Vesting and Control in Venture Capital Contracts

David R. Skeie*

Federal Reserve Bank of New York

June 2004

Abstract

Vesting of equity payments to an entrepreneur, which is time contingent compensation, is ubiquitous in venture capital contracts and has been shown empirically to be of economic importance. We show that vesting equity to an entrepreneur over a longer period of time, late vesting, acts as a screening device against bad entrepreneur types. But if contracts are incomplete such that payments and vesting cannot initially be contracted upon later outcomes, then late vesting gives lower effort incentives than early (short time-period) vesting since it is subject to holdup by the venture capitalist. Comparative statics show how equilibrium outcomes of screening, effort and assignment of control rights vary based on the ex-ante probability and the ex-interim signal of the entrepreneur's type. Control rights are a substitute for early vesting and allow for the largest effort incentives by fully protecting the entrepreneur from holdup. We also find that a new explanation for the link between equity control rights and equity cash flow claims is that residual equity control rights over the firm are necessary to protect residual equity claims from holdup.

JEL Classification: G24, D23, D82, J33, M52, M13, G32

Keywords: Venture capital, vesting, control rights, contingent compensation, incentives, adverse selection, incomplete contracts, hold-up problem

1. Introduction

This paper examines the timing of compensation to an entrepreneur in a venture capital contract. Promised payments of equity shares to the entrepreneur are often vested over time, or

---

paid out only after the entrepreneur has remained with the firm for a specified time period. If the entrepreneur quits or is fired from the firm prematurely, unvested shares are not paid to the entrepreneur; however the entrepreneur keeps any shares already vested.

While the focus of the theoretical venture capital contracting literature has been on the allocation of control rights, empirical research has shown that vesting is also heavily used in venture capital contracts. Kaplan and Stromberg (2002) highlight the importance of vesting and show that vesting is extensively used in association with the risk of general uncertainty and with the risks of asymmetric information and potential holdup between the venture capitalist and the entrepreneur. They also hypothesize how vesting may be useful to overcome these perceived risks. Kaplan and Stromberg (2002) suggest that vesting is used to overcome problems of asymmetric information of the quality of the management (e.g. the entrepreneur) or the project. This suggests that vesting acts as a screening device against less valuable entrepreneurs or projects. They also suggest that vesting is used to overcome situations of complexity of a project. Vesting may be used when the entrepreneur is able to hold up the venture capitalist due to the entrepreneur's human capital that is necessary for the project. In addition, Kaplan and Stromberg (2003) show that when contingent control rights are used, vesting is most common.

Given the evidence for the economic benefit of vesting, there is no explanation for why vesting is not always used to an extensive degree. What is the cost of vesting equity shares for a long period of time? The entrepreneur's liquidity, consumption or diversification needs are not typically important reasons against vesting. The entrepreneur usually could not sell equity shares before the firm is liquidated through an IPO or private sale. The liquidation event often does not occur until after the longest of typical vesting periods (four years). The entrepreneur may want to leave the firm for a better opportunity, but the first few years of the firm's development are when the entrepreneur is typically crucial for its success, which is a reason why shares are vested.

Rather, we show in an incomplete contracts model that the venture capitalist's ability to hold up the entrepreneur limits the extent to which long-term vesting can provide effort incentives. We show that the combination of ex-ante and interim asymmetric information, incomplete contracts due to the non-verifiability of termination actions, and the ability to divert funds can explain how vesting is used. Furthermore, each of these ingredients are necessary to fully explain vesting in our framework. Contingent control rights over the firm are explained in relation to vesting, and the importance of vesting and control rights to induce effort is analyzed.

Providing incentives for the entrepreneur's effort would typically also help improve screening of good from bad types of entrepreneurs when there is asymmetric information. The general

method for providing effort incentives is to create a wedge between payoffs for higher and lower outcomes. The general method for screening of types is to create a wedge between payoffs for higher and lower outcomes as well. If noisy signals or outcomes reflect better information over time about the entrepreneur's effort and type, then paying the entrepreneur contingent on the final outcome (and possibly interim outcomes) provides the greatest incentives and most efficient screening. In the case of vesting, this calls for vesting being delayed and contingent on the final production outcome.

If contracts are incomplete such that payments cannot initially be contracted upon later outcomes, then a trade-off between screening and incentives exists. Payments contracted upon earlier, noisier signals are needed to provide incentives for the entrepreneur to choose effort. However, the more that compensation is contracted upon early noisy signals, the less effective screening can be.

In our model, the venture capitalist buys assets which can be used solely by a good entrepreneur type to create a verifiable potential final profit. The assets can also produce a smaller non-verifiable cash flow at a loss at an intermediary stage but then become worthless. When the venture capitalist holds the residual control rights of the firm, termination of the entrepreneur (leading to a sale of the assets for the small cash flow value) cannot be verified as being due to the venture capitalist firing the entrepreneur versus the entrepreneur quitting the firm. Either the venture capitalist or the entrepreneur can threaten to cause the termination and thereby repudiate any contracted later payments to the entrepreneur, which we call late vesting and interpret as the entrepreneur's equity vested over a long period of time. This leads to a bargaining game over the surplus from continuing and not terminating the entrepreneur. This allows either the venture capitalist or the entrepreneur to hold up the other. Thus, late vesting cannot be contracted and contracts are incomplete.

However, only at the final outcome is the entrepreneur's type and effort fully revealed. In order to provide incentives for effort to be chosen, earlier payments, which we call early vesting and interpret as the entrepreneur's equity vested over a short period of time, can be made to the entrepreneur before repudiation occurs. These payments can be conditional on a verifiable interim signal that partially reveals the entrepreneur's type. But because the signal is noisy, the larger the early vesting is, the more that bad types will attempt to mimic the good types to collect the early vesting, and the worse the contract performs at screening out bad types.

Control rights may also be assigned to the entrepreneur in order to induce effort choice. In our model, control rights give the holder the ability to take all residual actions in the firm that are non-verifiable and thus non-contractible. Since the ability to fire the entrepreneur is one of the non-contractible actions, control assigned to the entrepreneur means that the venture capitalist cannot hold up the entrepreneur and so late vesting can be contracted. In

essence, granting control rights to the entrepreneur makes the incomplete contract complete. Late vesting contracted upon effort choice which is revealed at the final outcome provides the greatest of effort incentives. In effect, assigning the entrepreneur control rights entrenches him in the firm which protects late vesting, so that late vesting can be used to provide incentives.

However, control rights assigned to the entrepreneur also introduces a distortion by creating an agency problem. The venture capitalist has given up all ability to terminate the entrepreneur which is equivalent to the ability to liquidate the project. The entrepreneur may then produce the small cash flow from the assets and since it is non-verifiable divert it or steal it for himself. Even when control is contingent on an intermediary signal, if it is noisy enough bad types will pool with good types to receive control and then divert the small cash flow. The attempt to overcome the incomplete contract to protect effort incentives again leads to reduced screening capability.

We examine the trade-off between incentives and screening within the context of a model of venture capital contracting but this is likely to be the case in corporate contracting in general. Whenever late vesting or later wages are not contractible and an agent has specialized human capital that increases the value of the firm, there will be a trade-off between incentives and screening when the noise of the agent's effort and type decreases over time. For example, consider firms in which the board of directors contracts compensation with the CEO. Though some parts of the CEO compensation (such as equity or option grants) may be set effective for several years out, often the salary is set only at the beginning of the year and the bonus is set at only the year-end. If a CEO adds any specialized value to the firm that cannot be entirely replicated by a new CEO (from the CEO's experience at the firm, learned skills, firm specific knowledge, etc.), providing greater effort incentives through either greater early compensation or control rights (i.e. CEO appointed as chairman of the board) is necessary but conflicts with screening out less talented CEOs.

Even if part of the holdup in our model based on unverifiable termination threats may be overcome with severance packages or clauses from a CEO being fired without "reasonable cause," the lack of long term fully contracted performance compensation suggests that contracts are not complete. Other employees at firms typically have even less long term contingent compensation contracts even though many workers at technology firms or those with long-term firm experience may have extensive inalienable human capital. The point is that not only does compensation need to be contingent on performance, but compensation needs to be contracted for many years out contingent on performance to be a complete contract amidst inalienable human capital.

We also derive elegant general results for our model. As we have seen, greater incentives through early vesting or contingent control to the entrepreneur reduces the capability of screen-

ing. We show how the cost of relaxed screening increases with the ex-ante probability that an entrepreneur is a bad type. This is due to both the higher chance the bad type receives financing, and the chance the bad type is not detected by the noisy signal and so receives early vesting or contingent control by which he can divert funds. We also show how the cost of relaxed screening increases with the noise of the signal. This is because bad types are more likely to look for financing knowing they are less likely to be caught by the noisy signal later, and bad types are indeed caught less often and so receive early vesting or contingent control allowing them to divert funds. When the cost of relaxed screening is large enough from either more bad types or a noisier signal, contingent control is not given to the entrepreneur, but the entrepreneur is given large early vesting. As the cost increases further, early vesting is reduced. Both of these have the effect of lowering effort incentives further and further, until finally no effort occurs.

There is an opposite effect between the two causes for increased costs of lax screening on whether bad types look for financing in equilibrium. As the probability of bad types increases, the reduction in early vesting and ability to divert funds lowers bad types' desire to look for financing resulting in a separating equilibrium. Conversely, as the signal quality decreases, bad types find it increasingly attractive to look for financing and bear the decreasing risk of being caught even though early vesting or ability to divert funds is decreased.

The difference is because in the limit, when there are only bad types, effort incentives are worthless and so not worth paying for due to the loss from funding bad types. But even when the signal loses all quality and becomes uninformative, it may still be worthwhile to provide incentives for effort for the good types despite the losses of funding bad types.

The ex-ante probability of a good type can also be interpreted as partially due to the level of due diligence performed by the venture capitalist before the project, while the noise of the interim signal can be interpreted as partially due to the level of monitoring by the venture capitalist during the project. This allows for reconsidering the analysis in terms of the trade-off between greater due diligence versus greater monitoring by the venture capitalist.

In addition to the new focus we bring to the importance of vesting, we also find rich new interpretations and understanding of the role for contingent control. In particular, we show that the importance of control rights cannot be fully understood without analyzing them in conjunction with vesting. Contingent control acts to entrench the entrepreneur in the firm to protect late vesting. The aspect of contingent control that gives the entrepreneur equity-style control rights enables the entrepreneur to receive equity-style residual cash flow rights without holdup. This gives the entrepreneur the greatest incentives for effort which no amount of early vesting under venture capital control can give. An empirical prediction of the model is that control rights are associated with larger amounts of late vesting of equity.

Section 2 discusses the related literature. Section 3 presents the model and examines the effects of repudiation. Section 4 shows that first best results hold only in a limited case and focuses on second best results that obtain for more typical entrepreneurial projects. This section then analyzes early vesting and control in the trade-off of the cost of lax screening and incentives for effort, and finishes by highlighting the special features of control. Section 5 concludes with further interpretations of the model.

2. Related Literature

In a model of capital structure and security design, Aghion and Bolton (1992) show control may need to be contingent to implement optimal actions in the firm. We reach this result and also examine the timing of cash flows, showing how early vesting of equity or late vesting that is protected by entrepreneur control also helps implement optimal actions when there is asymmetric information. In our model, no action is dependent on the state as in Grossman and Hart (1994) or Aghion and Bolton (1992), but we still have unverifiability of actions that leads to incomplete contracts and holdup. The venture capitalist does not ever even observe the state, but she does observe actions. Hart (2001) questions why the entrepreneur necessarily receives control in a good state and the venture capitalist receives control in a bad state (as empirically shown in Kaplan and Stromberg (2003)) rather than based solely on personal benefits as in Aghion and Bolton (1992). He suggests what may be missing from the model is effort which needs to be rewarded and implicitly requires entrenchment. We confirm this intuition, and also show that ex-ante asymmetric information drives the result as well.

Models of debt with unverifiable cash flows and liquidation rights given to investors, including Bolton and Scharfstein (1990) and Hart and Moore (1994, 1998), are somewhat similar to our model in that ours has a potential interim unverifiable cash flow and entrepreneurial human capital with potential holdup of the investor, which necessitates that the entrepreneur cannot receive full payments up-front. However, this is counter-balanced by the entrepreneur's needs for up-front payments or control rights for effort incentives due to potential reverse holdup by the investor. Dewatripont and Tirole (1994) and Berkovitch and Israel (1996) examine the joint aspect of cash flow and control rights in the context of multiple classes of security holders, but they do not explain the timing of cash flow rights.

The structure of our model is related to Neher (1999), who examines a hold up problem involving an entrepreneur's required human capital in the financing of a project over periods. The venture capitalist stages financing to protect herself from hold up by the entrepreneur, as opposed to our model in which the entrepreneur is compensated over time to protect the venture capitalist from holdup, but in our model the entrepreneur may also need protection from the venture capitalist which requires early vesting or control.

Shleifer and Vishny (1989) recognize the potential benefit to purposely entrenching the manager with a contract to achieve efficient investment. However, they do not examine the potential agency issues of diversion and asymmetric information, nor do they consider the possibilities of early vesting as a substitute for entrenchment. Gorton and Grundy (1996) show that when late vesting of manager equity pay is needed so the manager does not quit and free ride his equity off the replacement manager's effort, there is a benefit to entrenching the manager (through control of the firm). This is so he cannot be fired but rather will stay to vest his equity even when he is less efficient as a manager ex-post, in order to provide him with effort incentives ex-ante. We show similar entrepreneur control and entrenchment is beneficial even if his human capital is vital so he cannot quit and free ride, but we also show when it is preferable to give the entrepreneur early vesting instead of control due to the larger agency costs of control from diversion and asymmetric information.

In Hellmann (1998), the entrepreneur relinquishes control (including firing rights) of the firm in the initial contract to the venture capitalist and accepts late payment because it protects the venture capitalist from hold up if she later needs to search for superior management, which increases firm value ex-ante. We show the entrepreneur may relinquish control in trade for early vesting, but for late vesting the entrepreneur requires control, otherwise late vesting is repudiated. Dessein (2001) is similar to our model in examining ex-ante asymmetric information of the entrepreneur's quality. He predicts that a good entrepreneur signals by giving up formal control in exchange for more *de facto* control, but does not examine the timing of payoffs. We predict the opposite: a good entrepreneur receives more control when giving up early for late vesting. Kirilenko (2001) also models a venture capital firm with asymmetric information, bargaining, and control rights, but also has no implications about the timing of the entrepreneur's compensation.

Landier (2001) models venture capital versus bank financing as depending on career concerns and project risk to explain U.S. versus European venture capital markets. In the conclusion, we show our model can be applied to explain venture capital versus bank (or analogously U.S. versus European) financing as depending on the ex-ante probability of good entrepreneur types and the quality of interim information.

Kaplan and Stromberg (2003) show empirically our prediction that when the entrepreneur receives cash flows and control based on performance, vesting is most common. Our model predicts that control is needed to protect late vesting. Kaplan and Stromberg (2001) show empirically that cash flows, control and liquidation rights shift to the entrepreneur with performance in interrelated ways as complements, not substitutes, as we obtain, and they also show that venture capitalists are concerned about the entrepreneur's ability as a manager. Kaplan and Stromberg (2002) show empirically that more complexity in contracts, which they
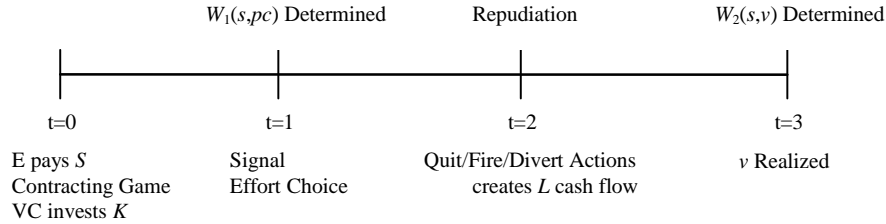
$W_1(s,pc)$ Determined	Repudiation	$W_2(s,v)$ Determined

t=0   t=1   t=2   t=3

E pays S Signal   Quit/Fire/Divert Actions v Realized
Contracting Game   Effort Choice   creates L cash flow
VC invests K

Figure 3.1: Timeline

interpret as an entrepreneur's human capital requirements, leads to more time vesting. Greater asymmetric information between the entrepreneur and the venture capitalist (primarily management quality risk) leads to more performance-based vesting and venture capital control. While our model has vesting as a function of time and performance, we do not analyze these aspects separately, nor have a model specifically analyzing asymmetric and complexity risk. Nevertheless, our model results are in alignment with the results on vesting in general and control rights found by Kaplan and Stromberg (2002).

3. Model

Timeline A timeline illustrates the steps of the project in Figure 3.1. The labels that are below the timeline are part of the exogenously specified framework of the model. The labels that are above the timeline show the endogenously determined contracted payments and repudiation.

At $t = 0$, the entrepreneur ("E" or "he") has a project that requires funding of I. E pays $S < I$ which is his only wealth and requires $K = I - S$ from a venture capitalist ("VC" or "she"). E has a type $\theta \in \{\theta_G, \theta_B\}$. If $\theta = \theta_G$, E is called "good". If $\theta = \theta_B$, E is called "bad". There is a probability $p \in (0,1)$ that θ equals θ_G, and a probability $1 - p$ that θ equals θ_B, which is common knowledge. E knows his own type from the outset at $t = 0$. VC does not know whether E is good or bad.

A contract assigns residual control rights to VC or E (possibly contingent on the signal s introduced below) and specifies one of two mutually exclusive project types. The project type can be chosen to be either effort-intensive or regular (non-effort intensive). An effort-intensive project pays off more than a regular project if effort is undertaken, but less than a regular project if effort is not undertaken. Assets specific to the project type are then bought.

At $t = 1$, a verifiable signal $s \in \{0, 1\}$ correlated with E's type is realized. If the project is

8

effort-intensive, E chooses whether to give effort, $e \in \{0, 1\}$.

At $t = 2$, E may quit the firm and if VC has control rights she may fire E. Termination of E is verifiable, but whether E quits of VC fires E is not verifiable. The assets may also be unverifiably operated by the party with control at $t = 2$ before project completion for a cash flow of $L < K$ diverted to the party in control and then expire worthless. If E leaves the firm before project completion (E is terminated), the assets can either be liquidated or operated by the party in control for L.

At $t = 3$, if E has stayed with the firm, the project pays off zero if E is bad or if the assets have been previously operated for L. If not and if E is good, the payoff is V_R for a regular project, V_1 for an effort-intensive project with effort ($e = 1$) from E, and V_0 for an effort-intensive project without effort ($e = 0$), where $V_1 > V_R > V_0 > 0$.

Assumptions   VC and E are risk neutral and interest rates are zero. E has no wealth beyond the S that he pays, and he has limited liability. VC has unlimited wealth and unlimited liability. An effort-intensive project by a good E with effort given that is completed, as well as a regular project by a good E that is completed, are efficient to undertake. A project which the good type diverts or which is liquidated is inefficient to start. A project undertaken by a bad type is always inefficient and liquidation or diversion is more efficient than completion.

Termination   When VC has control over the firm, contracts are incomplete and E cannot be given incentives based on late vesting. This is because residual control rights give the holder the ability to take the non-contractible actions in the firm. One is to operate the assets for a payoff of L before project completion. The other is to fire E. Although the termination of E is verifiable, whether E quits or VC fires E when VC has control is not verifiable. Either VC or E can threaten termination which allows either party to repudiate the late vesting contract, so contracts are incomplete. However, E may be paid early vesting conditional on the signal s. Thus early vesting is fully contractible.

E's inability to commit his human capital to a firm has often been assumed in the contracting literature. An interpretation of this is that a court will not enforce a contract that does not allow E to quit a firm. Typically, this is referred to in employment contracts as an "at will" employment agreement. This model includes the symmetric effect of VC being unable to commit to not fire E. The "at will" employment agreement also typically allows a firm to fire an employee at any time. While "at will" contracting means that either E or VC can terminate the employment, payment to E can still be contracted on termination. In the framework of vesting, upon termination, early vesting equity is still paid to E, but E does not receive unvested late vesting equity.

An explanation for why termination is not verifiable as due to VC firing or E quitting is

that under VC control, she is able to force non-pecuniary costs on E that are neither verifiable nor contractible if he were to stay with the firm, under which E would prefer to quit rather than stay (e.g. VC relocates E's office to Antarctica). However, the actions taken by VC and the personal costs to E of these actions are either not ex-ante contractible or not ex-post verifiable. Thus, a termination cannot be verified as due to VC forcing E out or E deciding to quit.

Alternatively, if E has control, then VC cannot fire E or impose non-pecuniary costs on E since all non-contractible and unverifiable actions of the firm are taken by E. Thus, if E quits, termination of E is verifiable as due to E's decision to quit.

Diversion of Assets or Sale of Completed Project   When E has control, he is able to operate the assets and divert the cash flow of L. This is because the operation of the assets for cash flow L before project completion is observable to both parties but not verifiable. If E is bad, he will always do this since he knows the project will fail and have a value of zero at completion otherwise. If E is good, he can threaten VC with diversion in order to hold up VC and repudiate a late vesting contract and essentially increase his bargaining position. Thus, E control will protect late vesting for E, but is costly in diversion losses to bad types and limits the payoff VC can receive even when E is good due to repudiation and the threat of diversion.

If VC were to attempt under VC control to operate the assets and divert L for herself, E could quit the firm. The termination is verifiable and would lead to E still keeping his early vesting. VC would have no ability to threaten to divert the full cash flow of L without paying E anything in order to hold up E. The difference for E diversion of cash flows under E control is that without control, VC has given up all ability to liquidate the project, and if she observes E divert funds she cannot do anything. Under VC control, E's inability to commit himself from not quitting always allows him to quit and cause the termination.

Furthermore, because the payoff of a bad E's project is always zero at project completion, it is not verifiable whether the project fails due to E being bad or E diverting the assets before project end. Thus, there is no verification at any time that E has diverted cash flows. Moreover, since E has limited liability, he cannot be punished or be committed to paying future wealth to VC for having a project failure.

If there is a termination under VC control, the assets may either be sold for their secondary value of L or operated by VC for the cash flow of L. E is paid the early vesting amount and VC keeps residual cash flows. Since VC has unlimited liability, E can collect early vesting from VC after termination even if VC receives the cash flow of L which itself is unverifiable. Under E control, E could always divert L even with termination, thus no contract would ever pay E early vesting under E control. Under E control, since E can always receive L through diversion

without termination, neither a good nor bad E would ever quit.

The early operation of the asset at a lower value may also be interpreted as changing the business model or operations of the firm that destroys the possibility for making a profitable firm but gives the controlling party a private benefit of L. For example, VC may divert the project to boost the value of another one of her firms. If E is in control, he may divert the project to research and develop intangible technology for a new startup with a separate VC or enjoy perks that are charged as business expenses.

The interpretation of a positive payoff at project completion is an IPO or private sale of the firm. Because the funds of an IPO or sale do not accrue privately to an individual party but are based on a legal contract of sale, the payoff is considered verifiable. Even though the payoff at completion is verifiable, because contracts are incomplete due to repudiation between VC and E when VC has control, late vesting to E is not contractible.

Characteristics of Control Rights Even while control rights may be separately delegated from cash flows, residual control over the firm itself is a complex bundle of rights. The nature of a non-contractible action is that it either cannot be defined in a contract ex-ante or verified ex-post. If there are more than one of these actions within a firm, we argue that control over the actions may not be assignable to separate parties. Thus, control over the action of operating the assets for a secondary value and the action of imposing non-pecuniary costs on E is not separable in our model. For instance, control over the assets may include control over the location of the assets which can effect non-pecuniary costs on E, and so the separate actions are not contractually distinguishable. Assigning control to E, which may be beneficial to protect him from being held up from a VC threat of firing him, also gives E control over assets which may be harmful because of his ability to threaten to divert cash flows.

We also show that assigning control rights to VC is not symmetric to assigning control rights to E. E's inalienable human capital, inability to commit not to quit, and limited wealth mean that even under VC control, E can quit and cause the liquidation of the firm at the secondary value of L. Under VC control, VC cannot divert and keep the entire L if early vesting is contracted for a positive amount. Under E control, however, VC has no ability to liquidate or collect anything even if E diverts L, regardless of what is contracted. In many models of debt, VC only has the ability to withhold further financing to E if E diverts funds. Because our model has only a onetime financing and payoff, VC has no ability to stop E from diverting and keeping the entire L. Thus, under VC control, the relationship of VC to E is similar to an employer to employee relationship in which E receives guaranteed current compensation but no contract for future compensation. Under E control, the relationship of VC to E is similar to capital markets or bank financing, which cannot guarantee full recovery

of firm cash flows due to agency problems.

Project Type One innovation of the model is the choice between mutually exclusive effort-intensive and non-effort intensive (or regular) project types. A good E has a project technology that can provide a positive net profit over the cost of assets purchased to develop the technology without "effort" from E. The project can provide an even higher net profit if effort-intensive assets are purchased and E gives effort. However, the effort-intensive assets provide a lower net profit than do the basic assets without effort from E.

An interpretation of this is that more expensive high capacity assets can be purchased which will give greater profit if E gives effort to develop the assets to full capacity. If low capacity assets are purchased, money is saved and can be spent to develop the assets up to their lower capacity without the effort of E (e.g. an extra employee is hired). But high capacity assets without E's effort can only be developed to a lower level than the low capacity assets since no extra money for developing the assets is available. This interpretation simplifies from the possibility of increasing the capital that VC finances the project with.

Another interpretation is that effort-intensive assets can be purchased that are aimed at capturing a large market share but with a long horizon until they generate revenues. This will be the most profitable strategy if E gives effort to capture the large market share. But if E does not give effort the market share achieved is the same as non-effort intensive assets aimed at a small market share but which generate revenues sooner and are thus more profitable.

E's decision to accept an effort-intensive project is different than E's decision to give effort once in an effort-intensive project. The reason we introduce effort-related project types is that E cannot be given incentives to take effort directly without E control. The reason for this is that without E control, giving E effort incentives would require paying E contingent on the realization of effort at the end of the project, but late vesting cannot be contracted under VC control. Any amount of early vesting paid to E is paid before effort is realized so does not incentivize E to give effort.

However, E can be given incentives to accept an effort-intensive project at the contracting stage. Under E control, late vesting can be contracted so E can be paid the full cost of his effort in late vesting, and E will choose the effort-intensive project. Under VC control, E will accept the effort-intensive project if the extra compensation he receives from early vesting for choosing the effort-intensive project is greater than the cost of effort he will take. In equilibrium, a good E will always give effort to any effort-intensive project that VC is willing to offer and E is willing to accept. If effort were not taken in equilibrium, E and VC would be both weakly better off and at least one party strictly better off under a non-effort intensive project.

Project Payoff The verifiable payoff of the project is given by $V(\theta, pc, e, completion)$. $\theta \in \{\theta_G, \theta_B\}$ is E's type. The project choice type is $pc \in \{eff\text{-}int, reg\}$. The effort given by E is $e \in \{0, 1\}$. For an effort-intensive project E decides whether to give effort and $e \in \{0, 1\}$. For a regular project, E does not choose whether to give effort and $e = 0$. Alternatively, we could assume that E could choose whether to give effort for a regular project but that the cost of effort is more than the product of effort for a regular project so that E never chooses to give effort. The variable *completion* $\in \{yes, no\}$ gives whether E stays with the project until final completion and the party in control does not divert early cash flows from the assets. A project with a bad E always has a final project value of zero, $V(\theta_B, pc, e, completion) = 0$. A project that is not completed due to termination or diversion of assets also has a final project value of zero, $V(\theta, pc, e, no) = 0$. A regular project by a good E that is completed pays off $V_R \equiv V(\theta_G, reg, 0, yes)$, an effort-intensive project by a good E that is completed with effort pays off $V_1 \equiv V(\theta_G, eff\text{-}int, 1, yes)$, and an effort-intensive project by a good E that is completed without effort pays off $V_0 \equiv V(\theta_G, eff\text{-}int, 0, yes)$, where $V_1 > V_R > V_0 > 0$. We define the product of effort as the difference between the value of an effort-intensive project with effort given and the value of a regular project, $\Delta V_e \equiv V_1 - V_R$.

Signal At $t = 1$, a verifiable signal $s \in \{0, 1\}$ that is correlated with E's type θ is publicly revealed. For simplicity of the model, we assume the signal is always correct if E is good: $\Pr(s = 1|\theta = \theta_G) = 1$. This implies that if the signal is low, E must be bad. The quality of the signal is measured by $q \in (0, 1)$. The probability the signal correctly indicates a bad type is $q \equiv \Pr(s = 0|\theta = \theta_B)$. We assume the signal is noisy, $q < \bar{q} \equiv \frac{L-S}{L}$. Control and early vesting can be conditioned on the signal at $t = 1$. We will refer to VC control if VC receives control regardless of the signal, and E control or contingent control if E receives control contingent on $s = 1$. In the limit case of $q = 0$, the signal would be always be $s = 1$ and would be uninformative, and E control could be interpreted as E receiving absolute control from the beginning of the project at $t = 0$.

After the signal, E decides whether to give effort during an effort-intensive project. In the model, effort occurs after the signal to make clear that the signal is only correlated with E's type and does not reveal his effort level. If effort were to occur earlier or later would not make any qualitative difference. The signal could occur after effort and be a function of effort as well as E's type. This would give some ability to contract early vesting on realized effort directly. Modeling the signal as uncorrelated with effort simplifies the model and makes the goal of inducing effort more difficult. This highlights the trade-off of better effort incentives at the cost of worse screening ability using early vesting and contingent control.

Cost of Effort   The cost of effort to E is given by $c(e)$, where $e \in \{0,1\}$. The cost to E of taking effort in an effort-intensive project, $c(1)$, as a fraction of the product of the effort, ΔV_e, defines $k \equiv \frac{c(1)}{\Delta V_e}$. The cost of taking no effort in an effort-intensive project or in a regular project, $c(0)$, is zero. We assume that effort is always efficient in an effort-intensive project: $k < 1$.

Contracting Game   The venture capital market for financing projects is competitive. At $t = 0$, E decides whether to pay an amount S to be able to do a project. S is E's entire wealth and is the seed costs of starting a business that E must pay before he can be approached by a venture capitalist for funding. S can be interpreted as the cost of writing a business model or building a prototype that E must perform before he can be known to a venture capitalist. Alternatively, S can be interpreted as E's opportunity cost to pursue an entrepreneurial project. Regardless, S cannot be recovered if E starts a project and then leaves.

If E invests S, a competitive VC offers him a take-it-or-leave-it contract

$$\{W_1(s, pc), W_2(s, v), C(s), pc\},$$

which is a general contract that allows for any payment or assignment of control rights conditional on any verifiable realization. Without loss of generality, we assume E receives payment from VC, and VC receives the payoff at project completion. Early vesting $W_1(s, pc)$ is conditional on the realization of s and the contracted project choice pc. Late vesting $W_2(s, v)$ is conditional on the project not being terminated early (E not terminated), s, and the outcome value of the project which we define as v for ease of notation, $v \equiv V(\theta, pc, e, completion)$. As shown above, $v \in \{V_1, V_0, V_R, 0\}$. Residual control of the firm $C(s) \in \{VC, E\}$ assigns control rights to VC or E conditional on s. Project choice type $pc \in \{eff\text{-}int, reg\}$ determines whether effort-intensive or regular type of assets are purchased by VC if the contract is accepted. If E accepts the contract, VC invests K into the specific assets of the project choice type.

Since $s = 0$ implies E is bad, E will never receive control contingent on $s = 0$, VC will fire E, and early vesting is zero, $W_1(s = 0) = 0$. Late vesting $W_2(s = 0, v)$ is not paid since the project is terminated. For simplicity, we suppress the argument s, so $W_1(pc)$ and $W_2(v)$ always refers to $s = 1$.

If the project completion value is zero, either E is bad or E has diverted funds, so late vesting is always zero, $W_2(0) = 0$. Since a good E always gives effort if he accepts an effort-intensive project, he is indifferent to a contract that pays late vesting of zero when the project outcome indicates no effort in an effort-intensive project, $W_2(V_0) = 0$. Thus we assume $W_2(V_0) = 0$ for simplicity. Since the project completion payoff outcome of V_R versus V_1 is determined by verifiable project choice, we write late vesting dependent on either outcome, $W_2(V_R)$ and

14

$W_2(V_1)$, as W_2 when late vesting as determined by project choice is understood. Similarly, we write early vesting dependent on either project choice, $W_1(\textit{eff-int})$ and $W_1(\textit{reg})$, as W_1, when early vesting as determined by project choice is understood. Total vesting is defined as $W_T(v, pc) = W_1(pc) + W_2(v)$. Since project choice is clear given outcome v, total vesting can be expressed as $W_T(v)$, which can be written without the argument as W_T when the project outcome is clear.

Repudiation and Bargaining   At $t = 2$, after a high signal, under VC control either VC or E can repudiate the contract with the threat of VC firing E or E quitting. A repudiation by either party leads to bargaining over the surplus value from continuing rather than terminating the project. We assume a Nash bargaining solution. A termination results in payoffs of $W_1(s)$ to E and $L - W_1$ to VC. These payoffs are the threat points of the Nash bargaining solution since either player can receive their amount if they refuse to bargain. The outcome of the Nash bargaining solution is that each player receives his threat point plus half the surplus amount from continuing the firm. Thus E's repudiation-proof late vesting is always half the surplus. The surplus is $v - L$, where $v \in \{0, V_R, V_1, V_0\}$. Although the outcome of the surplus is known by E but not by VC, the project choice and effort decision have already been made and E can take no action based on his asymmetric information other than to quit, and the outcome is contractible, so E and VC split the surplus contingent on the outcome. Since a bad E's project will always have a negative surplus outcome of $-L$, he prefers to quit so a bad project is always terminated and the bad type receives only early vesting W_1. For a good E, if the project is not effort-intensive, the surplus split at realization is $V_R - L$.

For simplicity, we assume that the good type E always supplies effort for an effort-intensive project by assuming $V_1 - V_0 > 2c(1)$. This means that once an effort-intensive project has been chosen, E will always give effort. This allows us to focus on the trade-off of how early vesting and E control act as incentives for E to choose the effort-intensive type of project. The assumption does not qualitatively change the results. Without this assumption, some projects would only be done with effort through E control, never just due to large early vesting. Thus, if E control were not feasible, the effort-intensive project would not be chosen. This assumption just makes our final proposition of the paper on the importance of E control for effort-intensive project incentives more difficult to hold and so more striking.

If the project is effort-intensive, we will show that E will always choose effort. We first fix the effort variable $e = 1$ and check whether E will deviate. E's early vesting W_1 is fixed and does not depend on effort. E's utility from effort is early vesting plus half the surplus (late vesting) minus effort costs, $U_E(e = 1) = W_1 + \frac{1}{2}(V_1 - L) - c(1)$. E's utility if he were to deviate

to no effort is $U(e=0) = W_1 + \frac{1}{2}(V_0 - L) - c(0)$. The value of deviating is

$$U_E(e=0) - U_E(e=1) = \frac{1}{2}(V_0 - V_1) + c(1).$$

Since this value of deviating is negative, E will always take effort under an effort-intensive project with VC control.[1] Thus, the repudiation-proof constraint under VC control is

$$W_T = W_1 + \frac{1}{2}(V^{pc} - L), \tag{RP}$$

where $V^{pc} \in \{V^{eff\text{-}int}, V^{reg}\}$, with $V^{eff\text{-}int} \equiv V(\theta_G, eff\text{-}int, 1, yes) = V_1$, and $V^{reg} \equiv V(\theta_G, reg, 0, yes) = V_R$. This implies repudiation-proof late vesting is $W_2 = W_T - W_1 = \frac{1}{2}(V^{pc} - L)$, half the surplus.[2]

If E has control at $t = 2$, VC can never fire E so an early termination is due to E quitting. Thus late vesting can be contracted contingent on the final outcome and VC cannot repudiate it. Early vesting W_1 is always set to zero in order to reduce the amount which the bad type can receive and the good type can use as bargaining power as seen below. E can repudiate with the threat of diverting funds L, which would lead to a final firm payoff of zero. E's threat point is L and VC's threat point is 0. Again, the solution is that E and VC split the surplus contingent on the outcome. A bad E's project will again always have a negative surplus outcome of $-L$. But since he has limited liability, late vesting can only be zero, and the bad E will divert the value L. For a good E, since VC cannot repudiate late vesting, E will always take the effort-intensive project and give effort. As above, the surplus from bargaining is $\frac{1}{2}(V^{pc} - L)$, where

---

[1] The assumption may be relaxed to $V_1 \geq 2c(1)$ if $V_0 < L$ because if the surplus to be split in the case of no effort in an effort-intensive project $(V_0 - L)$ is negative, E cannot be given negative late vesting due to his limited liability.

[2] Our interpretation of the payment of W_1 or $W_T = W_1 + W_2$ in terms of equity vesting is more specifically explained here. E receives an early vesting equity share of the firm α_1 at $t = 1$ (conditional on $s = 1$). E receives a late vesting equity share α_2 (for a total vesting share of $\alpha_T = \alpha_1 + \alpha_2$) if he stays with the firm until $t = 3$. If E terminates, his equity has a value of $\alpha_1 L$. If he stays, his total vesting shares have a value of $\alpha_T v = \alpha_1 v + \alpha_2 v$. The increase in value of his early vesting share is $\alpha_1(v - L)$. However, even if α_1 is received before repudiation, this increase in value is subject to the bargaining game since it is part of the total surplus from continuation, although actually only the late vesting share α_2 can be repudiated under VC control. Thus, the early vesting cannot give E incentives for taking effort though it gives incentives for choosing the effort-intensive project because the $\alpha_1(v - L)$ amount gained by staying and $\alpha_1 \Delta V_e$ from effort is partially lost in bargaining out of late vesting $\alpha_2 v$. The value from staying is the increase in total vesting $\alpha v - \alpha_1 L$, but this amount is what is subjected to bargaining, so this amount is set equal to half the surplus from continuation and is the amount that cannot be contracted (other than the repudiation-proof contract). For simplicity, we refer to $W_1 = \alpha_1 L$ as early vesting, and assume it is "vested" at $t = 1$ though it is actually paid at $t = 2$ if there is a termination or else it is paid at $t = 3$ upon completion as part of total vesting W_T. We refer to $W_2 = \alpha_1(v - L) + \alpha_2 v$ as late vesting which includes the change in value of the actual early vesting share α_1. Repudiation-proof under VC control implies $W_2 = \frac{1}{2}(v - L)$ (or half the surplus) paid at $t = 3$ upon completion. Total vesting is $W_T = W_1 + W_2 = v(\alpha_1 + \alpha_2)$.

$V^{eff\text{-}int} = V_1$ and $V^{reg} = V_R$. The E control repudiation proof constraint is:

$$W_T \geq L + \frac{1}{2}(V^{pc} - L). \tag{RP$_C$}$$

To focus on interesting cases, we assume that E's cost of effort is high enough that either some amount of early vesting or E control is always necessary for E to recover his cost of effort so that he is willing to choose the effort-intensive project: $k > \frac{1}{2}$. Without this assumption, E would always choose an effort-intensive project and effort during the project since he always receives at least half the product of his effort from his split over the bargaining surplus.

Assuming that repudiation can allow one party to force renegotiation through bargaining is controversial. DeMarzo and Fishman (2000) argue that repudiation is not a credible threat and that the other party should be able to enforce the original contract in court. Gromb (1994) shows that in an infinitely repeated game of lending without collateral, the principal's inability to commit to not renegotiate implies she can make only zero profit, because no outcome of the game can rely on a threat that is Pareto dominated by the outcome (the latter shown by Farrell and Maskin (1989)). Hart and Moore (1994, 1998), Hart (1995), Bulow and Rogoff (1989), and Neher (1999) use the repudiation approach. In Hart and Moore (1994), repudiation starts a Rubinstein bargaining game of alternating offers under which repudiation is subgame perfect. A Rubinstein bargaining game of alternating offers with a positive probability of exogenous breakdown delivers the Nash bargaining outcome that we assume.

An approach that we have not explored is to model repudiation as a bargaining game of alternating offers but which explicitly allows for any party to appeal to a court to enforce the original contract. If the appeal process were to reduce the value of the firm because the firm had to stop operations for a period of time until the court could rule on the contract, this discounted value of the firm could act as the typical discount factor in a Rubinstein bargaining game. This discounting may be enough to preclude a party from following through with the outside enforcement option and instead ensure an immediate bargaining result of a split of the surplus. Repudiation may then be a credible threat even allowing for court enforcement of the original contract.

Finally, modeling long term contracts as inherently non-contractible due to indescribableness or unverifiable actions would result in a similar outcome as our model. Assume that continuation of the firm at $t = 2$ depends on multiple rounds of staged financing (as shown in several papers, e.g. Neher (1999)), and that late vesting cannot be contracted until the staged financing is completed. The renegotiation that is voluntary and welfare-improving for both parties gives the same results as repudiation in our model. Although long-term VC contracts including vesting are typically used in reality, they are commonly updated due to events such as refinancing. In practice, long term vesting and equity ownership is often either formally or

implicitly renegotiated. Baker and Gompers (1999) show empirically that equity investments by venture capitalists just before an IPO reduce CEO ownership by about half, and this dilution is only partially mitigated by measures undertaken that are designed to do so. This implies that VC contracts are not complete and are subject to unilateral renegotiation as we assume.

Robustness to the Timing of Events We assume that the timing of the unverifiable fire action by VC, quit action by E, and divert action by the agent in control takes place at $t = 2$ after the signal at $t = 1$, but this timing in not important for our results. Since repudiation depends on the threat of taking one of the unverifiable actions, it occurs at the time of the unverifiable actions. However, the unverifiable quit, fire, and divert actions could occur at any time or multiple times during the life of the project and not significantly change the results.

The unverifiable actions could occur any time up to the final verifiable sale of the firm at $t = 3$. If the agent in control were to operate the assets and divert the cash flows just before $t = 3$, the diversion value is still only L and the assets expire worthless. If the assets have not been diverted by $t = 3$, the firm is sold for a verifiable price and thus the agent loses control at the time of the sale and no longer can divert the assets. If the unverifiable actions were to occur before the signal at $t = 2$, repudiation would also occur earlier. Since early vesting must be paid at or before the possibility of repudiation, early vesting would be paid before the signal and could not be conditional on the signal. The signal then could not be contracted upon, and the outcome would be the same as when the quality of the signal is zero. If the unverifiable actions were to occur at the beginning of the project, early vesting would be paid at the signing of the contract at $t = 0$. If the unverifiable actions were to occur multiple times or continuously throughout the life of the project, the model outcome would be unaffected. Once early vesting has been paid and repudiation determines late vesting given by (RP) or (RP$_\mathrm{C}$), any further repudiation only gives the same late vesting.

The timing of E's effort may also occur at any time throughout the life of the project without qualitatively changing the results. If effort were to occur at any time before the unverifiable actions and repudiation, the model results are the same. If effort were to occur after repudiation, the only change to model results would be that the cost of effort $c(1)$ would be shared by E and VC as a part of the surplus bargained over for effort-intensive projects rather than born solely by E. (RP) would be replaced by $W_T = W_1 + \frac{1}{2}[V^{eff\text{-}int} - L + c(1)]$, and (RP$_\mathrm{C}$) would be replaced by $W_T \geq L + \frac{1}{2}[V^{eff\text{-}int} - L + c(1)]$. Therefore, effort-intensive projects would be taken by E more easily and without as much early vesting or contingent control necessary, but results are qualitatively similar.

4. Results

4.1. First Best Results with Relaxed Model Assumptions

First best results are for VC to offer a contract with an effort-intensive project that has a separating equilibrium, in which the good E accepts and the bad E does not, and in which the good E gives effort. However, the bad type will accept the contract and pool whenever his expected payoff from early vesting or diversion of assets are greater than his initial cost of S. We say there exists lax screening if the contract results in pooling and so does not screen out the bad type.

We call a contract feasible if the good E's and VC's appropriate individual rationality constraints would hold if the good type were to accept. Of course, feasibility also depends upon whether the bad type would accept or not. The good type's individual rationality constraint holds if his total vesting after repudiation and bargaining is greater than S plus his cost of effort (if any). VC's individual rationality constraint, as given by (VC*) or (VC′) below, holds if she expects to at least break even on recovering her invested capital. Feasibility can refer to a specific class of contracts, such as those with E control, an effort-intensive project, or high levels of early vesting. Feasibility of VC investment refers to whether any type of contract is feasible.

Since the venture capital market for financing is competitive, and projects accepted by the good type are profitable for VC while those accepted by the bad type are not, the equilibrium will be whichever feasible contract maximizes the good type's utility (total vesting minus S and cost of effort).

We first show how first best results obtain if any assumption of the model is relaxed: non-verifiable termination actions, ex-ante asymmetric information, diversion of funds, and interim asymmetric information due to a noisy signal of E's type.

Verifiable Termination Actions If termination as due to VC firing or E quitting were verifiable (or alternatively, if E and VC were able to commit to not terminate E after a high signal $s = 1$), first best results would obtain. If the fire and quit actions are verifiable, late vesting can be contracted since the party causing termination can be contracted to receive none of the surplus rather than being able to bargain for half. With full commitment, late vesting can be contracted since commitment precludes the ability to repudiate the contract. Either way, contracts are complete. Contracting on late vesting allows for full incentives for the effort-intensive project and full screening of types. VC offers E a contract with VC control, an effort-intensive project, $W_1 = 0$, and late vesting that pays E the full residual, $W_T = V_1 - K$, giving E full incentives to take the effort-intensive project for any cost of effort $k \in (\frac{1}{2}, 1)$. The

equilibrium is separating with full screening, in which the good type accepts and gives effort and the bad type rejects.

Ex-Ante Symmetric Information   If E's type were known by VC at the outset, VC would never offer the bad type a contract and first best results would obtain. If the value of the project is large enough, VC offers E control. If $V_1 \geq 2K + L$, VC offers a contract with E control, an effort-intensive project, $W_1 = 0$, $W_T = V_1 - K$, and RP$_C$ is satisfied so that E does not hold up VC. The equilibrium is separating with full screening out of the bad type and the good type accepts and gives effort. If the project value is not large $(V_1 < 2K + L)$, VC offers the good type a contract which gives full up-front vesting to provide E with incentives to accept the effort-intensive project. VC offers no contract to the bad type and a contract to the good type with VC control, $W_1 = \frac{1}{2}(V_1 + L) - K$, $W_T = V_1 - K$, and an effort-intensive project. The equilibrium is separating with full screening out of the bad type and the good type accepts and puts in effort.

No Diversion of Funds   If the agent in control of the assets were not able to operate the assets early to divert funds, E control would always be efficient because the bad type could not divert and E could not hold up VC with the threat to divert under E control. VC offers a contract with E control, an effort-intensive project, $W_1 = 0$, and $W_T = V_1 - K$. The equilibrium is separating with full screening and the good type accepts and gives effort.

High Quality Interim Signal   If the signal quality q were high enough, $q \geq \overline{q} = \frac{L-S}{L}$, (and the project value were large enough), VC could offer E control. The bad type does not accept the contract because of the likelihood that he will be caught, and the good type cannot hold up VC, giving us first best results. The signal quality does not have to be perfect to be able to screen out the bad type. If $q \geq \overline{q}$, the bad type never accepts a contract that gives E control because the expected value of diversion for the bad type, $(1 - q)L$, is less than the bad type's cost of doing a project, S. If the project value is large enough, $V_1 \geq 2K + L$, RP$_C$ is satisfied and the good type does not repudiate the contract with the threat of diverting funds. VC offers an effort-intensive contract with E control, $W_1 = 0$, and $W_T = V_1 - K$. The equilibrium is separating and the good type accepts and gives effort.

4.2. Limited First Best Results: Semi-Entrepreneurial Projects

The bad type will accept any contract that pays him greater than S in expectation, the amount he pays to do the project. We assume the bad type does not accept a contract when he is indifferent. The value to the bad type of a contract with E control is the probability that the

bad type receives a high signal and does not get fired times the diversion value of the assets, $(1-q)L$. The signal quality of a noisy signal is $q < \bar{q} = \frac{L-S}{L}$. The expected value to the bad type is thus greater than S, so the bad type always accepts a contract with E control. Under E control, E can be contracted in late vesting the entire product of his effort ΔV_e so E will always accept the effort-intensive project and give effort, but the equilibrium is pooling so the contract has lax screening.

The good type takes the effort-intensive project if his total vesting minus the cost of effort is greater than total vesting under the regular project, $W_T(V_1) - c(1) \geq W_T(V_R)$, or else if the effort-intensive project is feasible but the regular project is not. For a VC control project, the repudiation proof condition for VC control (RP) gives the value for W_T after repudiation occurs. Substituting, the inequality for the effort-intensive project is

$$W_1(eff\text{-}int) + \frac{1}{2}(V_1 - L) - k\Delta V_e \geq (reg) + \frac{1}{2}(V_R - L).$$

Simplifying, this becomes

$$W_1(eff\text{-}int) \geq W_1(reg) + (k - \frac{1}{2})\Delta V_e. \tag{4.1}$$

Since k is always greater than one-half, early vesting of an effort-intensive project $W_1(eff\text{-}int)$ must be greater than early vesting of a regular project $W_1(reg)$. In order for a contract to have efficient screening and lead to a separating equilibrium, the bad type must receive (weakly) less in expectation from taking the contract than S. This means that early vesting W_1 must be low enough such that $(1-q)W_1 \leq S$, or $W_1 \leq \frac{S}{(1-q)}$.

With the combination of non-verifiable termination actions, ex-ante asymmetric information, diversion of funds, and a noisy interim signal, the model has limited first best results. Since the bad type accepts any contract that gives E control or good-sized early vesting, the first best contract must have VC control with limited early vesting. With this, E will only accept the effort-intensive project if the early vesting incentive is large enough to overcome the effort cost, or if the project is not feasible without taking the effort-intensive project. The following lemma states that projects for which the surplus value and the product of effort are not very large have first best results.

Lemma 1. *If $V_R - L \in [2(K-L) - \Delta V_e, \ \max\{2(K-L), \ 2(K - L + \frac{S}{1-q}) - \Delta V_e\})$ and $V_R - L \geq 2[(k-\frac{1}{2})\Delta V_e - \frac{q}{1-q}S]$, then there exists a unique first best separating equilibrium with VC control, an effort-intensive project, and effort is supplied.*

Proof. See the Appendix. ∎

First best results are limited to projects that are not what we define as "highly entrepre-

neurial." Highly entrepreneurial projects are those for which E's human capital are large in comparison to the project costs. We define highly entrepreneurial projects as those for which the fraction for which E can bargain of his added value due to his human capital over the value from the assets secondary value, $\frac{1}{2}(V_R - L)$, in excess of the early vesting E can receive without bad types pooling, $\frac{S}{1-q}$, is greater than the cost of the specificity of the assets, (or the loss in value from the assets secondary use), $K - L$:

$$\frac{1}{2}(V_R - L) - \frac{S}{1-q} \geq K - L. \tag{(HE)}$$

Any projects that are not highly entrepreneurial we call semi-entrepreneurial projects since E still adds value, $V_R > K > L$. The group of all highly entrepreneurial and semi-entrepreneurial projects are called entrepreneurial projects.

4.3. Second Best Results: Highly Entrepreneurial Projects

4.3.1. Tradeoff of Effort-Intensive Project and Screening

For a highly entrepreneurial project (HE) project, the surplus on a regular project is large enough that VC can recover all her investment from the half of the surplus she receives from repudiation. This allows E to receive the maximum possible amount under separation, $\frac{S}{1-q}$. But for an effort-intensive project, E is still not able to receive more than $\frac{S}{1-q}$ for the bad type to not pool, so E's early vesting cannot increase for taking the effort-intensive project to compensate him for his cost of effort, despite the increase from his product of effort. Thus, E does not have enough incentives to take the effort-incentive project.

Instead, VC makes profit in a separating equilibrium. Even though the venture capital market for financing entrepreneurs is competitive at $t = 0$, there is no way a VC can commit when the contract is signed to not hold up E other than by giving E control. When E control is not feasible, no VC can compete away the profits because any up-front payment is equivalent to early vesting that draws in the bad types and reduces screening capability, which would create losses and break VC's individual rationality constraint under separation. There is no other factor to screen the bad type out on than early vesting. Thus, under separation, E will never choose effort. VC is able to hold E to (RP) and is able to make a profit. The individual rationality constraint for VC under separation and VC control is

$$V^{pc} - W_T \geq K. \tag{VC*}$$

(VC*) holds but is not binding for $V^{pc} = V_R$.

E's payoff from late vesting is $W_2 = \frac{1}{2}(V^{pc} - L)$. E's marginal payoff to taking the effort-

intensive project and giving effort from late vesting is thus $\frac{1}{2}\Delta V_e$. E receives no marginal payoff to the effort-intensive project from early vesting, however. Since the constraint for early vesting is $W_1 \leq \frac{S}{1-q}$, it is not sensitive to ΔV_e. This is what allows (VC*) to be slack, and thus VC receives all of the product of effort that is not captured in late vesting; E captures none of it in early vesting. But E's cost of effort kX is greater than $\frac{1}{2}\Delta V_e$, so he will not take the effort-intensive project. The key is that VC not only makes a profit, but she receives the residual value of the firm. Thus, her stake is similar to equity while E's stake is similar to a fixed wage. The VC holdup of E, with the condition of a constant level of early vesting not based on final firm value that is necessary to achieve separation and efficient screening, precludes efficient E choice of the effort-intensive project. In order to induce E to choose the effort-intensive project, early vesting must be set to make VC's individual rationality constraint close to binding at $V^{pc} = V_R$ so that E, in his decision whether to choose the effort-intensive project, receives exposure to the product of effort in early vesting. In other words, VC must make near zero profits.

In order for early vesting to be sensitive to the product of effort, $(1-q)W_1$ must be greater than S so that the bad type accepts the contract creating a pooling equilibrium and lax screening. In this case, we need to use the individual rationality constraint for VC under a pooling equilibrium and VC control,

$$p(V^{pc} - W_T) + (1-p)(L - (1-q)W_1) \geq K. \tag{VC$'$}$$

The next proposition shows that highly entrepreneurial projects have no first best equilibrium. For highly entrepreneurial projects, early vesting or E control which protects late vesting give E incentives to take the effort-intensive project, but they reduce screening capability. There is a trade-off. Projects are either effort-intensive with lax screening or they are not effort-intensive.

Proposition 2. *All projects that are highly entrepreneurial (HE) and effort-intensive have pooling equilibria.*

Proof. See the Appendix. ∎

Greater early vesting in a pooling equilibria trades off the benefit of greater effort incentives with the cost of lax screening, to be defined specifically below. Our discussion of the model often focuses on the level of incentives, which is continuous, rather than just on the choice of the effort-intensive project, which is discrete, because a higher level of incentives will induce the effort-intensive project choice for a higher ranging cost of effort k.
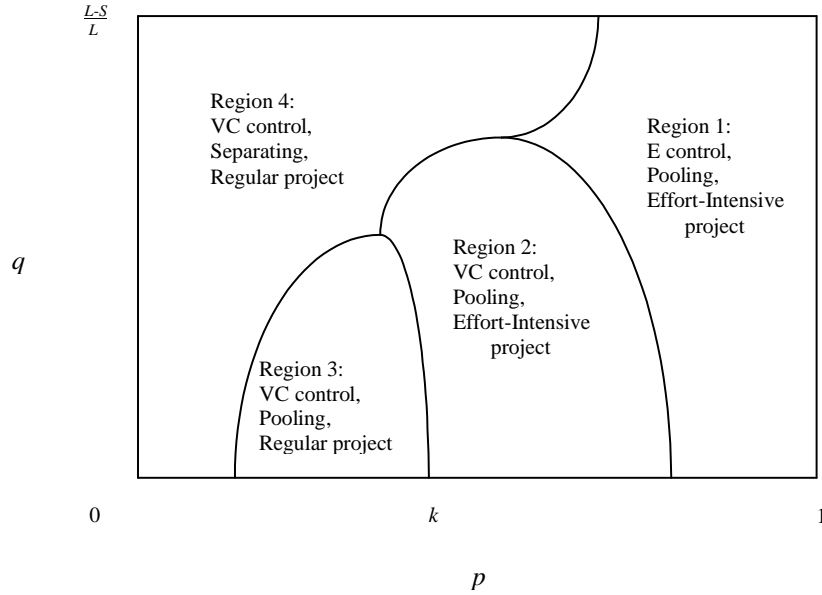
$\frac{L\text{-}S}{L}$

Region 4:
VC control,
Separating,
Regular project

Region 1:
E control,
Pooling,
Effort-Intensive
project

Region 2:
VC control,
Pooling,
Effort-Intensive
project

Region 3:
VC control,
Pooling,
Regular project

q

0   k 1

p

Figure 4.1: Illustrative Equilibrium Regions

4.3.2. Equilibrium Results

The possible types of equilibria for highly entrepreneurial projects are illustrated below in Figure 4.1, with the probability of a good type p on the x-axis and the signal quality q on the y-axis. We describe the results in this subsection and then give the intuition for the equilibrium selection in the next subsection. The divided regions illustrate the resulting equilibria classified as separating or pooling, effort-intensive projects or regular projects, and VC control or E control. In Region 4, the separating equilibrium, VC always has control and there is never an effort-intensive project. Within the pooling equilibria, Regions 1-3, E has control in Region 1 and chooses the effort-intensive project. Under VC control, E chooses the effort-intensive project in Region 2 and the non-effort intensive project in Region 3.

Region 4, separation, is feasible for all highly entrepreneurial projects, for all p and q. However, the good type prefers the contracts specified in Regions 1-3 for their corresponding levels of p and q, when they give him greater profit, as shown in Figure 4.1, and so these are the resulting equilibria when they are feasible for values of p and q. Region i is the equilibrium

rather than Region j if p is large enough such that $p > p_{i,j}$, where

$$p_{1,2} \equiv \frac{K - qL}{\frac{1}{2}(V_R + \Delta V_e - L) - qL} \tag{4.2}$$

$$p_{1,3} \equiv \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$
$$\text{where} \quad a = \tfrac{1}{2}(V_R - L) - qL$$
$$b = -a - c - (\tfrac{1-k}{1-q})\Delta V_e$$
$$c = K - qL - (1 - k)\Delta V_e$$

$$p_{1,4} \equiv \frac{K - qL}{\frac{1}{2}(V_R - L) + (1 - k)\Delta V_e + (1 - q)L - \frac{1}{1-q}S}$$

$$p_{2,3} \equiv \frac{(k - \frac{1}{2})(1 - q)}{\frac{1}{2} - (k - \frac{1}{2})q} \tag{4.3}$$

$$p_{2,4} \equiv \frac{K - L + (k - \frac{1}{2})(1 - q)\Delta V_e + S}{\frac{1}{2}(V_R - L) + [\frac{1}{2} - (k - \frac{1}{2})q]\Delta V_e - \frac{q}{1-q}S}$$

$$p_{3,4} \equiv \frac{K - L + S}{\frac{1}{2}(V_R - L) - \frac{q}{1-q}S}. \tag{4.4}$$

The feasibility of each region in Figure 4.1 depends on conditions implicit in $p > p_{i,j}$ from the appropriate $p_{i,j}$ above, such that the surplus $V_R - L$ is large enough and the product of effort ΔV_e is of appropriate size.

Proposition 3. *The unique equilibrium of a highly entrepreneurial (HE) project is:*

1. *Region 1, pooling with E control and an effort-intensive project, for the highest levels of p:*
   if $p > p_{1,2} > 0$, $p > p_{1,3} > 0$ and $p > p_{1,4} > 0$;

2. *Region 2, pooling with VC control and an effort-intensive project, for moderate levels of p and moderate to low levels of q :*
   if (1) does not hold, $p > p_{2,3} > 0$ and $p > p_{2,4} > 0$;

3. *Region 3, pooling with VC control and a non-effort intensive project, for low levels of p and q :*
   if (1) and (2) do not hold and $p > p_{3,4} > 0$;

4. *Region 4, separation with VC control and a non-effort intensive project, for the lowest levels of p, or for moderate levels of p and high levels of q :*
   if (1), (2) and (3) do not hold.

Proof. See the Appendix. ∎

The following corollary shows that there exist semi-entrepreneurial projects that are efficient to undertake but are not feasible.

Corollary 4. *If $V_R - L \in [K - L + S - (1 - k)\Delta V_e, 2(K - L) - \Delta V_e)$, the project is efficient to undertake as effort-intensive (and perhaps as non-effort intensive), but is not financed.*

Proof. See the Appendix. ∎

4.4. Effort-Intensive Project and Cost of Lax Screening

We define the cost of lax screening to be the expected amount of financing of a bad project that is not recovered by VC plus the expected amount of vesting and diversion of funds that is received by the bad type in a pooling equilibrium. Both of these occur in a pooling equilibrium in which bad types pool due to the benefits of E control or high early vesting, but would not occur in a separating equilibrium. We call this amount a cost because it both decreases VC's ability to recover K from the project, decreasing the project's financing feasibility, and inefficiently decreases the amount of early vesting or E control, decreasing a good type's incentives to take the effort-intensive project. The expected cost of lax screening due to inefficient investment is $(1 - p)(K - L)$, due to early vesting paid to the bad type under VC control is $(1 - q)(1 - p)W_1$, and due to diversion by the bad type under E control is $(1 - q)(1 - p)L$.

Under pooling, the bad type will always prefer to quit and receive early vesting under VC control or divert funds under E control. Thus, at $t = 2$, only the bad type will ever quit. VC will always bargain with the good type following his repudiation and so the good type will never quit in equilibrium. Furthermore, VC will never fire E when the signal is high. Thus, a termination in equilibrium with E taking early vesting W_1 implies that E is bad. However, $W_1 = 0$ is not the typical contract. The amount of early vesting that the bad type takes when quitting, which induces him to pool in the first place causing inefficient investment, is the same amount of early vesting that the good type uses in bargaining with VC due to (RP), that allows the good type to increase his overall payoff of total vesting above what the good type would receive if early vesting were set low so that the bad type would not pool. This early vesting also increases incentives for the good type to take the effort-intensive project.

Under separation with VC control and no effort-intensive project, as discussed above, VC makes profits. These profits are also inefficient in taking away from E's incentives to take the effort-intensive project. E chooses the initial contract based upon the trade-off of the cost of lax screening losses to the bad type under pooling, and losses to VC profit under separation.

The expected costs of lax screening are relatively low for high p and q, when the ex-ante probability of bad types is low and the probability of catching bad types with the signal after

contracting is high. When costs of lax screening are relatively low, E control is feasible. This gives E the greatest incentives to choose the effort-intensive project, which he always takes under E control, as seen in Region 1 of Figure 4.1. As costs of lax screening increase with the decrease of p and q, and E control becomes too costly, large early vesting may instead be still feasible. This may still give E large enough incentives to choose the effort-intensive project, as shown in the VC control pooling equilibrium with effort-intensive project in Region 2. As costs of lax screening increase even further, early vesting is decreased, decreasing incentives until the effort-intensive project is not chosen. However, there may still be a pooling equilibrium where the good type receives higher early vesting despite not taking the effort-intensive project, as seen in Region 3. Finally, for large enough costs of lax screening, E chooses separation (and profits to VC) rather than pooling with losses bad types, as shown in Region 4.

The level of p and q may also be interpreted further. Greater due diligence performed by VC before the project would increase the chance of weeding out bad types and so increase p. This is independent of the screening role played by the contract offered. If bad types know there is a chance of being denied for funding even if they are willing to accept a contract, fewer will try. Greater monitoring by VC during the life of the project may increase q, the quality of the interim signal. Hence, p and q may be interpreted in these ways as well, which gives insight as to the trade-off of better due diligence versus better monitoring by VC.

The following two propositions give comparative statics for changes in p and q. The results for changes in p hold everywhere. The results for changes in q hold everywhere except for possibly between the borders of Regions 1 and 4, 2 and 4, and 1 and 3, due to nonlinearities in q there.

Proposition 5. *For highly entrepreneurial projects, as p decreases:*
E control, early vesting plus E diversion of funds, incentives, choice of the effort-intensive project, and level of effort decrease weakly, and the equilibrium changes weakly from pooling to separating.

Proof. See the Appendix. ∎

Decreases in p and q have similar effects on E control, early vesting, incentives, and effort-intensive project choice, but they have opposite effects on the level of screening due to either a pooling or separating equilibrium obtaining, as seen in the next proposition.

Proposition 6. *For highly entrepreneurial projects, as q decreases within any region and between Regions 1 and 2, Regions 2 and 3, and Regions 3 and 4:*
E control, early vesting plus E diversion of funds, incentives, choice of the effort-intensive project, and level of effort decrease weakly, and the equilibrium changes weakly from separating to pooling.

27

Proof. See the Appendix. ∎

When p decreases enough, high early vesting effort incentives become worth so little (there are few good types to take effort) that separation is eventually preferable for E, whereas when q is very low, pooling may still allow for large enough effort incentives that the effort-intensive project is more worthwhile than separation, which has no effort-intensive project.

However, Figure 4.1 shows that as q decreases the equilibrium may turn from separating to pooling (from Region 4 to 3) even without the effort-intensive project being chosen. The choice of either separating or pooling equilibrium is made by the good type. In a separating equilibrium, early vesting has a cap of $\frac{S}{1-q}$ and the good type "loses" excess firm value to VC who makes profits. In a pooling equilibrium, the good type loses profits ex-ante to investment in bad projects that cannot be recovered by VC. The good type also loses profits ex-post to bad types who are not caught by the signal and receive early vesting. Both of these losses decrease the amount of early vesting that can be paid to the good type. As q decreases, both of these losses increase, reducing the good type's early vesting under pooling, but early vesting decreases under separation as well as the cap goes down. However, capped early vesting available under separation decreases with q faster than would early vesting under pooling decrease with q. This is because the costs of lax screening due to losses in investment $(1-p)(K-L)$ is independent of q. Only the costs of lax screening due to the ex-post early vesting paid to the bad type, $(1-p)(1-q)W_1$, increases with q. Thus, early vesting under pooling, $W_1 = \frac{\frac{1}{2}p(V_1-L)-(K-L)}{1-(1-p)q}$, does not decrease as fast as capped early vesting under separation, $\frac{S}{1-q}$, the entire amount of which is sensitive to q. Basically, when q is so low as to be a nearly informationless signal, the good type loses more in "profit" to VC under separation than he would lose to costs of lax screening and the bad type under pooling, so pooling is selected. Thus, for a high q, separation gives a high cap making it more attractive than pooling. As q decreases, pooling is eventually chosen when the separation capped vesting eventually falls below the pooling early vesting amount.

In the case of p decreasing, the costs of lax screening also increase. This decreases early vesting to the good type under pooling. However, the capped early vesting available under separation is unchanged with p. Thus, for low enough p, separation is eventually preferred.

In the pooling regions, early vesting decreases with q because a worse signal detects fewer bad types. Since VC's individual rationality constraint is binding, early vesting to the increased number of non-detected bad types is taken from the early vesting of the remaining entrepreneurs including the good types. Within the pooling regions, however, lower q does not decrease investment in bad projects because within these regions there is not a reduction in pooling, and the bad type always liquidates the project at $t=2$, which is efficient after investment is undertaken. Interestingly, the bad types who avoid detection at $t=1$ end up receiving lower

early vesting as well so make lower profits, but the bad type's expected profit increases since his decreasing chance of being caught dominates. This lower early vesting leads to lower incentives for good types and less effort-intensive projects as we move from pooling with effort-intensive projects to pooling without effort-intensive projects as q decreases.

As signal quality decreases, fewer bad types are detected, and so the pay to increased number of surviving bad types is taken away from incentivizing good types. However, the signal is after investment, so marginal decreases in signal quality do not increase the initial investment amount in bad projects. Conversely, as p decreases, not only is the cost of investment in bad projects increased, but the cost of early vesting payments to bad types is also increased, and both are taken from early vesting of good types, decreasing incentives.

4.5. Importance of Control Rights

The model shows not only the importance of early versus late vesting but gives a new explanation for control rights. Control rights and early vesting are (imperfect) substitutes for providing effort-intensive project incentives, whereas control rights and late vesting are compliments. E control acts to entrench E in the firm in order to protect late vesting from holdup. Thus, E control over residual actions in the firm completes the incomplete contract and allows E to receive cash flows without holdup, which gives full effort-intensive project incentives.

Without E control, no amount of early vesting can give full effort-intensive project incentives. Early vesting incentives may be large enough to induce E to take the effort-intensive project for a given p if the fractional cost of effort k is not too large, but the next proposition shows that for any p, there is some $\overline{k}$ above which for all $k > \overline{k}$, early vesting cannot induce the effort-intensive project. If E control is feasible, it will always induce the effort-intensive project. The reason is that E control makes E the residual claimant so he receives the full product of effort ΔV_e without holdup. Under VC control, early vesting can never give the good type the full value of the product of effort if there is any asymmetric information ($p < 1$), because some bad types would receive the extra early vesting as well. VC must lower early vesting to compensate for that loss. This outcome is similar to that that found in many papers with incomplete contracts that assigning control rights to E is sometimes necessary for first best actions. However, other papers typically rely on private benefits from control for which monetary payments cannot compensate. We show that even without private benefits, promised monetary payments are sometimes never large enough to compensate for the monetary benefits gained from E control. However, due to the special problems of asymmetric information combined with holdup, the issue of E control cannot be solved by giving E a payment based on the signal and allowing E to purchase control from VC. There is a distinction between contingent control and contingent compensation. Bad types would not purchase control but would keep

the payment. Payment to E at $s = 1$ conditional on E buying control from VC is just the same as contingent control to E.

Proposition 7. *Under E control, E has full effort-intensive project incentives and the effort-intensive project is chosen for all $p < 1$ and $k < 1$. Under VC control for a highly entrepreneurial project, for any $p < 1$, there exists a $\overline{k}(p) < 1$ such that, for all $k > \overline{k}(p)$, the effort-intensive project is not chosen.*

Proof. See the Appendix. ∎

Although for simplicity we assume in our model that E can choose effort levels of only zero or one, if effort choice were a continuous variable between zero and one (with appropriate variable effort costs and effort-intensive project choices and payoffs) we would achieve intermediary results. A graph of equilibria regions with continuous levels of effort would look similar to Figure 4.1. Under continuous effort, constant-effort indifference curves separating regions of greater effort within the VC control pooling regions would look similar to the curve separating Regions 2 and 3 in Figure 4.1.

A continuous choice of effort and effort-intensive project types would particularly demonstrate the importance of control rights. Early vesting could never give incentives to induce as large of effort and effort-intensive project choice as could E control, since only E control allows E to receive repudiation-proof one hundred percent residual cash flows of the firm, giving him the full returns from his effort. Early vesting giving E all residual cash flows is never feasible. Thus, only E control could induce the first-best effort and effort-intensive project in a continuous model.

An interpretation of E control is that by having equity-like control rights over the firm, E also has equity-like residual cash flow rights and thus equity-like incentives. When VC cedes control rights, she has a debt-like claim. Under VC control, VC has equity/ownership type control rights and cash flow rights and E has an employment-type relationship wage. The contingent nature of the control rights helps make the contingent employee or owner nature of E's position possible, so that the owner incentives are possible to give to E on a contingent basis.

5. Conclusion

An application of the model is that since the entrepreneur and the venture capitalist can extract rents through repudiation, control and early payments must be given to the more valuable party to protect their larger claim to payoffs. During times when entrepreneurial projects are expected to have smaller profits, the entrepreneur is not as essential to the firm, or managerial skill or the entrepreneur's ability is hard to distinguish, the entrepreneur would extract too

much profit and so he has to give the venture capitalist control and accept smaller early vesting. The power that the venture capitalist receives to allow her to break even actually leads to the venture capitalist making larger than competitive profits in a separating equilibrium. This may provide a new explanation to the empirical puzzle regarding the apparent above-market returns attained by venture capitalists, for which some authors have tried to attribute excessive profits due to value added services and skills provided by the venture capitalist.

Alternatively, during times when entrepreneurial projects have very high profits or technologies for which the entrepreneur is essential, the venture capitalist would extract rents, so she must give up control and give easy investment terms that ex-post looks inefficient for the cases of bad entrepreneurs who were financed and failed, but ex-ante is constrained-efficient in order to satisfy and protect the highly valuable efforts of the good entrepreneurs. This may partially explain the recent internet boom in which many of the failed startups appear to have been given excessive financing and management control, but several firms have succeeded.

The model can also be interpreted as a comparison of banking or debt markets versus venture capital financing, in a setup of only one round of financing and one cash flow. When asymmetric risk is low, a large fraction of entrepreneurs are good, or when a signal is correlated highly enough with the continuation value of the firm (such as if loan default signals insolvency and not just illiquidity), banks or debt markets can finance entrepreneurs (which is equivalent to entrepreneur control in our model). In this case, the financing party has no control over the firm except as provided by the contractible signal. Giving up non-contractible ability to manage (firing or renegotiating with the entrepreneur) is acceptable when the signal protects the outside investor enough. However, when asymmetric risk is high, many entrepreneurs are bad, or the quality of the signal is low, firms should be financed by venture capitalists who hold control of the firm (which is equivalent to venture capitalist control in our model), and who can more actively manage and renegotiate when needed.

Finally, the model can be seen as a hybrid of the property rights model of the firm (Grossman and Hart, 1986; Hart and Moore, 1990) and the agency model of the firm. Our model combines the question of which party should have control rights in the face of holdup and ex-ante investment decisions with the problem of the separation of ownership and management in the face of asymmetric information and hidden action. Since in our model the entrepreneur has the up-front choice of taking the effort-intensive project, which is similar to an up-front investment decision, and the entrepreneur is the party with valuable human capital, the property rights perspective implies that the entrepreneur should receive control rights to protect him from holdup so that he maximizes his "investment" of taking the effort-intensive project. However, this party receiving control is not an owner-manager as in the property rights literature but rather the agent of the other party who is the owner. As an agent his type is unknown

and the diversion action is not observable. From the agency perspective, the venture capitalist should hold control rights to mitigate the asymmetric information and diversion problems. We show how the assignment of control rights depends on the extent of the holdup versus agency problems in a combined model. We also show when assigning early vesting can be a substitute tool that provides a better solution than assigning control rights to the party with the greatest human capital and investment needs, in order to overcome holdup in the face of agency problems.

Appendix

Proof of Lemma 1. See the proof of Proposition 3 below for the formal statement of E's maximization problem and constraints under which the choice of contract is made. A first best equilibrium requires separation and the effort-intensive project with $e = 1$. E control implies the bad type will pool to divert funds: $L > \frac{S}{1-q}$, so first best requires VC control. Separation requires $W_1 < \frac{S}{1-q}$. (RP) due to VC control requires $W_T = W_1 + \frac{1}{2}(V_1 - L)$. The VC individual rationality constraint requires $V_1 - W_T \geq K$, so with (RP) implies $\frac{1}{2}(V_1 + L) - W_1 \geq K$. This requires

$$V_1 - L \geq 2(K - L). \tag{5.1}$$

Hence, $W_1 = \min\{\frac{1}{2}(V_1 + L) - K, \frac{S}{1-q}\}$. To satisfy E's individual rationality constraint, $W_T = \min\{V_1 - K, \frac{S}{1-q} + \frac{1}{2}(V_1 - L)\} \geq S + k\Delta V_e$. This requires $V_1 - K > S + k\Delta V_e$, or $V_R + (1-k)\Delta V_e > K + S$, which always holds, and requires

$$V_R - L \geq 2[(k - \frac{1}{2})\Delta V_e - \frac{q}{1-q}S]. \tag{5.2}$$

E accepts the contract that maximizes $W_T - c(e)$. Proposition 3 below shows that for pooling with VC control and an effort-intensive project to be chosen over separation requires $p > p_{2,4} \equiv \frac{K - L + (k - \frac{1}{2})(1-q)\Delta V_e + S}{\frac{1}{2}(V_R - L) + [\frac{1}{2} - (k - \frac{1}{2})q]\Delta V_e - \frac{q}{1-q}S}$. If $p_{2,4} > 1$, for which

$$V_R - L < 2(K - L + \frac{S}{1-q}) - \Delta V_e \tag{5.3}$$

is sufficient, then E prefers separation. Proposition 3 below also shows that for pooling with E control and an effort-intensive project to be chosen over separation requires $p > p_{1,4} \equiv \frac{K - qL}{\frac{1}{2}(V_R - L) + (1-k)\Delta V_e + (1-q)L - \frac{1}{1-q}S}$. If $p_{1,4} > 1$, for which (5.3) is sufficient, then E prefers separation. Proposition 3 below also shows that for pooling with VC control and a regular project to be chosen over separation requires $p > p_{3,4} \equiv \frac{K - L + S}{\frac{1}{2}(V_R - L) - \frac{q}{1-q}S}$. If $p_{3,4} > 1$, for which (5.3) is sufficient, then E prefers separation.

Thus, if (5.3) holds, this implies that E only accepts the effort-intensive project under separation with VC control if either (4.1) holds:

$$W_T(V_1) - k\Delta V_e \geq W_T(V_R), \tag{5.4}$$

or else if the project is not feasible without accepting the effort-intensive project.

For a regular project under VC control and separation, if

$$V_R - L < 2(K - L), \tag{5.5}$$

the VC individual rationality constraint combined with (RP) implies $V_R - W_T(V_R) \geq K$, or $\frac{1}{2}(V_R + L) - W_1(reg) \geq K$, which is equivalent to $V_R - L \geq 2(K - L) + W_1(reg) \geq 2(K - L)$, a contradiction. Thus, the project is not feasible without the effort-intensive project and so E accepts it.

If $V_R - L \geq 2(K - L)$, consider whether E prefers the effort-intensive project. Under separation and VC control, (5.4) with (RP) is equivalent to $W_1(eff-int) + \frac{1}{2}(V_1 - L) - k\Delta V_e \geq W_1(reg) + \frac{1}{2}(V_R - L)$, or

$$W_1(eff-int) - W_1(reg) \geq (k - \frac{1}{2})\Delta V_e, \tag{5.6}$$

implying $W_1(eff-int) > W_1(reg)$. Suppose $W_1(reg) = \frac{S}{1-q}$. Since under separation $W_1(pc) = \min\{\frac{1}{2}(V^{pc} + L) - K, \frac{S}{1-q}\}$, it follows that $W_1(reg) = \frac{S}{1-q} < \frac{1}{2}(V_R + L) - K < \frac{1}{2}(V_1 + L) - K$. This also implies that $W_1(eff-int) = \frac{S}{1-q}$, a contradiction to $W_1(eff-int) > W_1(reg)$. Thus, $W_1(reg) = \frac{1}{2}(V_R + L) - K$. This implies $\frac{1}{2}(V_R + L) - K < \frac{S}{1-q}$, or

$$V_R - L < 2(K - L + \frac{S}{1 - q}). \tag{5.7}$$

If $V_1 + L - K \geq \frac{S}{1-q}$, so that $W_1(eff-int) = \frac{S}{1-q}$, then for (5.6) to hold requires $\frac{S}{1-q} - [\frac{1}{2}(V_R + L) - K] \geq (k - \frac{1}{2})\Delta V_e$, or

$$V_R - L \leq 2[K - L + \frac{S}{1 - q} - (k - \frac{1}{2})\Delta V_e]. \tag{5.8}$$

Instead, if $V_1 + L - K < \frac{S}{1-q}$, or

$$V_R - L < 2(K - L + \frac{S}{1 - q}) - \Delta V_e, \tag{5.9}$$

so that $W_1(eff-int) = \frac{1}{2}(V_1 + L) - K$, then for (5.6) to hold requires $\frac{1}{2}(V_1 + L) - K - [\frac{1}{2}(V_R + L) - K] \geq (k - \frac{1}{2})\Delta V_e$, or $k \leq 1$, which always holds. (5.9) is sufficient for (5.8) and (5.7) to hold and is equivalent to (5.3), so E takes the effort-intensive project if (5.9) holds.

Thus, if (5.1) and (5.2) hold, and either (5.5) or (5.9) holds, summarized as

$$V_R - L \;\geq\; 2[(k - \frac{1}{2})\Delta V_e - \frac{q}{1 - q}S]$$
$$V_R - L \;\in\; [2(K - L) - \Delta V_e, \; \max\{2(K - L), \; 2(K - L + \frac{S}{1 - q}) - \Delta V_e\}),$$

the equilibrium is the first best contract with separation, VC control, the effort-intensive project and $e = 1$. ∎

Proof of Proposition 2. In a separating equilibrium with a regular project, $W_T(V_R) = W_1(reg) + \frac{1}{2}(V_R - L)$, where $W_1(reg) = \min\{\frac{1}{2}(V_R + L) - K, \frac{S}{1-q}\}$. (HE) implies that $W_1(reg) = \frac{S}{1-q}$. A regular project is always feasible since $W_T(V_R) > S$, which satisfies E's individual rationality constraint, and (RP) with (HE) implies $V_R - W_T(V_R) = \frac{1}{2}(V_R + L) - \frac{S}{1-q} \geq K$, which satisfies VC's individual rationality constraint. E control implies L is available for diversion so the expected payoff to bad types is $(1-q)L > S$, so there is pooling. Under VC control, for E to accept an effort-intensive project requires $W_T(V_1) - k\Delta V_e \geq W_T(V_R)$. By (RP), this implies $W_1(eff-int) + \frac{1}{2}(V_1 - L) - k\Delta V_e \geq W_1(reg) + \frac{1}{2}(V_R - L)$, or $W_1(eff-int) \geq W_1(reg) + (k - \frac{1}{2})\Delta V_e > W_1(reg) \geq \frac{S}{1-q}$. Hence, the bad type pools since $(1-q)W_1(eff-int) > S$. ∎

Proof of Proposition 3. The contract chosen in equilibrium is the feasible contract that maximizes the good E's utility. The problem is given as:

$$\max_{W_1, W_T, C(s), pc} \quad W_T - c(e) \tag{5.10}$$

$$\text{s.t.} \quad W_T - c(e) \geq S \tag{Good E IR}$$

$$W_T(V_1) - k\Delta V_e \geq W_T(V_R) \tag{Good E IC}$$

$$C(s = 1) = VC \Rightarrow (RP) \tag{5.11}$$

$$C(s = 1) = E \Rightarrow (RP_C) \tag{5.12}$$

$$W_1 + L\mathbf{1}_{C(1)=E} > \frac{S}{1-q} \Rightarrow (VC') \tag{VC IR Pooling}$$

$$W_1 + L\mathbf{1}_{C(1)=E} \leq \frac{S}{1-q} \Rightarrow (VC^*), \tag{VC IR Separation}$$

where $\mathbf{1}_{[\cdot]}$ denotes the indicator function. A feasible contract is one that satisfies all of the constraints for (5.10).

Proposition 2 implies that there can be no equilibrium with separation and the effort-intensive project. Since E control implies the effort-intensive project is always taken, there cannot be an equilibrium with separation and E control. This implies that the only potentially feasible contracts are separation with VC control and a regular project (Sep_R), pooling with VC control and a regular project ($Pool_R$), pooling with VC control and an effort-intensive project ($Pool_e$), and pooling with E control and an effort-intensive project ($Pool_c$).

Let $c(e, x)$ equal the cost of effort, and let $W_t(x)$ equal the vested wage paid for time t that satisfies all constraints for (5.10) for contract x, where contract $x \in \{Sep_R, Pool_R, Pool_e, Pool_c\}$. Specifically, separation implies $W_1 \leq \frac{S}{1-q}$ for the bad E's incentive constraint to hold to refuse the contract and implies VC's individual rationality constraint for separation (VC*) must hold. Pooling implies $W_1 > \frac{S}{1-q}$ for the bad E's incentive constraint to hold to take the contract and implies VC's individual rationality constraint for pooling (VC') must hold. Under VC control, for $C(s = 1) = VC$, the repudiation proof constraint (RP) must hold. Under E control, for

$C(s = 1) = E$, the repudiation proof constraint (RP$_C$) must hold.

First we show that Sep_R is always feasible. (VC*) and (RP) imply that $(V_R - L) \geq 2(K - L)$ must hold, which does by (HE). Wages determined by (VC*), (RP) and the separation condition that $W_1 \leq \frac{S}{1-q}$, is given by $W_1(Sep_R) = \min\{\frac{1}{2}(V_R + L) - K, \frac{S}{1-q}\}$ and $W_T(Sep_R) = \min\{\frac{1}{2}(V_R - L) + \frac{S}{1-q}, V_R - K\}$, which by (HE) implies $W_1(Sep_R) = \frac{S}{1-q}$ and $W_T(Sep_R) = \frac{1}{2}(V_R - L) + \frac{S}{1-q}$. E's individual rationality constraint (Good E IR) holds: $W_T(Sep_R) \geq S$. Hence, Sep_R is always feasible. Thus, an equilibrium satisfying (5.10) always exists.

Consider any contract $y \in \{Pool_R, Pool_e, Pool_c\}$.

$$W_T(y) - c(e, y) > W_T(Sep_R) \tag{5.13}$$

implies contract y is preferred by E to Sep_R. Additionally, (5.13) implies that contract y satisfies (Good E IR) since Sep_R does. (Good E IC) is always satisfied from above when the effort-intensive project is chosen.

Under $Pool_R$, solving (VC$'$) and (RP) for wages gives

$$
\begin{aligned}
W_T(Pool_R) &= \frac{[p + \frac{1}{2}(1-p)(1-q)](V_R - L) - (K - L)}{p + (1-p)(1-q)} \\
W_1(Pool_R) &= \frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}.
\end{aligned}
$$

Since

$$W_2(Pool_R) = W_2(Sep_R) = \frac{1}{2}(V_R - L),$$

if $W_T(Pool_R) > W_T(Sep_R)$, then $W_1(Pool_R) > W_1(Sep_R)$.

By (HE), $W_1(Sep_R) = \frac{S}{1-q}$. Hence, if $W_T(Pool_R) > W_T(Sep_R)$, $W_1(Pool_R) > \frac{S}{1-q}$ so the bad type's incentive constraint to pool is satisfied, so all constraints for (5.10) are satisfied, thus $Pool_R$ is feasible. Substituting for $W_T(Pool_R)$ and $W_T(Sep_R)$ in $W_T(Pool_R) > W_T(Sep_R)$ and solving for p gives $p > p_{3,4}$.

Under $Pool_e$, solving (VC$'$) and (RP) for wages gives

$$
\begin{aligned}
W_T(Pool_e) &= \frac{[p + \frac{1}{2}(1-p)(1-q)](V_1 - L) - (K - L)}{p + (1-p)(1-q)} \\
W_1 &= \frac{\frac{1}{2}p(V_1 - L) - (K - L)}{p + (1-p)(1-q)}.
\end{aligned}
$$

Since

$$W_2(Pool_e) - c(1) = \frac{1}{2}(V_R - L) - (k - \frac{1}{2})\Delta V_e$$

$$< W_2(Sep_R) = W_2(Pool_R) = \frac{1}{2}(V_R - L),$$

if $W_T(Pool_e) - c(1) > W_T(Sep_R)$, then $W_1(Pool_R) > W_1(Sep_R) = \frac{S}{1-q}$, so the bad E's incentive constraint to pool is satisfied, thus all constraints for (5.10) are satisfied, and $Pool_e$ is feasible. Substituting and solving for p, $W_T(Pool_e) - c(1) > W_T(Sep_R)$ is equivalent to $p > p_{2,4}$, and $W_T(Pool_e) - c(1) > W_T(Pool_R)$ is equivalent to $p > p_{2,3}$.

Under $Pool_c$, solving (VC′) and (RP$_C$) for wages gives $W_T(Pool_c) = V_1 + \frac{(1-p)qL-K}{p}$. Under E control, the bad type will always divert assets for L and so the bad type's incentive constraint to pool is always satisfied, so all constraints for (5.10) are satisfied, and $Pool_c$ is feasible. Substituting and solving for p, $W_T(Pool_c) - c(1) > W_T(Sep_R)$ is equivalent to $p > p_{1,4}$, and $W_T(Pool_c) - c(1) > W_T(Pool_e)$ is equivalent to $p > p_{1,2}$.

$Pool_c > Pool_R$ is equivalent to

$$(1-q)(1-p)[\frac{1}{2}p(V_R - L) + (1-k)\Delta V_e] + p(1-k)\Delta V_e \tag{5.14}$$

$$> (1-q)(1-p)[K - (1-p)qL] \tag{5.15}$$

$$(1-q)(1-p)\{p[\frac{1}{2}(V_R - L) - qL] - (K - qL) \tag{5.16}$$

$$+(1-k)\Delta V_e(\frac{q}{1-q})\} + (1-k)\Delta V_e > 0. \tag{5.17}$$

Sufficient for (5.14) is:

$$\frac{1}{2}p(V_R - L) + (1-k)\Delta V_e > K - (1-p)qL$$

$$p > \bar{p}_{1,3} \equiv \frac{K - qL}{\frac{1}{2}(V_R - L) + (1-k)\Delta V_e - qL}$$

The solution of (5.14) is given by the solution to the quadratic equation:

$$Q \equiv ap^2 + bp + c < 0, \tag{5.18}$$

where

$$a = \frac{1}{2}(V_R - L) - qL$$

$$b = -a - c - \left(\frac{1-k}{1-q}\right)\Delta V_e$$

$$c = K - qL - (1-k)\Delta V_e.$$

When there exists a real solution ($b^2 - 4ac > 0$), define the roots of $Q = 0$ as $\{p^-, p^+\}$, where $p^- = \frac{-b-\sqrt{b^2-4ac}}{2a}$ and $p^+ = \frac{-b+\sqrt{b^2-4ac}}{2a}$. The roots are difficult to analyze directly. At $k = 1$, the roots are $\{p^-, p^+\} = \{\frac{K-qL}{\frac{1}{2}(V_R-L)-qL}, 1\}$. Since $a > 0$ by (HE), of $p^- < 1$, then the quadratic inequality (5.18) is graphed as a parabola with vertex below zero and roots $p^- < 1$ and $p^+ = 1$, so the solution to (5.18) is $p \in (p^-, p^+)$. Since $\frac{dQ}{dk} < 0$ and $\frac{dQ}{dp}|_{k \leq 1, p \geq 1} < 0$, this implies that for $k < 1$, p^+ must increase to be a root of $Q = 0$. Thus, $p^+ \geq 1$. Hence, when $p^- < 1$, the solution to (5.18) is $p \in (p^-, p^+)$, so the relevant solution is $p > p_{1,3} \equiv p^- > 0$.

If $p^- \geq 1$, then since $\frac{dQ}{dk} < 0$ and $\frac{dQ}{dp}|_{k \leq 1, p \geq 1} < 0$, $p^- < 1$ for all $k < 1$, and $p^+ \geq 1$, so there is no solution for $p < 1$.

If $p > p_{1,2} > 0$, $p > p_{1,3} > 0$ and $p > p_{1,4} > 0$, then $Pool_c$ (Region 1) is the preferred feasible contract and uniquely solves (5.10). If $p \leq |p_{1,2}|$, $p > p_{2,3} > 0$ and $p > p_{2,4} > 0$, then $Pool_e$ (Region 2) is the preferred feasible and uniquely solves (5.10). If $p \leq |p_{1,3}|$, $p \leq |p_{2,3}|$ and $p > p_{3,4} > 0$, $Pool_R$ (Region 3) is the preferred feasible contract and uniquely solves (5.10). If none of these equilibria exists, then $p \leq |p_{1,4}|$, $p \leq |p_{2,4}|$, and $p \leq |p_{3,4}|$, so Sep_R (Region 4) is the preferred feasible contract and uniquely solves (5.10). ∎

Proof of Corollary 4. $V_R - L \geq K - L + S - (1-k)\Delta V_e$ implies that the costs of an effort intensive project are less than the payoff, rewritten as $K + S + k\Delta V_e < V_R + \Delta V_e$, so the effort-intensive project is efficient to undertake. A regular project requires $V_R - L \geq K - L + S$ for efficiency, which may hold as well. Assume

$$V_R - L < 2(K - L) - \Delta V_e, \tag{5.19}$$

and suppose a project is feasible. (VC*) is necessary for the VC individual rationality constraint to hold either separation or pooling. Under E control, the effort-intensive project is chosen and (RP$_C$) with (VC*) implies $V_R - L \geq 2K - \Delta V_e$, a contradiction to (5.19). Under VC control, (RP) with (VC*) implies $V_R - L \geq 2(K - L) - \Delta V_e \mathbf{1}_{pc=eff-int} + W_1 \geq 2(K - L) - \Delta V_e$, a contradiction to (5.19). Thus, no projects are feasible for the VC to finance. ∎

Proof of Proposition 5. For any q and for any Regions i and j defined by Proposition 3 such that $i < j$, where $i \in \{1, 2, 3\}$ and $j \in \{2, 3, 4\}$, any point (p^i, q) in Region i must be such that $p^i > p_{i,j}(q)$ and any point (p^j, q) in Region j must be such that $p^j \leq p_{i,j}(q)$, hence

$p^j < p^i$. Thus, for a fixed q, as p decreases, the equilibrium region increases in cardinal value. For an increase in cardinal value of region numbers, Regions 2, 3, and 4 have VC control and Region 1 has E control, so E control decreases weakly among regions. Within regions there is no change. Regions 1 and 2 have effort-intensive projects and $e = 1$ while Regions 3 and 4 do not, so the effort-intensive project and the level of effort decrease weakly among regions. Within regions, there is no change. Region 4 has separation while Regions 1, 2 and 3 have pooling, so there is a change from a pooling equilibrium to a separating equilibrium. Within regions there is no change.

The level of incentives for each region is the value of accepting the effort-incentive project as follows. $Pool_c$:

$$W_T(Pool_c, eff-int) - c(1) - W_T(Pool_c, reg) = (1-k)\Delta V_e.$$

$Pool_e$:

$$W_T(Pool_e, eff-int) - c(1) - W_T(Pool_e, reg)$$
$$= \left[\frac{p + \frac{1}{2}(1-p)(1-q)}{p + (1-p)(1-q)} - k\right]\Delta V_e|_{p \le |p_{1,2}|, p > p_{2,3} > 0, p > p_{2,4} > 0} \in (0, (1-k)\Delta V_e).$$

$Pool_R$:

$$W_T(Pool_R, eff-int) - c(1) - W_T(Pool_R, reg)$$
$$= \left[\frac{p + \frac{1}{2}(1-p)(1-q)}{p + (1-p)(1-q)} - k\right]\Delta V_e|_{p \le |p_{1,3}|, p \le |p_{2,3}|, p > p_{3,4} > 0} \le 0.$$

Sep_R:
$$W_T(Sep_R, eff-int) - c(1) - W_T(Sep_R, reg) = -k\Delta V_e \le 0.$$

Thus, the level of incentives decreases weakly with Region number. Within the regions of $Pool_c$, $Pool_R$, and Sep_R there is no change. Within the region of $Pool_e$,

$$\frac{d}{dp}\left\{\left[\frac{p + \frac{1}{2}(1-p)(1-q)}{p + (1-p)(1-q)} - k\right]\Delta V_e\right\} = \frac{\frac{1}{2}(1-q)\Delta V_e}{[p + (1-p)(1-q)]^2} > 0,$$

so the level of incentives decreases.

Diversion of funds in $Pool_c$ is L and zero for other regions, $W_1(Pool_c) = 0$. Comparing

diversion of funds plus early vesting across regions, again holding q constant,

$$L + W_1(Pool_c) = L$$
$$> W_1(Pool_e) = \frac{\frac{1}{2}p(V_1 - L) - (K - L)}{p + (1-p)(1-q)}|_{p \leq |p_{1,2}|, p > p_{2,3} > 0, p > p_{2,4} > 0}$$
$$> W_1(Pool_R) = \frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}|_{p \leq |p_{1,3}|, p \leq |p_{2,3}|, p > p_{3,4} > 0}$$
$$> W_1(Sep_R) = \frac{S}{1-q}|,$$

so the amount of early vesting plus diversion of funds decreases with Region number. Early vesting plus diversion of funds is constant within Regions 1 and 4. Within Region 2 ($Pool_e$),

$$\frac{d}{dp}\left[\frac{\frac{1}{2}p(V_1 - L) - (K - L)}{p + (1-p)(1-q)}\right] = \frac{\frac{1}{2}(1-q)(V_1 - L) + q(K - L)}{[p + (1-p)(1-q)]^2} > 0.$$

Within Region 3 ($Pool_R$),

$$\frac{d}{dp}\left[\frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}\right] = \frac{\frac{1}{2}(1-q)(V_R - L) + q(K - L)}{[p + (1-p)(1-q)]^2} > 0.$$

Thus, the level of early vesting plus diversion of funds decreases within Regions 2 and 3. ∎

Proof of Proposition 6. From the proof of Proposition 3, $p > p_{3,4}$ is equivalent to $W_T(Pool_R) > W_T(Sep_R)$. Conversely, let $W_T(Sep_R) > W_T(Pool_R)$ be referred to by $p < p_{4,3}$, where $p_{4,3} \equiv p_{3,4}$. Solving $p > p_{1,2}$, $p > p_{2,3}$ and $p < p_{4,3}$ for q gives the inequality $q > q_{i,j}$, where $(i,j) \in \{(1,2),(2,3),(4,3)\}$, such that

$$q > q_{1,2} \equiv \frac{K - \frac{1}{2}p(V_R + \Delta V_e - L)}{(1-p)L}$$
$$q > q_{2,3} \equiv \frac{k - \frac{1}{2}(1+p)}{(1-p)(k - \frac{1}{2})}$$
$$q > q_{4,3} \equiv \frac{\frac{1}{2}p(V_R - L) - (K - L) - S}{\frac{1}{2}p(V_R - L) - (K - L) - (1-p)S}.$$

For any p and for Region pairs $(i,j) \in \{(1,2),(2,3),(4,3)\}$ defined by Proposition 3, any point (p, q^i) in Region i must be such that $q^i > q_{i,j}(p)$ and any point (p, q^j) in Region j must be such that $q^j \leq q_{i,j}(p)$, hence $q^j < q^i$. Thus, for a fixed p, as q decreases, the equilibrium region changes from Region i to j. For such a change of regions, Regions 2, 3, and 4 have VC control and Region 1 has E control, so E control decreases weakly among regions. Within regions there is no change. Regions 1 and 2 have effort-intensive projects and $e = 1$ while Regions 3 and 4

do not, so the effort-intensive project and the level of effort decrease weakly among regions. Within regions, there is no change. Region 4 has separation while Regions 1, 2 and 3 have pooling, so there is weakly a change from a separating equilibrium to a pooling equilibrium. Within regions there is no change.

The level of incentives for each region is the value of accepting the effort-incentive project as follows. $Pool_c$:

$$W_T(Pool_c, eff-int) - c(1) - W_T(Pool_c, reg) = (1 - k)\Delta V_e.$$

$Pool_e$:

$$W_T(Pool_e, eff-int) - c(1) - W_T(Pool_e, reg)$$
$$= \left[\frac{p + \frac{1}{2}(1 - p)(1 - q)}{p + (1 - p)(1 - q)} - k\right]\Delta V_e|_{p \leq |p_{1,2}|, p > p_{2,3} > 0, p > p_{2,4} > 0} \in (0, (1 - k)\Delta V_e).$$

$Pool_R$:

$$W_T(Pool_R, eff-int) - c(1) - W_T(Pool_R, reg)$$
$$= \left[\frac{p + \frac{1}{2}(1 - p)(1 - q)}{p + (1 - p)(1 - q)} - k\right]\Delta V_e|_{p \leq |p_{1,3}|, p \leq |p_{2,3}|, p > p_{3,4} > 0} \leq 0.$$

Sep_R:
$$W_T(Sep_R, eff-int) - c(1) - W_T(Sep_R, reg) = -k\Delta V_e \leq 0.$$

Thus, the level of incentives decreases with decreases in q from Region i to j for Region pairs $(i, j) \in \{(1, 2), (2, 3), (4, 3)\}$. Within the regions of $Pool_c$, $Pool_R$, and Sep_R there is no change. Within the region of $Pool_e$,

$$\frac{d}{dq}\left\{\left[\frac{p + \frac{1}{2}(1 - p)(1 - q)}{p + (1 - p)(1 - q)} - k\right]\Delta V_e\right\} = \frac{\frac{1}{2}p(1 - p)\Delta V_e}{[p + (1 - p)(1 - q)]^2} > 0,$$

so the level of incentives decreases.

Diversion of funds in $Pool_c$ is L and zero for other regions, $W_1(Pool_c) = 0$. Comparing

diversion of funds plus early vesting across regions, again holding p constant,

$$L + W_1(Pool_c) = L$$
$$> W_1(Pool_e) = \frac{\frac{1}{2}p(V_1 - L) - (K - L)}{p + (1-p)(1-q)}\Big|_{p \leq |p_{1,2}|, p > p_{2,3} > 0, p > p_{2,4} > 0}$$
$$> W_1(Pool_R) = \frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}\Big|_{p \leq |p_{1,3}|, p \leq |p_{2,3}|, p > p_{3,4} > 0},$$
$$W_1(Sep_R) = \frac{S}{1-q}$$
$$> W_1(Pool_R) = \frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}\Big|_{p \leq |p_{1,3}|, p \leq |p_{2,3}|, p > p_{3,4} > 0},$$

so the amount of early vesting plus diversion of funds decreases with decreases in q from Region i to j for Region pairs $(i, j) \in \{(1,2), (2,3), (4,3)\}$. Early vesting plus diversion of funds is constant within Region 1. Withing Region 2 ($Pool_e$),

$$\frac{d}{dq}\left[\frac{\frac{1}{2}p(V_1 - L) - (K - L)}{p + (1-p)(1-q)}\right] = \frac{(1-p)[\frac{1}{2}p(V_1 - L) - (K - L)]}{[p + (1-p)(1-q)]^2} > 0.$$

Within Region 3 ($Pool_R$),

$$\frac{d}{dq}\left[\frac{\frac{1}{2}p(V_R - L) - (K - L)}{p + (1-p)(1-q)}\right] = \frac{(1-p)[\frac{1}{2}p(V_R - L) - (K - L)]}{[p + (1-p)(1-q)]^2} > 0.$$

Within Region 4 (Sep_R),
$$\frac{d}{dq}\left[\frac{S}{1-q}\right] = \frac{S}{(1-q)^2} > 0.$$

Thus, the level of early vesting plus diversion of funds decreases within Regions 2, 3 and 4. ∎

Proof of Proposition 7. E's benefit from choosing the effort-intensive project under E control is

$$W_T(Pool_c, eff{-}int) - c(1) - W_T(Pool_c, reg) = (1-k)\Delta V_e > 0$$

for all $p < 1$, $k < 1$, so he always takes it. E's benefit from choosing the effort-intensive project under E control is

$$B_{pool,eff-int} \equiv W_T(Pool_e, eff{-}int) - c(1) - W_T(Pool_R, reg)$$
$$= \left[\frac{p + \frac{1}{2}(1-p)(1-q)}{p + (1-p)(1-q)} - k\right]\Delta V_e.$$

Setting this equal to zero and solving for k gives $\overline{k}(p)$:

$$\overline{k}(p) = \frac{p + \frac{1}{2}(1-p)(1-q)}{p + (1-p)(1-q)}.$$

For $k > \overline{k}$, $B_{pool,eff-int}\big|_{k>\overline{k}} < 0$, so the effort-intensive project is not chosen. $\blacksquare$

References

[1] Aghion, Philippe, and Patrick Bolton (1992), "An Incomplete Contracts Approach to Financial Contracting," *Review of Economic Studies*, 77:473-494.

[2] Baker, Malcolm, and Paul A. Gompers (1999), "Executive Ownership and Control in Newly Public Firms: The Role of Venture Capitalists," working paper, Harvard University.

[3] Berkovitch, Elazar, and Ronen Israel (1996), "The Design of Internal Control and Capital Structure," *Review of Financial Studies*, 9:209-240.

[4] Bolton, Patrick, and David S. Scharfstein (1990), "A Theory of Predation Based on Agency Problems in Financial Contracting," *American Economic Review*, 80:93-106.

[5] Bulow, Jeremy, and Kenneth Rogoff (1989), "A Constant Recontracting Model of Sovereign Debt," *Journal of Political Economy*, 97:155-178.

[6] DeMarzo, Peter M., and Michael J. Fishman (2000), "Optimal Long-Term Financial Contracting with Privately Observed Cash Flows," working paper, Stanford University.

[7] Dessein, Wouter (2001), "Information and Control in Alliances & Ventures," working paper, University of Chicago.

[8] Dewatripont, Mathias, and Jean Tirole (1994), "A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence," *Quarterly Journal of Economics*, 1027-1054.

[9] Farrell, Joseph, and Eric Maskin (1989), "Renegotiation in Repeated Games," *Games and Economic Behavior*, 1:327-360.

[10] Gorton, Gary, and Bruce D. Grundy (1996), "Executive Compensation and the Optimality of Managerial Entrenchment," NBER Working Paper Series, 5779.

[11] Gromb, Denis (1994), "Renegotiation in Debt Contracts," dissertation, Ecole Polytechnique.

[12] Grossman, Sanford J., and Oliver D. Hart (1986), "The Costs and Benefits of Ownership: A Theory of Verical and Lateral Integration," *Journal of Political Economy*, 94:691-719.

[13] Hart, Oliver D. (1995), *Firms, Contracts, and Financial Structure*, (Oxford University Press).

[14] Hart, Oliver D. (2001), "Financial Contracting," *Journal of Economic Literature*, 39:1079-1100.

[15] Hart, Oliver D., and John Moore (1990), "Property Rights and the Nature of the Firm," *Journal of Political Economy*, 98:1119-1158.

[16] Hart, Oliver D., and John Moore (1994), "A Theory of Debt Based on the Inalienability of Human Capital," *Quarterly Journal of Economics*, 109:841-879.

[17] Hart, Oliver D., and John Moore (1998), "Default and Renegotiation: A Dynamic Model of Debt," *Quarterly Journal of Economics*, 113:1-41.

[18] Hellmann, Thomas (1998), "The Allocation of Control Rights in Venture Capital Contracts," *RAND Journal of Economics*, 29:57-76.

[19] Kaplan, Steven N., and Per Stromberg (2001), "Venture Capitalists as Principals: Contracting, Screening, and Monitoring," *American Economic Review, Papers and Proceedings*, 91:426-430.

[20] Kaplan, Steven N., and Per Stromberg (2002), "Characteristics, Contracts, and Actions: Evidence from Venture Capitalist Analyses," NBER Working Paper Series, 8764.

[21] Kaplan, Steven N., and Per Stromberg (2003), "Financial Contracting Theory Meets the Real World: An Empirical Analsis of Venture Capital Contracts," *Review of Economic Studies*, forthcoming.

[22] Kirilenko, Andrei A. (2001), "Valuation and Control in Venture Finance," *Journal of Finance*, 56:565-587.

[23] Landier, Augustin (2001), "Start-up Financing: Banks vs. Venture Capital," working paper, MIT.

[24] Neher, Darwin V. (1999), "Staged Financing: An Agency Perspective," *Review of Economic Studies,* 66:255-274.

[25] Shleifer, Andrei, and Robert W. Vishny (1989), "Management Entrenchment: The Case of Manager-Specific Investments," *Journal of Financial Economics*, 25:123-139.