means that it would be impossible or extremely costly to enforce a contract contingent on this variable in a court of law.

Finally, between periods, a new technique will be announced (assuming it has not been announced before) with probability p.

For simplicity, we assume that managers are not paid a salary, perhaps because their reservation wage is zero. Their compensation is therefore completely determined by the portion of the cash flows they retain for themselves. Managers are assumed to have no money initially so that shareholders cannot require newly engaged managers to buy shares of the firm. Since we assume that the managerial labor pool is infinitely deep, once a manager has been fired, he is re-hired with probability zero.

Formally the model is an infinitely repeated game. As a result we know from the Folk Theorem there are likely to be infinitely many Nash Equilibria in the game. As is common in these settings we focus on subgame perfect equilibria in stationary strategies. Subgame perfection means that agents are assumed to behave rationally in all possible situations, even in those which do not occur in equilibrium. The analysis of the game proceeds recursively from the subgame where the firm has adopted the new technique and is being operated by a new style manager.

3 A new technique has been adopted

As mentioned above, we focus on stationary equilibria where the new style manager uses the same payout rate every period, i.e., $y_{2t} = y_2 \ \forall t$. We start by taking this payout rate as given and ask what is the best response for shareholders. Since any other outside manager would pay identical dividends, shareholders have no reason to replace the current manager as long as he sticks to his strategy. However, shareholders may do better by liquidating the firm. If they never fire the current outside manager, shareholders receive dividends of $y_2\pi_2$ every period forever. Therefore, at any date, the shareholders will not liquidate if and only if

$$y_2\pi_2\frac{1+r}{r} \geqslant L$$

This can be rearranged as

$$\frac{rL}{(1+r)\pi_2} \leqslant y_2, \tag{1}$$

which shows that the investors' incentive compatibility constraint (not to liquidate) imposes a lower bound on y_2.

To get the current management to pay out $y_2\pi_2$ at every date, as has been assumed in (1), there must be a credible threat of punishment if he pays less. Since outside managers are indistinguishable from each other, it is

credible for shareholders to replace the current manager whenever he pays out less than $y_2\pi_2$. Therefore, a best reply for shareholders is to choose

$$s_{t+1} = \begin{cases} \text{retain} & \text{if } y_{2t} \geqslant y_2 \text{ and } y_2 \geqslant rL/(1+r)\pi_2 \\ \text{replace} & \text{if } y_{2t} < y_2 \text{ and } y_2 \geqslant rL/(1+r)\pi_2 \\ \text{liquidate} & \text{if } y_2 < rL/(1+r)\pi_2. \end{cases} \tag{2}$$

Given that investors use (2), the best response of the current manager depends on y_2. If investors' incentive compatibility constraint (1) is not satisfied, the best the manager can do is to divert the entire current cash flow to himself, i.e., set $y_{2t} = 0$, since shareholders will liquidate no matter what he does. More interestingly when investors' incentive compatibility constraint is satisfied, the current manager knows that he will be retained as long as he pays a dividend of $y_2\pi_2$. If so, he will receive a constant consumption stream of $(1 - y_2)\pi_2$ every period forever. His best alternative is to divert the entire current cash flow to himself, which will lead to him being fired. Thus the manager pays out $y_2\pi_2$ if and only if

$$(1 - y_2)\pi_2 \frac{1+r}{r} \geqslant \pi_2$$

This can be written as

$$y_2 \leqslant \frac{1}{1+r}, \tag{3}$$

which establishes that the manager's incentive compatibility constraint (to pay dividends) imposes an upper bound on y_2.

The LHS of the investors' incentive compatibility constraint (1) is increasing in r, whereas the RHS of the manager's incentive compatibility constraint (3) is decreasing in r. For small discount rates, there are multiple payout ratios that simultaneously satisfy both incentive compatibility constraints. However, for sufficiently high r, there is no incentive compatible payout ratio. By equating the two expressions (1) and (3), we find that there is an incentive compatible payout ratio if and only if $r \leqslant r^*$, where

$$r^* \equiv \frac{\pi_2}{L} \tag{4}$$

These results are depicted graphically in Figure 1.

From this figure we see two important points. First, for interest rates less than 20%, there are multiple stationary going concern equilibria. That is, there is a range of payout rates, y_2, all consistent with investors' and manager's incentive compatibility. Second, for interest rates in excess of 20%, there is no positive payout rate that simultaneously satisfies both the investors' and manager's incentive compatibility constraints. Hence, for these high interest rates, the only equilibrium is liquidation. Finally, for any r it is also possible to have a liquidation equilibrium (i.e., $y_2 = 0$).

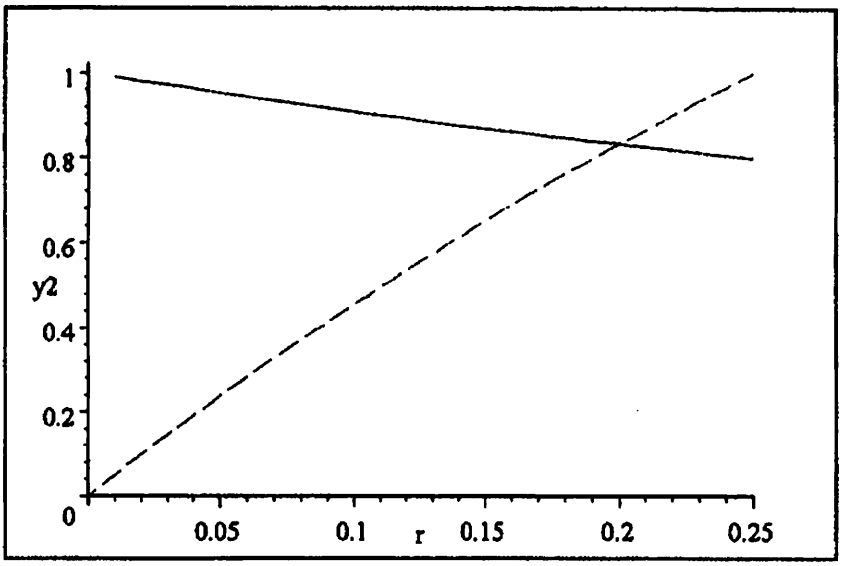

Figure 1 : *Investors'(dashed line) and New-Style Managers' (solid line) Incentive Compatibility Constraints : Parameters;* $L = 100$ *and* $\pi_2 = 20$,*implying* $r^* = 20\%$.

Recalling that y_2 is the rate of payout that shareholders would expect from a new manager, *we can interpret* y_2 *as an index of managerial moral hazard prevailing in the firm's operating environment.* When y_2 is relatively high, prevailing moral hazard is relatively low. The potential replacement managers serve as a relatively severe discipline on incumbents. In contrast, when y_2 is relatively low, the incumbents face little pressure to curb their tendency for consuming perquisites. Prevailing moral hazard is relatively high, and the potential replacement managers serve as a relatively lax discipline on incumbents. Nothing in the structure of our very stylized model allows us to say with great confidence which equilibria will emerge. In reality there may be may be features of accounting rules, corporate law, exchange rules, public regulations, or even general social mores which determine the behavior of the group of managers as a whole and which pin down the equilibrium to a narrower range of possibilities. We will return to this issue in Section 4 below. However, at this stage, we should emphasize that there is nothing that automatically leads to efficient outcomes. Indeed, as we have seen, for positive interest rates there is always some irreducible amount of moral hazard ($y_2 << 1$) so that investors never capture the full rents created by the firm. This will mean that there will always be the possibility of underinvestment, i.e., positive NPV projects may be foregone by investors.

For future reference, it is useful to record the payoffs to shareholders and managers once the new technique has been adopted and the firm has

settled into a going concern equilibrium. The value of equity is

$$E_2 = y_2\pi_2\frac{1+r}{r}$$

The corresponding value of manager's present and future perquisite consumption is

$$M_2 = (1-y_2)\pi_2\frac{1+r}{r}$$

We now consider the prior issue of whether an available new technique will be adopted by shareholders.

4 A new technique has been announced

A critical stage in the life of an enterprise is when it is operating under an existing technology and a new improved technology becomes available. Will the improvement be adopted? To do so will often require changing management. However, incumbents may take steps to impede the change and to secure their positions.

In our framework where shareholders can hire and fire the managers, the adoption of the new technique is equivalent to replacing the old-style management with new. Therefore we study the decision of whether or not to replace existing old management. We do so in the context of a stationary equilibrium where, before the new technique is announced, shareholders retain the incumbent as long as he uses a payout rate of y_1 or larger.[3] An interesting aspect of our analysis is the extent to which an incumbent manager may change the payout rate upon the announcement of a new technique.

Suppose the first date at which the new technology can be implemented is $t = T$. At that date, investors will implement the change only if they expect the firm to be more valuable under the new management operating the new technique. This will depend upon the equilibrium $y_2\pi_2$ that is anticipated and how it compares to the dividend payout of incumbents. Let y_{1T-i} be the payout rate adopted by old style incumbents in the transition period i dates before T.

Consider the decision one period before the new technique can be implemented ($t = T-1$). If the firm would not be viable as a going concern under new managers ($y_2 = 0$), the incumbent faces no additional disciplinary threat by the new technique. The only discipline he faces is that exerted by other managers similar to himself or the threat of liquidation. The analysis in this case would be the same as in the previous subsection, but with old

[3] Constraints on y_1 are studied below.

style managers' payout rate, y_1, substituting for new style managers' pay out rate, y_2. Another case where the imminent arrival of new style managers with a new technique has no impact is where the equilibrium dividend under new-style management is less than that which would be paid by alternative old-style management ($y_2\pi_2 \leqslant y_1\pi_1$). In sum, if moral hazard among the new vintage of managers would be extremely high, in equilibrium, the firm will continue operating the old technique with the incumbent manager.

Consider now the more interesting case where the new technique would be viable and $y_2\pi_2 > y_1\pi_1$ so that it serves as a new threat to incumbent, old-style managers. Under what conditions will the incumbent retain control of the firm ?

Shareholders will be willing to retain incumbent management if they will pay at least as much in dividends as would the new management operating the new technique. Thus if the incumbent seeks to retain control he must match dividends, i.e.,

$$y_{1T-i}\pi_1 = y_2\pi_2 \quad \forall i \leqslant N$$

At date $T-1$, the alternative to matching dividends is to consume all the present periods cash flow and be replaced. Thus, assuming it is feasible to do so ($\pi_1 \geqslant y_2\pi_2$), the old-style incumbent will match dividends at date $T-1$ and remain in control if and only if

$$(\pi_1 - y_2\pi_2)\frac{1+r}{r} \geqslant \pi_1,$$

or, equivalently,

$$y_2 \leqslant \frac{\pi_1}{\pi_2}\frac{1}{1+r} \tag{5}$$

Thus only if the new style management's payout rate would not be too high compared to the relative productivity of the old technique will the old-style incumbent attempt to retain control of the firm.

Let us now assume that the incumbent's incentive compatibility constraint at date $T-1$, (5), holds and consider his decision one period earlier ($T-2$). What must an incumbent do in order to satisfy shareholders ? The shareholders' alternative to retaining incumbent management is to replacement him with an equivalent old-style manager. This manager would produce π_1 at $T-1$ and would choose to match new technique managers' dividends if it is optimal to do so, which is our working assumption. Thus at $T-2$ the incumbent manager would need to set $y_{1T-2}\pi_1 = y_2\pi_2$ in order to retain control. Since the alternative is to consume the entire current cash flow π_1, we see that the incentive compatibility condition for incumbent managers at $T-2$ is also given by (5). Hence, the incumbent would choose to match at $T-2$ if he expects to do so at $T-1$.

The same analysis can be repeated for earlier periods. Consequently, if the incumbent manager would choose at $T-1$ to match the new technique's

dividend, then he would choose to do so at all earlier times in the transition period. Hence, in this case, once the new technique is announced, the dividend would immediately jump to the new (matching) level. As a result, shareholders would get the full benefit of the announced technique, even before the new technique would become viable. This is particularly interesting because under entrenchment, the new technique will actually never be implemented.

Consider next the case that (5) is not satisfied. In this case, at $T-1$ the incumbent manager would anticipate being replaced by a new-style manager and would therefore consume maximum perquisites, i.e., set $y_{1T-1} = 0$. What happens one period earlier? At $T-2$, the incumbent manager has no credible means of committing to paying out next period. Therefore, at $T-2$, the incumbent also chooses to divert all cash flows to himself, i.e., set $y_{1T-2} = 0$. In response to this, shareholders may choose to fire the incumbent and temporarily replace him with another old-style manager. This analysis can be repeated for earlier dates in the transition period. The implication is that if (5) does not hold, then $y_{1T-i} = 0$ during the transition period.

This shows that if (5) does not hold, shareholders will go N periods without a dividend before they can implement the new technique and receive dividends. Instead of waiting these N periods before receiving any cash, shareholders may instead decide to liquidate as soon as the new technique is announced. They choose to liquidate if and only if (5and

$$\frac{y_2\pi_2}{r(1+r)^{N-1}} \leqslant L \tag{6}$$

This shows that unless y_2 is sufficiently high, the announcement of a new and improved technique may actually lead to the foreclosure of the business. What happens is that old-style incumbents, who see that they soon will be replaced by new-style managers, accelerate their perquisite consumption and, in the process, reduce dividends to such an extent that shareholders are better off closing the firm down because the period of transition is too long. The following proposition summarizes the discussion so far.

Proposition 1. *Suppose at date $T-N$ that a new technique is announced which can be implemented at time T and which will generate cash flows of π_2 in perpetuity if operated by new-style managers with appropriate skills. (a) If the equilibrium dividend payout rate of new-style managers satisfies, $y_2 \leqslant \frac{\pi_1}{\pi_2}\frac{1}{1+r}$, then incumbent old-style managers will set $y_{1T-i}\pi_1 = y_2\pi_2 \ \forall i \leqslant N$. Old-style incumbent management will be retained and the new technique will not be implemented. (b) If $y_2 > \frac{\pi_1}{\pi_2}\frac{1}{1+r}$ old-style managers will set $y_{1T-i} = 0 \ \forall i \leqslant N$. If (6) does not hold, then at time T old-style managers will be replaced and the new technique will be implemented. Otherwise, shareholders liquidate the firm when the new technique is announced at date $T-N$.*

The proposition merits some comments. First, the reaction of old-style management to the announcement of an improved technique has a

knife-edge property. In an *entrenchment equilibrium* (part a of the proposition) the announced improvement is minor or will be subject to considerable moral hazard. The result is that old-style management takes measures to secure their positions. In a *maximum rent-extraction equilibrium* (part b of the proposition where the firm is viable after the new technique is implemented) the improvement is major or moral hazard would not be too great. Old-style incumbents will react to the announcement by consuming maximum perquisites during the time that they remain on the job.

Second, in entrenchment equilibria the new technique is not implemented which is socially inefficient. Nevertheless, shareholders experience an increase in dividends as incumbents are forced to pay out a higher fraction of the cash flows. Thus *measured productivity* of the firm may increase even though there has been no improvement in real productivity. It is simply that rent extraction by management has decreased. There has been a redistribution of rents from managers to shareholders.

Third, in the maximum rent-extraction equilibrium, the new technique is implemented at the earliest possible date, which is *ex post* socially efficient. Nevertheless, the shareholders experience a precipitous drop in earnings upon the announcement of the new technique. Only later, when the new technique is implemented will earnings improve. The distribution of the benefits of the new technique is complicated. The clear beneficiaries are the new managers with the skills adapted to the new technique who will capture a share of the rents once it is adopted. Shareholders may gain because the dividend paid under the new technique may be higher than under the old, but they certainly lose during the transitional time of N periods when earnings are negligible. Old managers lose out on the benefit of being able to extract a fraction of the rents on the old technique indefinitely into the future. However, they gain because, as a group, they capture all the rents during the N transitional periods. Finally, we should not forget that if the transition period is too long, shareholders may prefer to liquidate the firm instead of going through the entire transition period without receiving dividends.

Notice that the last three points imply that shareholders may have a bias against lines of business that are susceptible to major advances. For if the incumbent management perceives that it will one day be made redundant, it will be difficult to convince them to abstain from short-term rent extraction. In contrast, when the firm is exposed to less radical improvements, incumbents can be induced to strive harder even if they are not under the immediate threat of replacement by the new technique.

For future reference we note the value of equity during the transition period between the time the new technique has been announced and the time it can be first implemented. If there is an entrenchment equilibrium,

$$E_{1T-i} = y_2 \pi_2 \frac{1+r}{r} \quad \forall i \leqslant N$$

If in contrast, if there is a maximum rent-extraction equilibrium,

$$E_{1T-i} = \frac{1}{r(1+r)^{i-1}} y_2 \pi_2 \quad \forall i \leqslant N$$

The fact that a large-scale improvement may be preceded by a period of rent extraction will potentially be an impediment to certain investments in the first place. We now complete the analysis of the problem by considering the initial period before the new technique has been announced.

5 An old technique is in place and a new technique has not been announced

At an earlier stage when the firm is operating the old technique and a new technique has yet to be announced, both investors and old-style managers are aware that a new technique *may* be announced at any time. Players will evaluate the situation under certain assumptions about the stochastic process governing the arrival of new technique announcements. Very little will be lost from our analysis if we assume this process to be of a very simple sort. In particular, we assume that with probability p there is an announcement of a new technique of known size, π_2 (given that a new technique has not been announced previously). Furthermore, this distribution is common knowledge among all agents involved.

Given this assumption the model is time-homogenous, and we will characterize stationary subgame perfect equilibria. The analysis follows along the same lines as the case studied above where a new style manager has been hired to run the firm under the new technique.

Each period investors decide whether or not to liquidate the firm, to continue the firm under a replacement manager, or to continue the firm under the incumbent manager. Given that potential replacement managers are playing a stationary strategy where $y_{1t} = y_1$, shareholders will be willing to retain the incumbent if his payout ratio is at least as great as this level and if the current dividend plus the continuation value of equity is at least as great as the liquidation value. Let E_1 be the value of equity as a going concern under the old technique and let E_1^* be the value equity announced at the end of the period. Given the stationary nature of the problem we have,

$$E_1 = y_1 \pi_1 + \frac{1}{1+r}[(1-p)E_1 + pE_1^*],$$

which can be rearranged as

$$E_1 = \frac{y_1 \pi_1 r + y_1 \pi_1 + pE_1^*}{r+p}$$

Hence, investors will not liquidate if and only if

$$y_1 \geqslant \frac{L(r+p) - pE_1^*}{\pi_1(1+r)} \tag{7}$$

Incumbents will choose to pay out y_1 if the current consumption of perquisites plus the continuation value of staying in charge is at least as great as one period's cash flow. Let M_1 be the value of being an incumbent retained under the old technique and let M_1^* be the value of being an incumbent old-style manager just after the announcement of the new technique. We have

$$M_1 = (1-y_1)\pi_1 + \frac{1}{1+r}[(1-p)M_1 + pM_1^*],$$

which can be solved as

$$M_1 = \frac{(1-y_1)\pi_1 r + (1-y_1)\pi_1 + pM_1^*}{r+p}$$

Thus the incumbent manager's incentive compatibility condition, $M_1 \geqslant \pi_1$, can be written as

$$y_1 \leqslant \frac{1-p}{1+r} + \frac{pM_1^*}{\pi_1(1+r)} \tag{8}$$

Conditions (7) and (8) give the lower and upper bounds of payout ratios for incumbent old-style management that are compatible with maintaining the firm as a going concern under the old technique. As in the analysis of the going concern under the new technique, given r there may be an interval of payout rates that are consistent with going concern equilibria. But it also may be that the firm will be liquidated in equilibrium. However, here the analysis is complicated by the probability of an announcement of a new technique and the values for the managers (M_1^*) and shareholders (E_1^*) after the announcement of a new technique. These in turn will depend upon the length of the transition phase and whether the transition would be one of entrenchment or of maximal rent-extraction. Next, we analyze these cases in turn.

5.1 Announced new technique induces entrenchment

Let us suppose that following the announcement of a new technique the optimal response of the old-style manager would be entrench himself by matching dividends (see Proposition 1). In this case the post-announcement values of equity and manager wealth are

$$E_1^* = y_2\pi_2\frac{1+r}{r},$$

and

$$M_1^* = (\pi_1 - y_2\pi_2)\frac{1+r}{r}$$

Using the first expression the incentive compatibility condition for shareholders can be written as

$$y_1 \geqslant \frac{L(r+p)}{\pi_1(1+r)} - p\frac{y_2\pi_2}{\pi_1 r} \tag{9}$$

Similarly, the incentive compatibility condition for managers can be written as

$$y_1 \leqslant \frac{1-p}{1+r} + \frac{p(\pi_1 - y_2\pi_2)}{\pi_1 r} \tag{10}$$

Notice that condition (9) is decreasing in $y_2\pi_2$. The interpretation is that the higher will be the dividends paid once the new technique is announced the lower the pre-announcement payout rate that would be tolerated by investors. Similarly, condition (10) is decreasing in $y_2\pi_2$. The interpretation is that the higher would be the payout required to retain his job after the announcement of a new technique, the less willing will be the old-style manager to forego perk consumption in the present.

5.2 Announced new technique induces maximum rent extraction

Here, we suppose that following the announcement of a new technique, the optimal response of the old-style manager would be divert all cash flows to himself while he is in charge (see Proposition 1). In this case the post-announcement value of equity is

$$E_1^* = \max\left[\frac{1}{r(1+r)^{N-1}}y_2\pi_2, L\right] \tag{11}$$

Suppose that investors choose not to liquidate during the transition period. Then, assuming that shareholders will adopt a policy of replacing the incumbents with alternative old-style managers until the new technique can be implemented, the value for incumbent management after an announcement is

$$M_1^* = \pi_1$$

In this case, using (11), investors' pre-announcement incentive compatibility condition (7) can be written as

$$y_1 \geqslant \frac{L(r+p)}{\pi_1(1+r)} - \frac{py_2\pi_2}{\pi_1}\frac{1}{r(1+r)^N} \tag{12}$$

Similarly, the pre-announcement incentive compatibility condition for old-style managers (8) can be written as

$$y_1 \leqslant \frac{1}{(1+r)} \tag{13}$$

Notice that condition (12) is decreasing in $y_2\pi_2$ for reasons similar to the case where announcements induce entrenchment. In short, the higher the new technique dividend the better news is its announcement and the more tolerant will be shareholders of old management's rent extraction. Also, it should be noted that this expression is increasing in N. The interpretation is that the longer the delay between announcement of a new technique and its implementation, the longer the period that shareholders go without dividends and thus the less tolerant will shareholders be of current rent extraction by incumbent management. The old managers incentive compatibility condition (13) is identical to that of new managers once the new technique is implement.

6 The incentive to invest

So far we have studied a firm that is up and running. In this subsection, we address whether investors would advance equity capital to get the firm started in the first place. The analysis above shows that some fraction of the cash flows of the firm can be diverted by insiders. These take three specific forms : perquisite consumption by old managers under normal operations of the old technique, high perquisite consumption by old managers once they are lame ducks, and normal perquisite consumption by new managers once the new technique is in place. The relative sizes of these rent concessions to insiders depends upon the parameters of the model and the degree of moral hazard prevailing among the pool of prospective managers. Even in the circumstances most favorable for shareholders these concessions cannot be reduced to zero because the payout ratio, y_2, is strictly less than 1 for positive interest rates. Therefore there is inevitably the possibility of underinvestment in productive projects.

To make this explicit let V be the first-best value of the project operating under the old technique with the prospect that a new technique will be announced and let V^* be its value after the new technique is announced. These satisfy $V = \pi_1 + \frac{1}{1+r}[(1-p)V + pV^*]$, so that

$$V = \frac{\pi_1(1+r) + pV^*}{r+p}$$

Once the new technique has been announced the first-best action is to implement the improvement as soon as possible. Consequently,

$$V^* = \frac{\pi_1((1+r)^N - 1)}{r(1+r)^{N-1}} + \frac{\pi_2}{r(1+r)^{N-1}}$$

Combining the last two expressions, we find that the firm's *ex ante* value is

$$V = \frac{\pi_1(1+r)}{r+p} + \frac{p\pi_1((1+r)^N - 1)}{(r+p)r(1+r)^{N-1}} + \frac{p\pi_2}{(r+p)r(1+r)^{N-1}} \tag{14}$$

The first term on the RHS is the value of an annuity of π_1 which dies with a conditional probability of p each period. The second term is the value of an annuity π_1 of which is born with a conditional probability of p each period and which would last N periods. The third term is the value a perpetual claim of π_2 which would be announced with a probability of p each period and which would commence N periods after announcement.

Underinvestment occurs whenever the value of equity of the firm operating under the old technique would be less than V. As we have seen, the value of equity depends upon whether a new technique announcement is expected to induce entrenchment, maximum rent-extraction, or liquidation. In the former case, the results above can be used to show that the initial value of equity is

$$E_1 = \frac{y_1\pi_1(1+r)}{r+p} + \frac{py_2\pi_2(1+r)}{(r+p)r} \tag{15}$$

Comparing this with (14) above we see that if new technique announcements induce entrenchment, we may have underinvestment *ex ante* because (a) old managers may pay out less than the cash flows the firm generates while they are in charge ($y_1 < 1$), (b) dividends during transition may be less than available cash flows ($\pi_1 > y_2\pi_2$), and (c) payout of new-style managers will certainly be less than full ($y_2 < 1$, see equation (3)).

Similarly, if new technique announcements will give rise to a period of maximum rent-extraction (but not liquidation), the initial value of equity is

$$E_1 = \frac{y_1\pi_1(1+r)}{r+p} + \frac{py_2\pi_2}{(r+p)r(1+r)^{N-1}} \tag{16}$$

Comparing this with (14) above we see that in this case we may have underinvestment *ex ante* because (a) old managers may pay out less than the cash flows generated under them ($y_1 < 1$), (b) dividends during transition are totally absent, and (c) payout of new-style managers will be less than full ($y_2 < 1$).

Finally, if new technique announcements will give rise to the immediate liquidation of the firm, the initial value of equity is

$$E_1 = \frac{y_1\pi_1(1+r) + pL}{r+p} \tag{17}$$

In this case, underinvestment *ex ante* would arise because (a) old-style managers' payout rate is $y_1 < 1$, (b) the firm is prematurely liquidated, and (c) the new technique is not implemented.

Given limited liability, underinvestment will certainly occur any time a positive NPV project cannot issue equity claims that cover the costs of initial investment. In fact, underinvestment problems may be more severe than this. For example, if initial investments require the participation of two or more parties with interests that cannot be perfectly well-aligned, contracting problems among these agents may also serve as an impediment to productive investment. This idea is develop at length by Anderson and Nyborg (2001a) who study a firm whose original product idea is the result of an R&D project by an entrepreneur but which requires outside finance for capital investments. Other forms of possible, early-stage contracting inefficiency are studied in the literature on venture capital.

7 Conclusions

We have studied the relation of financial development and the pace of technological advance in a dynamic agency theoretic model. A firm which is financed by outside shareholders, but run by managers has the prospect of a process innovation which arrives stochastically. Adopting the innovation requires firing old management and hiring new ones with skills appropriate for the new technique. We show that subgame perfect equilibrium in this game can be of two types. In "entrenchment" equilibrium once the new technique has been announced old style management raises their dividend payout sufficiently to preempt the innovation. This is inefficient socially but is beneficial to shareholders because measured profitability will increase at the time of the announcement of the new technique. In "maximum rent extraction" equilibrium' managers are unable or unwilling to match the impending productivity improvement and instead respond by increasing their perquisites for the remaining time of their tenure. This may lead to the immediate liquidation of the firm. But if not, it is *ex post* socially efficient because the new technique is eventually implemented; however, it may be harmful for shareholders. We show that moral hazard associated with both equilibria may result in *ex ante* inefficiency, because the resulting loss in equity value means that investors may not be willing to advance the requisite funds to take all positive NPV projects.

Our analysis sheds light on the relationship between financial development and economic growth. This issue has been studied in a long and illustrious literature including classic contributions by Schumpeter (1942) and Gershenkron (1962). Empirical studies by Goldsmith (1969) and King and Levine (1993) document a positive correlation between various measure of financial development and growth. More recently, Rajan and Zingales (1998) find evidence supporting the hypothesis that financial development stimu-

lates growth. Various aspects of the relation of financial development and economic growth have been subjected to theoretical analysis by Greenwood and Jovanovic (1990), Banerjee and Newman (1991), Aghion and Bolton (1992), and. Kiyotaki and Moore (1997).

Neither the empirical nor the theoretical literature just surveyed explicitly addresses the source of imperfection in the financial sector. Our paper has explored this issue by showing how financial contracting can affect the behavior of managers and the incentives of shareholders to implement technological improvements that have become feasible. In this context, financial development can impact the model in several ways and can reduce inefficiencies brought on by agency problems. Improved reporting standards can reduce the scope for diversion of cash flows by insiders. More complicated financial contracts can alleviate underinvestment problems. Managerial incentive contracts can help as well.[4]

[4] We have developed these ideas explicitly within the framework of our model in a companion piece to this paper (Anderson and Nyborg (2001b)). Another aspect of the issue is the impact of financial contracting on the incentive to create growth opportunities through research and development. This issue has been studied in Anderson and Nyborg (2001a).

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