On the Efficiency of Stock-based Compensation

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When the market can observe the profitability of all projects with equal precision, then with stock compensation (i) the weight on any given project in managerial compensation is independent of the marginal productivity of effort in the project; (ii) the projects that are the noisiest indicators of managerial effort receive the most weight in compensation; and (iii) investors have the greatest incentive to collect information about projects that are the noisiest indicators of managerial effort.

One of the principal issues in finance is the role of financial markets in providing incentives for the efficient operation and control of the firm. Recently, there has been substantial interest among both academics and practitioners in tying top management compensation to the firm's stock price as a means of aligning the interests of management and shareholders [e.g., Scholes (1991)]. In this article, I examine the effectiveness of stock-based compensation in providing incentives for managers to work hard and effectively.

An efficient market weights information according to its informativeness about asset payoffs. The result-

This article was previously titled "Do Stock Markets Aggregate Information Efficiently for Principal-Agent Problems?" I would like to thank Anat Admati, Jim Bodurtha, Jim Brickley. Harry DeAngelo, Kathleen Weiss Hanley, Barbara Mace, Paul Pfleiderer, Paul Seguin, editor Chester Spatt, Joe Stiglitz, Jaime Zender, the referee (Milt Harris). and especially Tim Bresnahan and Paul Milgrom. I would also like to thank seminar participants at Berkeley, Carnegie Mellon, Chicago, Indiana, Maryland. Michigan, MIT, Rochester, and Yale, and especially Craig Holden, Pete Kyle, David Scharfstein, and Jean. Luc Vila. All errors, of course, remain my own. Address correspondence to Jonathan ht. Paul, School of Business Administration, University of Michigan, Ann Arbor, MI 48109.1234.

The Review of Financial Studies 1992 Volume 5, number 3, pp. 471-502

ing price is the present value of the payoffs arising from holding the asset. To provide optimal incentives in a principal-agent problem, we need to weight information according to its informativeness about the manager's contribution[1] or *value-added* to the firm. For the stock price (of an all-equity firm) to be an optimal aggregator of information for the incentive problem, it would have to measure the *value-added* of the manager, instead of the *value* of the firm's assets.[2] Gjesdal (1981) and Bresnahan, Milgrom, and Paul (1992) show that the optimal weightings on information for the valuation problem will not necessarily be the same as the optimal weightings for the incentive problem.

In this article, I show that there is a fundamental conflict between aggregating information to assess value and aggregating information for the incentive problem. The article shows that this conflict can have important effects on the operation of the firm. Intuitively, investors are interested in a signal to the extent that it resolves uncertainty about the firm's ultimate payoffs. The more uncertainty it resolves about firm payoffs, the more weight the signal receives in the stock price. However, in choosing a monitor for a principal-agent problem, the principal is interested in a signal to the extent that it accurately measures the agent's unobservable effort level (or ability). When the market can observe the profitability of all projects with equal precision, I find that with stock compensation:

(i) The weight on any given project in managerial compensation is independent of the marginal productivity of effort in the project.

(ii) The projects that are the noisiest indicators of managerial effort receive the most weight in compensation.

(iii) Investors have the greatest incentive to collect information about projects that are the noisiest indicators of managerial effort.

There is a large empirical literature documenting the extensive use of accounting earnings as a basis for CEO compensation. This literature finds that CEO compensation is more closely tied to the firm's accounting earnings than to its stock returns and that accounting earnings are a significant determinant of CEO compensation even when stock returns are also included as an explanatory variable [see Antle and Smith (1986), Lambert and Larcker (1987), Jensen and Murphy (1990), Clinch and Magliolo (1991), Ely (1991), and Sloan (1991)].[3] Studies by Healy (1985), McNichols and Wilson (1988), and

[1] Effort or ability.

[2] I thank Tim Bresnahan for this phrasing.

[3] Antle and Smith (1986) do not regress compensation on stock returns and accounting earnings simultaneously. Jensen and Murphy (1990) find that CEO pay is equally sensitive to accounting earnings and stock returns.

Defeo, Lambert, and Larcker (1989) find that CEOs report accounting income so as to increase their compensation. The findings of these last three studies suggest that the relation between accounting income and management compensation is causal. If the relation were only a statistical correlation, managers would have no incentive to shift accounting income. DeAngelo (1988) reports evidence that “dissident stockholders who wage a proxy fight for board seats typically cite poor accounting earnings rather than poor stock price performance.” A number of studies document the explicit relationship between management compensation and accounting earnings. Jensen and Murphy (1990) estimate the sensitivity of CEO wealth to stock returns. They conclude that CEO wealth is too insensitive to stock returns to provide appropriate incentives for good performance by the CEO.*

The major role of accounting earnings in determining management compensation and the relative insensitivity of management compensation to stock performance has been regarded as “puzzling” [see, e.g., Jensen and Murphy (1990), Healy (1985), and Dechow and Sloan (1990)]. After all, the purpose of compensation contracts is to align the interests of the agent (the manager) with that of the principal (the firm’s shareholders or, more generally, securityholders). What better way to align the interests of management with securityholders than to pay the manager with the firm’s securities? Also, it is well known that principal-agent problems arise from the agent (the manager) having superior information about his effort or ability than the principal (the securityholders). In an efficient market, one might expect that the best way to minimize the firm’s incentive problem would be to pay the manager with the firm’s securities and, thereby, harness the security market’s powerful ability to reduce information asymmetry.

One well-known problem with stock compensation is that it can subject the manager to additional risk by making his compensation a function of industry-specific and economy-wide shocks that are beyond his control. The recent empirical literature on relative performance evaluation examines the extent to which CEO compensation is made a function of the performance of rival firms in order to filter out common shocks to stock returns. This literature has found mixed results [see Antle and Smith (1986), Gibbons and Murphy (1990), and Janakiraman, Lambert, and Larcker (1991)].

Jensen and Murphy (1990) suggest that the insensitivity of mana-

[4] It is not clear how to interpret Jensen and Murphy’s results since it is difficult to know what sensitivity of CEO wealth to stock returns would be predicted by incentive theory once risk aversion and liquidity constraints on the part of the CEO are taken into consideration.

gerial compensation to stock prices is due to political forces that limit the maximal payoff the firm can award the CEO. This hypothesis, however, seems at a loss to explain why accounting earnings are such an important determinant of managerial compensation. Sloan (1991) finds that accounting earnings are much less sensitive to macroeconomic risk than stock returns and argues that CEOs are paid primarily according to accounting earnings to shield CEOs from macroeconomic risk. Sloan acknowledges that this story only makes sense if there are some hidden costs to paying managers as a function of the firm's excess return[5] or in allowing the CEO to hedge in the market index (also see Section 5.5).

In this article, I propose a theory of stock-based compensation that is consistent with the empirical findings that accounting earnings (as well as stock returns) are an important component of managerial compensation. The asset price measures the value of the asset-not the value-added of the individual managing the asset. In an efficient market, accounting earnings will be superfluous in determining firm value given asset prices. However, accounting earnings will not be superfluous given asset prices in determining the value-added contributed by the manager. Therefore, one would expect accounting data to be used in managerial compensation (in conjunction with security prices), even when accounting data cannot be used to improve upon security prices as a measure of firm value.

There have been a number of articles in the theoretical literature concerning stock-based compensation. Jensen and Meckling (1976) show that the existence of outside equity diminishes the manager's incentive to undertake unobservable effort. Haugen and Senbet (1981) demonstrate that compensating the manager with stock options can greatly reduce or eliminate the costs of external financing discussed in Jensen and Meckling (1976). Diamond and Verrecchia (1982) and Ramakrishnan and Thakor (1984) show that the presence of moral hazard can lead firms to introduce security prices into managerial incentive contracts, and, therefore, optimal project valuation will consider diversifiable risk as well as systematic risk. Jackson and Lazear (1988) compare the incentive properties of stock, stock options, and deferred compensation. Holmstrom and Tirole (1990) study noise trading and its implications for the effectiveness of stock as a monitor in the moral hazard problem. Kihlstrom and Matthews (1990) study the effect of stock compensation on the efficiency of the stock market equilibrium. Scholes (1991) contrasts tax and incentive motivations for stock compensation. Hagerty, Ofer, and Siegel (1991) show that

[5] Diamond and Verrecchia (1982) and Holmstrom and Tirole (1990) argue that the ability to compensate managers based on excess returns completely insures managers from market-wide risk.

stock options can be especially effective at inducing far-sighted managerial behavior. Bushman and Indjejikian (1991) and Kim and Suh (1991) look at the interaction between stock-based and accounting-based components of compensation. Stoughton and Talmor (1991) analyze the implications of managerial bargaining power for the stock compensation problem. Bizjak, Brickley, and Coles (1991) examine the effects of short-term versus long-term compensation contracts on investment incentives.

The article is organized as follows. In Section 1, I describe the model. In Section 2, I solve for the optimal aggregation of information for the managerial compensation problem. In Section 3, I solve for the weights given to different types of information in stock market pricing. In Section 4, I examine investors' incentives to collect information. In Section 5, I discuss some extensions of the model. In Section 6, I discuss implications for the efficiency of takeovers as an incentive mechanism for good management. The article concludes with Section 7.

1. The Model

The firm consists of n projects.[6] The firm faces a moral hazard problem: it cannot observe the manager's effort levels in the various projects. The terminal payoff from project i is

$$X_i = f_i(\mu_i) + \theta_i, \qquad \text{for } i = 1,\ldots,n,$$

where μ_i is the manager's (unobservable) effort on project i, and θ_i is the stochastic component of the payoff of project i.

The technology for translating the manager's effort into output in project i is given by the function f_i: $\mathcal{R} \to \mathcal{R}$. The terminal payoff of the firm's assets is

$$X_0 = \sum_{i=1}^{n} X_i.$$

The manager's effort levels μ_1 to μ_n, the random components of the projects' payoffs θ_1 to θ_n, the individual project payoffs X_1 to X_n,[7] and the firm's aggregate payoff X_0 are unobservable.[8] However, there are

[6] In Section 5.2, I apply the article's results to the case in which there is only one project

[7] There are two principal reasons why individual project payoffs may not be observable or contractible: (i) part of the project's payoffs may take the form of enhancing nontangible assets such as brand name reputation for quality; and (ii) the manager may have considerable latitude in allocating the firm's aggregate revenues and costs across different projects and may be able to cross-subsidize various projects. One obvious means for doing this is through the manager's discretion in setting prices for intrafirm transfers. (This assumes that outsiders do not have access to information that would enable them to determine what the true value of internal transfers are.)

[8] In Section 5.1, I treat the case in which X_0 (the firm's aggregate payoff) is observable

signals Y_1 to Y_n, where Y_i is a noisy observation of the payoff from project i:

$$Y_i = X_i + \epsilon_i, \qquad i = 1,\ldots,n.$$

The measurement error ϵ_i is independent of the payoff of project i.

I will consider two interpretations of the Y_i signals: (i) the Y_i signals are public information, such as coming from accounting reports or other public news about the firm; or (ii) the Y_i signals are private information observed by competitive, risk-neutral, informed investors. In both cases, the equilibrium stock price will be

$$P = E[X_0 - w \mid Y_1,\ldots,Y_n],$$

where w is the manager's wage. For simplicity, I have assumed that the financial market is risk neutral and competitive, and that the firm is financed entirely with equity. Note that, under interpretation (ii), the stock market is strong form efficient in that the informed investors do not make any profits from their information.

Let $C(\mu_1,\ldots,\mu_n)$ be the private cost the manager bears from undertaking effort levels μ_1, to μ_n. The manager can receive a certainty equivalent of W_0 by working elsewhere in the economy. Thus, the firm must offer the manager a wage contract in which the manager receives a certainty equivalent of at least W_0 or else the manager will reject the contract.

I make the following assumptions.

(A1) The manager's utility is given by $U(w) - C(\mu_1,\ldots,\mu_n)$ where $U(w) = -e^{-\rho w}$ and $C(\mu_1,\ldots,\mu_n)$ is convex.

(A2) For each project, $f_i' > 0$ and $f_i'' < 0$.

(A3) The random vector $(\theta_1,\ldots,\theta_n, \epsilon_1,\ldots,\epsilon_n)$ has a joint normal distribution; all elements of this vector are mutually independent; $\theta_i \sim N(0, \sigma_i^2)$ and $\epsilon_i \sim N(0, \omega_i^2)$.

Formally, this model is completely static with all actions occurring in the same period. However, it is easiest to think of events as occurring in the following order: The firm sets the wage contract so as to maximize the ex ante value of the firm $E[X_0 - w]$. The manager then picks an effort level μ_i for each project and bears the private cost $C(\mu_1,\ldots,\mu_n)$. The manager chooses the effort levels $(\mu_1,\ldots,\mu_n)$ that maximize his expected utility given the wage contract and his chosen effort levels.[9] The financial markets then observe Y_1 to Y_n, which result in the equilibrium stock price $P = E[X_0 - w \mid Y_1,\ldots,Y_n]$. Finally, the

[9] The results of this article hold regardless of whether or not the manager knows the vectors $(\theta_1,\ldots,\theta_n)$ and $(\epsilon_1,\ldots,\epsilon_n)$ at the time he chooses his effort levels. However, the manager does not know either of these vectors when he must decide whether to accept the contract.

manager is paid his wage w according to the previously determined wage contract.

2. Efficient Aggregation of Information for Managerial Compensation [10]

The stock price is completely determined by the information observed by the market $(Y_1,..., Y_n)$. Therefore, when stock is used to compensate the manager, the manager is compensated based on the Y_i signals with the relative weight on each Y_i signal given by the signal's weight in determining the stock price. The central objective of this article is to see how efficient the stock market is at aggregating information for principal-agent problems.

In order to judge the efficiency of stock compensation, we first need to develop a benchmark with which to compare stock compensation. In this section, we will develop such a benchmark. This section studies the optimal weights that would be placed on the various signals Y_1 to Y_n if the compensation contract could be written directly on the stock market's information. Specifically, we consider the wage contract

$$w = \gamma_0 + \gamma_1 Y_1 + \cdots + \gamma_n Y_n$$

and solve for the optimal weights γ_1 to γ_n for the compensation problem. In the next section, these weights will be compared to the weights given to the different pieces of information in stock market pricing.

Note that this wage contract is linear in the Y_i signals and a constant. Since the manager has exponential utility and payoffs are normally distributed, I can embed this static model in a dynamic model, as described in Holmstrom and Milgrom (1987), to show that there is an optimal contract that is linear.

The Holmstrom and Milgrom (1987) model not only shows that it can be consistent to use linear contracts, but it does so in an economically appealing setting. They consider the situation in which the payoffs X_1 to X_n and the signals Y_1 to Y_n evolve as Brownian motions. The manager's (unobservable) effort levels at time t determine the drifts of these Brownian motions at time t. Holmstrom and Milgrom also make the economically plausible assumption that the manager can observe the observe the past progress of the Brownian motions when he sets the drifts. They show that, in this environment, there

[10] This section is modeled after section 2 of Holmstrom and Milgrom (1991).

is an optimal contract that is linear.[11] They also show that every static model of the type described in the current article can be rewritten in their dynamic context and, when viewed as a reduced form of such a dynamic model, these static models have an optimal contract that is linear.[12]

2.1 The manager's choice of effort levels

In this subsection, I will solve for the conditions that describe the manager's choice of effort levels as a function of the wage contract. For ease of exposition, I will assume that the manager's cost of effort function has the following separable form in this section: $(\mu_1,\ldots,\mu_n) = c_1(\mu_1) + \cdots + c_n(\mu_n)$. Since the manager has exponential utility, his certainty equivalent from choosing effort levels $(\mu_1,\ldots,\mu_n)$ is

$$E[w \mid \mu_1,\ldots,\mu_n] - \frac{\rho}{2}\mathrm{Var}(w \mid \mu_1,\ldots,\mu_n) - \sum_i c_i(\mu_i).$$

Since w equals $\gamma_0 + \gamma_1 Y_1 + \cdots + \gamma_n Y_n$, where $Y_i = f_i(\mu_i) + \theta_i + \epsilon_i$, the manager's objective function reduces to

$$\gamma_0 + \sum \gamma_i f_i(\mu_i) - \frac{\rho}{2}\sum \gamma_i^2(\sigma_i^2 + \omega_i^2) - \sum c_i(\mu_i). \qquad (1)$$

Since each f_i function is concave and $C(\mu_1,\ldots,\mu_n)$ is convex, this objective function is concave in $(\mu_1,\ldots,\mu_n)$. The utility-maximizing effort levels are given by the first-order conditions

$$\gamma_i = c_i'(\mu_i)/f_i'(\mu_i), \qquad i = 1,\ldots,n. \qquad (2)$$

Note that the right-hand side of Equation (2) is strictly increasing in μ_i. Therefore, Equation (2) assigns a unique value of μ_i to each wage coefficient γ_i. Let $\mu_i^*(\gamma_i)$ be the function that maps the wage contract coefficient γ_i into the manager's chosen effort level. The

[11] The intuition behind the Holmstrom-Milgrom (1987) model is roughly as follows: An optimal contract maximizes the expected value of output (X_0) minus the private cost of effort incurred by the manager minus the manager's risk premium. Note that the information flow and payoffs are distributed i.i.d. over time. Also, at each point in time, the functions that map the manager's effort into output are the same and the manager's cost of effort function is the same. Since the manager has exponential utility, the risk premium he demands for any given effort level is the same in each period regardless of the state of the Brownian motions. Thus, the optimal contract makes the manager's marginal reward for effort the same regardless of the state of the Brownian motions. Therefore, the optimal contract is linear.

[12] To use the Holmstrom and Milgrom model, the manager's task must be to control the drift of a Brownian motion. There are many ways to do this. The simplest is to let $F_i(t) = f_i(\mu_i(t))$ and $Y_i(t) = F_i(t) + \theta_i(t) + \epsilon_i(t)$, $t \in [0, 1]$, where $(\theta_i(t), \epsilon_i(t))$ is a two-dimensional Brownian motion with drift vector (0, 0) and a diagonal diffusion matrix. σ_i and w_i are the diffusion coefficients for $\theta_i(t)$ and $\epsilon_i(t)$, respectively. The manager controls the drift vector $(F_1(t),\ldots,F_n(t)) \in \Omega$, where Ω is a compact set and incurs private cost $\int_0^1 C(F_1(t),\ldots,F_n(t))\,dt$, where the cost function C is twice continuously differentiable, strictly convex, and strictly increasing over Ω. It also must be the case that the optimal effort level in the second-best problem is interior to Ω. At time t, the manager knows the history of the variables $\{Y_i(t)\}$. The manager can set $(\mu_1(t),\ldots,\mu_n(t))$ as a function of $(Y_1(s),\ldots,Y_n(s))$, $s < t$.

inverse function theorem implies

$$\frac{d\mu_i^*(\gamma_i)}{d\gamma_i} = \frac{f_i'/c_i'}{\upsilon_f + \upsilon_C} > 0, \qquad i = 1,\ldots,n, \tag{3}$$

where υ_f is the curvature of f and υ_c is the curvature of C. ($\upsilon_f = |f_i''/f_i'|$ and $\upsilon_C = |c_i''/c_i'|$.) Equation (3) will be useful in the next subsection, when I characterize the γ_i coefficients in the optimal contract.

The manager's wage contract must also yield him a certainty equivalent of at least his reservation wealth W_0, or else the manager will refuse the contract and will work elsewhere in the economy. For the contract that maximizes ex ante firm value, this constraint will be binding. Setting γ_0 so that the manager's obective function [Equation (l)] equals W_0 yields

$$\gamma_0 = W_0 + \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) + \sum_i c_i(\mu_i) - \sum_i \gamma_i f_i(\mu_i). \tag{4}$$

2.2 The efficient wage contract

The firm wants to set the contract that maximizes the ex ante value of the firm $E[X_0 - w]$ subject to conditions (2) and (4). The firm's objective function is

$$E[X_0] - \left[W_0 + \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) + \sum_i c_i(\mu_i^*(\gamma_i)) - \sum_i \gamma_i f_i(\mu_i^*(\gamma_i))\right] - \sum_i \gamma_i f_i(\mu_i^*(\gamma_i)).$$

This reduces to

$$\sum_i f_i(\mu_i^*(\gamma_i)) - W_0 - \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) - \sum_i c_i(\mu_i^*(\gamma_i)).$$

The following first-order condition describes the wage coefficients that maximize ex ante firm value:

$$\gamma_i = \frac{(f_i' - c_i')}{\rho(\sigma_i^2 + \omega_i^2)} \frac{d\mu_i^*(\gamma_i)}{d\gamma_i}, \qquad i = 1,\ldots,n. \tag{5}$$

Equation (5) gives us the optimal weight to put on information about the i th project when we allow the compensation contract to be written directly on the information observed by the market about the firm's projects. Equation (5) reinforces the intuition that the weight on information about a project in the optimal contract should be:

(i) increasing in the marginal surplus created by additional effort on the project $(f_i' - c_i')$;

(ii) increasing in the sensitivity of the manager's effort level on the project to γ_i [this is $d\mu_i^*(\gamma_i)/d\gamma_i$, which is positive and solved for in Equation (3)];

(iii) decreasing in the imprecision of information about the project as a measure of the manager's effort $(\sigma_i^2 + \omega_i^2)$.

Equation (5) provides us with a benchmark with which to compare the incentives generated by stock-based compensation. With this benchmark established, we proceed to the next section where we will examine the incentives created by stock-based compensation.

3. The Stock Price as an Incentive Mechanism

In this section, I will solve for the stock price in terms of the market's information about the firm's projects and examine the resulting incentives when the manager is compensated with stock. To start off, we will restrict attention to the case in which the manager's compensation is linear in the stock price and a constant: $w = a_o + aP$. As in Section 2, this can be justified by thinking of this model as being embedded in the dynamic model studied in Holmstrom and Milgrom (1987). In Section 5.3, I show my article's results hold for nonlinear contracts as well.

Since $Y_1,\ldots,Y_n$ are independent and $(X_0, Y_1,\ldots,Y_n)$ has a joint normal distribution,

$$E[X_0 \mid Y_1,\ldots,Y_n] = \beta_0 + \sum_i \beta_i Y_i,$$

$$\beta_i = \frac{\mathrm{Cov}(X_0, Y_i)}{\mathrm{Var}(Y_i)}, \qquad i = 1,\ldots,n, \tag{6}$$

$$\beta_0 = \sum_i (1 - \beta_i) f_i(\mu_i^{eq}),$$

where μ_i^{eq} is the effort level the manager chooses in equilibrium for project i. Equation (6) writes X_0 in terms of its projection on the independent signals Y_1 to Y_n and is analogous to regressing X_0 on Y_1 to Y_n.

The investors understand the manager's incentive problem and can solve for the effort level the manager will choose in equilibrium for each project. Thus, while investors cannot observe the manager's effort level μ_t, they have rational expectations and understand that the manager will choose effort level μ_i^{eq} in equilibrium.[13] Thus, investors take μ_i^{eq} to be a known constant, and

$$\mathrm{Cov}(X_0, Y_i) = \mathrm{Cov}\left(\sum_i [f_i(\mu_i^{eq}) + \theta_i], f_i(\mu_i^{eq}) + \theta_i + \epsilon_i\right) = \sigma_i^2.$$

Since P is a known constant once the market's information is observed,

$$E[w \mid Y_1,\ldots,Y_n] = \alpha_0 + \alpha P.$$

From Equation (6),

$$E[X_0 - w \mid Y_1,\ldots,Y_n] \tag{7}$$

Since $E[X_0 - w \mid Y_1,\ldots,Y_n] = P,$ Equation (7) reduces to

$$P = \frac{\beta_0 - \alpha_0}{1 + \alpha} + \frac{1}{1 + \alpha} \sum_i \beta_i Y_i \tag{8}$$

where

$$\beta_i = \frac{\mathrm{Cov}(X_0, Y_i)}{\mathrm{Var}(Y_i)} = \frac{\sigma_i^2}{\sigma_i^2 + \omega_i^2} = \frac{1}{1 + \omega_i^2/\sigma_i^2}, \qquad i = 1,\ldots,n,$$

$$\beta_0 = \sum_i (1 - \beta_i) f_i(\mu_i^{eq}).$$

Equation (8) can also be written in the form

$$P = \frac{1}{1 + \alpha}\left[\sum_i f_i(\mu_i^{eq}) - \alpha_0 + \sum_i \beta_i (Y_i - f_i(\mu_i^{eq}))\right].$$

Equation (8) shows that the equilibrium stock price is linear in the signals $(Y_1,\ldots,Y_n)$ and a constant. The "regression" coefficient b_i determines the weight given to signal Y_i in stock market pricing.

3.1 Stock compensation and the marginal productivity of effort

When stock is used to compensate the manager, the b_i coefficients determine the weight the market's information about project i has in the manager's compensation. Thus, to understand the incentives created by stock compensation, we need to look more closely at the b_i

[13] In a hidden action moral hazard model, the principal can solve for the agent's equilibrium action. Thus, while the principal cannot observe the agent's action, the principal knows what effort level the agent will pick. This does not, however, allow the principal to improve incentives in the moral hazard problem. The moral hazard problem diminishes only to the extent that the principal is better able to detect *deviations* from the contractually specified (equilibrium) effort level.

coefficients. The stochastic component of project *i's* cash flow is q_i. Since q_i and Y_i have a joint normal distribution,

$$E[\theta_i \mid Y_i] = \text{constant} + \frac{\sigma_i^2}{\sigma_i^2 + \omega_i^2} Y_i,$$

since

$$\frac{\mathrm{Cov}(\theta_i, Y_i)}{\mathrm{Var}(Y_i)} = \frac{\sigma_i^2}{\sigma_i^2 + \omega_i^2}.$$

Note that the coefficient on Y_i in this equation is b_i. The coefficient b_i is determined solely by the information Y_i contains about the stochastic component of the firm's cash flow. As can be seen from Equation (8), the marginal productivity of effort for project *i* and the marginal cost of effort for project *i* do not enter into the b_i coefficients. Yet with stock-based compensation, the b_i coefficients determine the relative weight information about project *i* has in the manager's compensation. However, from Equation (5) in Section 2, we have that the optimal compensation contract would place increasing weight on information as f_i' increases and c_i' decreases.[14]

This brings us to Proposition 1.

Proposition 1. *With stock compensation, the weight signal Y_i receives in managerial compensation is independent of (i) the marginal productivity of effort in theproject (f_i') and (ii) the marginal surplus created by effort in the project$(f_i' - c_i')$.*

Proof. See Equation (8). //

The intuition behind this result is roughly as follows: Investors in the stock market are concerned with predicting the firm's future payoffs. Thus, the stock market weights each Y_i signal according to how much of the uncertainty about the firm's future profits it resolves. This has nothing to do with the marginal productivity of additional effort f_i' or the marginal cost of additional effort c_i' in a particular activity.

Note that the functions $f_1(\mu_1),\ldots,f_n(\mu_n)$ and the actual cost of effort function $C(\mu_1,\ldots,\mu_n)$ do not enter into the formula for the b_i coefficients in Equation (8). Thus, stock compensation aggregates the Y_t signals in the same way, regardless of the actual set of functions $(\mu_1),\ldots,$ $f_n(\mu_n)$ and the actual cost of effort function $C(\mu_1,\ldots,\mu_n)$. Also, see Bresnahan, Milgrom, and Paul (1992) for a discussion of this.

[14] Recall that Equation (5) was derived under the additional assumption that $C(\mu_1,\ldots,\mu_n)$ was additively separable.

3.2 Stock compensation and risk

From principal-agent theory, it is well known that efficient contracts put the most weight in compensation on the signals that are the most precise observations of effort. We can see this from Equation (5), which describes the weights on the Y_i signals in the optimal contract.[15] Since $Y_i = f_i(\mu_i) + \theta_i + \epsilon_i$, the term $\theta_i + \epsilon_i$ is the *ith* signal's error in measuring the manager's contribution to project *i*. Recall that $\mathrm{Var}(\theta_i + \epsilon_i)$ is $\sigma_i^2 + \omega_i^2$. In Equation (5), the weight a signal receives under the optimal contract is decreasing in $\sigma_i^2 + \omega_i^2$.

With stock compensation, the weight the *ith* signal gets in the manager's compensation is given by the "regression" coefficient b_i, which equals $1/(1 + \omega_i^2/\sigma_i^2)$ Thus, with stock compensation, a signal's weight in compensation is increasing in σ_i^2 instead of decreasing in σ_i^2.

Proposition 2. *With stock compensation, the weight signal Y_i receives in managerial compensation is increasing in σ_i^2 and decreasing in ω_i^2.*

Proof. See Equation (8). //

The manager will devote excessive effort to projects whose cash flows have high variability (high σ_i) relative to the projects whose cash flows have low variability (low s_i). If the profitability of each project can be measured with equal precision by the stock market, the activities that are the noisiest observations of managerial effort receive the greatest weight in compensation.

Intuitively, investors are interested in a signal to the extent that it resolves uncertainty about the firm's ultimate payoffs. The more uncertainty it resolves about the firm's ultimate payoffs, the more weight the signal receives in stock market pricing. However, in choosing a monitor for the moral hazard problem, the principal is interested in a signal to the extent that it accurately measures the manager's actual effort level (should he deviate from the equilibrium effort level). As σ_i^2 increases, Y_i resolves more uncertainty about the firm's ultimate payoffs (firm value) but is less informative in measuring the manager's actual effort (manager's value-added). Thus, as σ_i^2 increases, Y_i receives more weight in stock market pricing, even though it becomes a less effective monitor for the principal-agent problem.

Proposition 2 shows that there is a systematic bias in stock market pricing to put the greatest weight on the projects that are the noisiest indicators of managerial effort. To see this, suppose there are two

[15] Again recall that Equation (5) was derived under the additional assumption that $(\mu_1, \ldots, \mu_n)$ was additively separable.

activities: managing project 1 and managing project 2. Suppose that the payoff from project 1 is much more variable than the payoff from project 2. Suppose project 1 is responsible for 70 percent of the variance of firm profits and project 2 is responsible for 30 percent of the variance of firm profits, and that firm performance in each project can be measured with equal precision. In this case, information about project 1 provides more information about firm profits than information about project 2. So information about project 1 will receive more weight in stock market pricing. Therefore, when stock is used to compensate the manager, firm performance on project 1 will have greater weight in compensation than firm performance on project 2. However, firm performance in project 1 is the noisier indicator of effort. It has a higher variance than performance in project 2.

Investors cannot make profits in the stock market trading based on their knowledge of the deterministic component of the firm's payoff distribution. With rational expectations, the stock market views the deterministic component of the firm's payoff as known and therefore uninteresting. The stock market is instead concerned with measuring the stochastic component of the firm's payoff. For the simple principal-agent problem described in Section 1, the stochastic component of the firm's payoff is the noise in the optimal compensation problem. The crux of the matter for the stock market is the noise in the principal-agent problem.

3.3 A simple example

The defects with stock market incentives described in Sections 3.1 and 3.2 can lead to substantial inefficiencies. Consider the following example in which the manager allocates effort between the following two projects:

$$X_1 = 2\sqrt{\mu_1} + \theta_1, \qquad X_2 = 2\sqrt{\mu_2} + \theta_2.$$

Note that there is declining marginal productivity of effort in each project.

Consider the case in which the market observes firm performance in both projects with equal precision. Let $\omega_1^2 = \omega_2^2 = 1$, and

$$Y_1 = 2\sqrt{\mu_1} + \theta_1 + \epsilon_1, \qquad Y_2 = 2\sqrt{\mu_2} + \theta_2 + \epsilon_2.$$

Suppose effort in project 1 and effort in project 2 are perfect substitutes in terms of their disutility to the manager. In this example, suppose that μ_1 is the number of hours the manager works on project 1, and μ_2 is the number of hours the manager works on project 2. Also, let the marginal cost of the manager's time be increasing in the total number of hours worked. In this case, the manager's cost of effort function can be written $c(\mu_1 + \mu_2)$ with $c(\cdot)$ convex. Specifically, let $C(\mu_1, \mu_2) = \frac{1}{2}(\mu_1 + \mu_2)^2$.

Since the manager has exponential utility, his certainty equivalent from undertaking effort levels μ_1 and μ_2 when facing wage contract $\alpha_0 + \alpha P$ is

$$\alpha_0 + \alpha E[P|\mu_1, \mu_2] - (\rho/2)\alpha^2 \mathrm{Var}[P|\mu_1, \mu_2] - C(\mu_1, \mu_2).$$

From Equation (8), this reduces to

$$\alpha_0 + \frac{\alpha(\beta_0 - \alpha_0)}{1 + \alpha} + \frac{\alpha}{1 + \alpha} 2 (\beta_1\sqrt{\mu_1} + \beta_2\sqrt{\mu_2})$$
$$- \frac{\rho}{2}\frac{\alpha^2}{(1 + \alpha)^2}[\beta_1^2(\sigma_1^2 + \omega_1^2) + \beta_2^2(\sigma_2^2 + \omega_2^2)] - \frac{1}{2}(\mu_1 + \mu_2)^2.$$

In this case, the manager's objective function is concave in μ_1 and μ_2. From the first-order conditions, we get that, in any interior solution, the manager will set μ_1 and μ_2 such that

$$\frac{\mu_1}{\mu_2} = \left(\frac{\beta_1}{\beta_2}\right)^{2/3}.$$

Thus, if $\beta_1 > \beta_2$, the manager will allocate excessive time to project 1. If $\beta_2 > \beta_1$, the manager will spend excessive time on project 2. Since $\omega_1^2 = \omega_2^2 = 1$ in this example, the values of b_1 and b_2 are given in the following equations:

$$\beta_1 = \frac{1}{1 + 1/\sigma_1^2}, \qquad \beta_2 = \frac{1}{1 + 1/\sigma_2^2}.$$

Optimal contracting would put more emphasis on whichever project had a lower s_i value and would result in the manager allocating more effort to that project [see Equation (5)]. However, in equilibrium, the manager will allocate excessive time to whichever project has the greatest s_i value. This can lead to arbitrarily bad outcomes as the ratio σ_i/σ_j increases.

If the Y_i signals can be contracted upon, the firm should leave the stock price out of its managerial compensation contracts and, instead, write them directly on the Y_i signals themselves. If the Y_i signals cannot be directly contracted upon, the firm may have no choice but to include the stock price in management compensation, but it cannot rely on the stock market to aggregate information optimally for the compensation problem.

4. Endogenously Acquired Information

The stock price will only reflect information observed by investors. Thus, with stock compensation, the manager's compensation depends entirely on the information observed by the stock market. In this section, I investigate the incentives investors have to collect information. I look at whether investors' incentives will lead them to collect the right type of information for the managerial compensation problem.

In order to study investors' incentives to collect information, I will use a version of the Grossman-Stiglitz (1980) model to describe stock market pricing in this section. The financial markets will remain competitive in that there will be an infinite number of investors: each with exponential utility function $U(W) = -e^{-rW}$. Investors no longer observe the signals $(Y_1,...,Y_n)$. Instead, investors will only be able to make their demands a function of the equilibrium stock price. Investors will have rational expectations and understand the relationship between the equilibrium stock price and the distribution of the firm's terminal value. Let Z be the random per capita supply of the firm's stock.[16] The vector $(Z,\theta_1,...,\theta_n,\epsilon_1,...,\epsilon_n)$ has a joint normal distribution. All elements of this vector are mutually independent. As in Grossman and Stiglitz (1980), I will only consider equilibria with linear pricing.

Now suppose one investor is given the opportunity to choose one signal from the set $\{Y_1,...,Y_n\}$ to observe. From Grossman and Stiglitz (1980: theorem 2), the investor's willingness to pay to observe signal Y_i is

$$\frac{1}{2\tau}\ln\left\{\frac{\mathrm{Var}[X_0 - w \mid P]}{\mathrm{Var}[X_0 - w \mid Y_i, P]}\right\}. \tag{9}$$

Since w is known with certainty once P is observed, the expression in braces reduces to

$$\mathrm{Var}[X_0 \mid P]/\mathrm{Var}[X_0 \mid Y_i, P].$$

Suppose the informed investor chose to observe Y_i. The stock price P contains no information about X_0 beyond that contained in Y_i. Therefore, $\mathrm{Var}[X_0 \mid Y_i, P] = \mathrm{Var}[X_0 \mid Y_i]$. The informed investor amounts to a proportion of zero of the total number of investors, which implies $\mathrm{Var}[X_0 \mid P] = \mathrm{Var}(X_0)$ [Grossman and Stiglitz (1980: theorem l)]. Therefore the investor's willingness to pay for signal i is proportional to

[16] The randomness in supply comes from unpredictable liquidity trading [see Grossman and Stiglitz (1980)].

$\mathrm{Var}(X_0)/\mathrm{Var}[X_0 \mid Y_i]$. Since X_0 and Y_i have a joint normal distribution,

$$\mathrm{Var}[X_0 \mid Y_i] = \mathrm{Var}(X_0) - \frac{\mathrm{Cov}^2(X_0, Y_i)}{\mathrm{Var}(Y_i)}.$$

This is analogous to the residual sum of squares from regressing X_0 on Y_i. This yields

$$\frac{\mathrm{Var}(X_0)}{\mathrm{Var}[X_0 \mid Y_i]} = \frac{1}{1 - \sigma_i^2/[\mathrm{Var}(X_0)(1 + \omega_i^2/\sigma_i^2)]}. \tag{10}$$

Combining Equations (9) and (10), we have shown the following.

Proposition 3. *The investor's willingness to pay for a signal is increasing in σ_i^2 and decreasing in ω_i^2.*

Investors' incentives to collect information lead them to prefer signals with high values of σ_i^2. However, from Equation (5), the quality of a signal for use in the compensation problem is decreasing in σ_i^2. If the profitability of each project can be measured with equal precision, the activities that are the noisiest indicators of managerial effort are the signals investors have the greatest incentive to learn.

An example. The intuition behind Proposition 3 can be seen in the following example in which all investors are endowed only with the signal S_1, where S_1 equals $\Sigma_i f_i(\mu_i)$. S_1 is a direct observation of the value of the manager's effort. Consider the limit as the variance of the supply noise goes to zero. In the limit, the stock price will fully reflect the manager's effort, and we can obtain first-best outcomes.

Now suppose that, in addition to observing S_1, the investors had an opportunity to observe S_2, where S_2 is a noisy observation of the stochastic component of firm profits. If the cost of acquiring S_2 is low enough, investors will choose to observe it. This will make the stock price a noisy indicator of the manager's effort and will reduce welfare.

Finally, suppose that instead of being endowed with S_1, investors had to pay an arbitrarily low cost to observe it. Investors would never be willing to pay a positive amount to observe S_1. S_1 only gives the investors information about the deterministic component of the firm's payoff, and the stock market does not reward investors for early verification of the deterministic part of the firm's payoff. In this case, the stock price would only be a function of the stochastic component of the firm's payoff. Welfare in the principal-agent problem would be as bad as if the stock market did not exist.

5. Extensions of the Basic Model

Up to this point, I have kept the model quite sparse in order to convey the basic ideas of the article as simply as possible. In this section, I extend the model in various ways to show that these basic ideas can be applied in a wide range of settings.

5.1 Observable terminal asset payoff

The entire motivation behind stock compensation plans is to proxy for the terminal payoff of the firm's assets in cases in which this terminal payoff is unobservable or cannot be contracted on. For firms with significant retained earnings and nontangible assets, the terminal value of the firm's assets cannot be observed until liquidation. For a long-lived firm, this may not occur until well after the lifetime of the manager (if at all). Therefore, one needs a proxy for the terminal value of the firm's assets in the compensation problem. The stock price is often used as this proxy since, with efficient financial markets, the stock price will be the present value of all the uncertain future cash flows arising from the firm's assets. Since the stock price is typically used as a proxy for the unobservable value of X_0, I have assumed up to this point that X_0 (the terminal payoff of the firm's assets) is unobservable and cannot be included in the manager's compensation contract.

In this subsection, the manager's contract can be a function of the terminal payoff of the firms asset's (X_0) as well as the current stock price P. This allows for ex post settling up as discussed in Fama (1980) and Gibbons and Murphy (1992). The problems with stock compensation described in this article remain if we allow the manager to be paid as a function of both the current stock price and the terminal payoff of the firm's assets.

Let the manager's wage be $\alpha_0 + \alpha_1 P + \alpha_2 X_0$.[17] In this subsection, another stage is added to the model. The stock market sets the current stock price as a function of its information Y_1 to Y_n and the manager is paid $\alpha_0 + \alpha_1 P$. Subsequently, X_0 is observed, and the manager is paid the remaining $\alpha_2 X_0$.

In this subsection, contracts can be written on the output in the principal-agent problem. However, it is well known from principal-agent theory that merely being able to include terminal output in the compensation contract does not get rid of the principal-agent problem. Eliminating the stock price from the compensation contract throws away the information contained in the Y_i signals that is not contained in the terminal payoff of the firm's assets. Therefore, in general, it will be useful to include the stock price in the manager's

[17] The discussion in Section 2 concerning the optimality of linear contracts applies here as well.

wage contract even when the manager is also paid as a function of the terminal payoff of the firm's assets. The question now becomes, "Does the stock market aggregate the Y_i signals in the manner that most effectively supplements the information contained in the terminal payoff of the firm's assets?"

To answer this, I will solve for the weighting stock market pricing gives to the Y_i signals when the wage contract is of the form $\alpha_0 + \alpha_1 P + \alpha_2 X_0$. Recall that $E[X_0 | Y_1,\ldots,Y_n] = \beta_0 + \Sigma_i \beta_i Y_i$. With $w = \alpha_0 + \alpha_1 P + \alpha_2 X_0$, we have

$$E[X_0 - w | Y_1,\ldots,Y_n] = E[X_0 | Y_1,\ldots,Y_n] - \alpha_0 - \alpha_1 E[P | Y_1,\ldots,Y_n] - \alpha_2 E[X_0 | Y_1,\ldots,Y_n].$$

Since $E[X_0 - w | Y_1,\ldots,Y_n] = P$, $E[P | Y_1,\ldots,Y_n] = P$, and $E[X_0 | Y_1,\ldots,Y_n] = \beta_0 + \Sigma_i \beta_i Y_i$, this reduces to

$$P = \frac{(1 - \alpha_2)\beta_0 - \alpha_0}{1 + \alpha_1} + \frac{(1 - \alpha_2)}{1 + \alpha_1} \sum_i \beta_i Y_i.$$

With wage function $w = \alpha_0 + \alpha_1 P + \alpha_2 X_0$, the relative weight given to each Y_i signal in the stock price is unchanged. The previous pricing coefficients are merely all scaled down by the constant $(1 - a_2)$. Since all the old pricing coefficients are scaled down by the same multiple, there is no sense in which the market aggregates the Y_i signals in the manner that most effectively supplements the information in the terminal payoff of the firm's assets for the incentive problem.

5.2 Compensation with just one project

In the model described in Section 1, the manager has several different projects to which he can allocate effort. The problems with stock compensation described in this article do not depend on there being more than one project. Consider the case in which there is one project. The terminal payoff of the project is

$$X = f(\mu) + \sum_i \theta_i,$$

where $i = 1,\ldots, n$ and

$$Y_1 = f(\mu) + \theta_1 + \epsilon_1,$$

$$Y_i = \theta_i + \epsilon_i, \qquad i = 2,\ldots,n.$$

Y_2 to Y_n are now the market's information about the random shocks q_2 to q_n that hit the firm's future payoffs but are completely beyond the control of the manager.

In this case, Equation (8) still describes stock market pricing. With stock compensation, b_i still describes the relative weight signal Y_i

receives in managerial compensation. The marginal productivity of the manager's effort, f' still does not enter into the weight on Y_1. The weight signal Y_i receives in managerial compensation is still increasing in s_i even though signals 2 to n contain no information about the manager's effort and just add variability to his compensation.

The results in this subsection show that a large multiproject firm will still be subject to the inefficiencies in Propositions 1, 2, and 3 even if it were to break itself up into several single-project firms with each new single-project firm having a separate stock price.

5.3 Nonlinear compensation and stock options

In this subsection, I will extend the ideas discussed in this article to nonlinear wage contracts. In this subsection, let the wage function $w(P)$ be any nondecreasing function of the stock price. Note that call options fall in this category.[18] One would expect the wage contract to be nondecreasing in P, since in any region in which the wage is decreasing in P, the manager has an incentive *to* drive down the value of the firm's assets.

Recall that

$$E[X_0 \mid Y_1,\ldots,Y_n] = \beta_0 + \sum_i \beta_i Y_i.$$

Since P is a known constant once $(Y_1,\ldots,Y_n)$ is observed,

$$E[X_0 - w \mid Y_1,\ldots,Y_n] = \beta_0 + \sum_i \beta_i Y_i - w(P).$$

Since $E[X_0 - w \mid Y_1,\ldots,Y_n] = P$, we have

$$P + w(P) = \beta_0 + \sum_i \beta_i Y_i.$$

Let $T(P) = P + w(P)$. Since $w(P)$ is nondecreasing in P, $T(P)$ is strictly increasing in P and, therefore, is invertible:

$$P = T^{-1}\left[\beta_0 + \sum_i \beta_i Y_i\right],$$

$$\text{wage} = w\left(T^{-1}\left[\beta_0 + \sum_i \beta_i Y_i\right]\right).$$

Thus, the b_i coefficients determine the relative weight signal Y_i receives. in the statistic that managerial compensation is based on. Therefore, Propositions 1, 2, and 3 remain unchanged in this subsection.

[18] Haugen and Senbet (1981), Jackson and Lazear (1988), and Hagerty, Ofer, and Siegel (1991) have shown that options can be a particularly effective means of reducing certain managerial incentive problems.

This same argument can be used to extend Propositions 1, 2, and 3 to any case in which the firm has short-term financial obligations whose payoffs are solely a function of $(Y_1,\ldots, Y_n)$ and are nondecreasing in the market value of equity.

In this subsection, I never use the assumption that the manager has exponential utility. Thus, when nonlinear contracts are allowed, Propositions 1, 2, and 3 no longer require assumption (Al) and instead hold for all utility functions satisfying $U' > 0$, $U'' < 0$

5.4 Image-enhancing effort versus substance-enhancing effort

In this subsection, I consider the case in which the manager's effort only affects the information the market receives rather than the ultimate payoffs of the firm's projects. Here, I consider the case in which the manager can spend his time making the accounting numbers look good or adding to the favorability of news the financial markets receive about the firm.

The terminal payoff of the firm's assets is

$$X = \sum_i \theta_i.$$

However, the market observes Y_1 to Y_n, where Y_i is

$$Y_i = g_i(\mu_i) + \theta_i + \epsilon_i, \qquad i = 1,\ldots,n.$$

The manager's unobservable effort can shift up the favorability of the news the market observes about firm payoffs, but cannot affect firm payoffs themselves.

Once again, Equation (8) still describes stock market pricing.[19] The β_i coefficients still determine the relative weight signal Y_i receives in managerial compensation. With stock compensation, the manager will exert effort to improve the Y_i signals even though this does nothing to enhance the firm's ultimate profits. The firm indirectly bears the cost of the manager's (unproductive) effort, since the manager will require a higher wage to compensate for his privately costly effort. One can also use this methodology to consider situations in which effort affects both project payoffs and the market's perceptions about project payoffs, but affects them in different ways. One example of this is to have $Y_i = g_i(\mu_i) + \theta_i + \epsilon_i$ and $X_0 = \Sigma_i [f_i(\mu_i) + \theta_i]$. Equation (8) continues to describe pricing with the equation for b_0 changing to $\beta_0 = \Sigma_i [f_i(\mu_i^{eq}) - \beta_i g_i(\mu_i^{eq})]$.

[19] The formula for β_0 is now given by $\beta_0 = -\Sigma_i \beta_i g_i(\mu_i^{eq})$.

5.5 An example in which effort affects the variability of payoffs
In this subsection, I consider a case in which the manager's effort affects not just the mean of project payoffs but the variance as well. Consider the following example in which the manager's effort affects the scale of the project. The payoff from project i is

$$X_i = \mu_i(a_i + \theta_i), \qquad i = 1,\ldots,n,$$

where μ_i is the manager's unobservable effort in project i and the constant a_i is the marginal productivity of effort. The market observes

$$Y_i = X_i + \epsilon_i, \qquad i = 1,\ldots,n.$$

Once again, $Y_1,\ldots, Y_n$ are independent and $(X_0, Y_1,\ldots,Y_n)$ has a joint normal distribution:

$$E[X_0 \mid Y_1,\ldots,Y_n] = \beta_0 + \sum_i \beta_i Y_i,$$

$$\beta_i = \frac{\mathrm{Cov}(X_0, Y_i)}{\mathrm{Var}(Y_i)} = \frac{(\mu_i^{eq})^2\sigma_i^2}{(\mu_i^{eq})^2\sigma_i^2 + \omega_i^2}, \qquad i = 1,\ldots,n, \quad 11$$

$$\beta_0 = \sum_i (1 - \beta_i) a_i \mu_i^{eq},$$

where μ_i^{eq} is the effort level the manager chooses in equilibrium for project i.

From Section 5.3, we can see that, when the manager is compensated with wage contract w(P), the stock price will be given by the following equation:

$$P = T^{-1}\left[\beta_0 + \sum_i \beta_i Y_i\right],$$

with the β_i coefficients derived in Equation (11) and $T(P) = P + w(P)$.

With stock compensation, β_i determines the relative weight signal Y_i receives in the statistic managerial compensation is based on. From Equation (11) we can see that, with stock compensation, a signal's weight in determining compensation will (i) be independent of the marginal productivity of effort (a_i), and (ii) overemphasize risky projects (high $\mu_i^{eq}\sigma_i$). Also, when the manager's effort affects payoff variances, the manager will have an incentive to reduce the scale of risky projects and increase the scale of safe projects, and, thereby, decrease his exposure to risk.[20,21]

[20] It is possible to create examples in which the manager's incentive to reduce the scale of risky projects causes $\mu_i^{eq}\sigma_i < \mu_j^{eq}\sigma_j$ even though $\sigma_i > \sigma_j$. In this case, stock-based compensation loads excessive risk on the manager even though it places greater weight on the project with the lower technological risk $(\sigma_j < \sigma_i)$.

[21] This example can also give us insight into the case in which the manager can affect the CAPM beta

5.6 Unobservable ability

In this subsection, I examine the case in which the manager's ability as well as his effort is unobservable. Specifically, the manager's actual cost of effort function is unknown. Type r managers have cost function $C_r(\mu_1,...,\mu_n)$. The manager does not learn the true cost of effort function until after he is hired. This case is difficult to solve in full generality; however, many of its essential features can be seen in the following example. Let the payoff from project i be

$$X_i = a_i\mu_i + \theta_i,$$

where a_i is a constant, and let the cost of effort function be of the form

$$C_r(\mu_1,...,\mu_n) = \sum_i c_i(\mu_i; r_i),$$

where

$$c_i(\mu_i; r_i) = \begin{cases} k_i(\mu_i - r_i)^2/2, & \text{if } \mu_i > r_i, \\ 0, & \text{otherwise,} \end{cases}$$

with $k_i > 0$ for all i. The random vector $(r_1,...,r_n,\theta_1,...,\theta_n,\epsilon_1,...,\epsilon_n)$ has a joint normal distribution and all its elements are mutually independent. Since the manager will always set μ_i to be greater than r_i, this cost of effort function is strictly increasing in the relevant region.

In the Appendix, I show that a manager of type $r = (r_1,..., r_n)$ will set his effort level μ_i in project i to $(a_i\gamma_i/k_i) + r_i$ when faced with wage function $\gamma_0 + \gamma_1 Y_1 + \cdots + \gamma_n Y_n$. Thus, each μ_i is normally distributed. In the Appendix, I also show that the coefficients in the optimal contract are given by

$$\gamma_i = \frac{a_i^2}{a_i^2 + \rho k_i[a_i^2 \mathrm{Var}(r_i) + \sigma_i^2 + \omega_i^2]}. \tag{12}$$

Since μ_i is normally distributed, $E[X_0 \mid Y_1,...,Y_n]$ is linear in $(Y_1,...,Y_n)$. Let $E[X_0 \mid Y_1,...,Y_n] = \beta_0 + \Sigma_i \beta_i Y_i$. When the manager is

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of the firm. Consider the extreme case in which each θ_i is a multiple of the return on the market portfolio. Thus, the firm's projects only contain market-wide risk. In this case, the firm can achieve the first-best outcome. The firm can do this by essentially selling the firm to the manager. The firm should give the manager a wage of $a_o + aP$, where a_o equals W_0 - NPV of the firm and $a = 1$. The firm should also allow the manager to take any position he chooses in the market portfolio to offset the risk he bears from the wage contract. This will result in the first-best outcome. The basic idea is that the market is no more efficient at holding marketwide risk than the manager. Thus, we may as well let the manager hold all the firm's risk (it is all market-wide) and, thereby, eliminate the principal-agent problem. The manager-owner can always then take the appropriate hedge position in the market index. The advantage of this approach is that it does not require the firm to calculate its CAPM beta. This approach makes the manager internalize the costs and benefits of altering the firm's CAPM beta. Note the manager is not allowed to take outside positions in the firm's stock itself-only in the market index.

compensated with wage contract $a_0 + aP$, we can use the argument in Section 3 to show that the stock price can be written in a form analogous to Equation (8):

$$P = \frac{\beta_0 - \alpha_0}{1 + \alpha} + \frac{1}{1 + \alpha} \sum_i \beta_i Y_i, \tag{13}$$

where

$$\beta_i = \frac{\mathrm{Cov}(X_0, Y_i)}{\mathrm{Var}(Y_i)} = \frac{a_i^2 \mathrm{Var}(r_i) + \sigma_i^2}{a_i^2 \mathrm{Var}(r_i) + \sigma_i^2 + \omega_i^2}$$

$$= \frac{1}{1 + \omega_i^2/(a_i^2 \mathrm{Var}(r_i) + \sigma_i^2)}, \qquad i = 1,\ldots,n,$$

$$\beta_0 = \sum_i (1 - \beta_i) a_i E[\mu_i].$$

The β_i coefficients are solely a function of the informativeness of Y_i about the terminal payoff of the firm's assets. They are not the optimal weightings on information for managerial compensation. These are given in Equation (12). Yet with stock compensation, the β_i coefficients determine the relative weight the different Y_i signals receive in managerial compensation. Note that from Equation (12) the optimal weightings for compensation decrease in the cost parameter k_i. However, the cost parameter k_i does not enter into the β_i weights. In this subsection, both γ_i and β_i are increasing in the marginal productivity of effort (a_i). However, a, enters into the formulas for γ_i and β_i in very different ways. The γ_i coefficients in Equation (12) are decreasing in Var (r_i) and σ_i^2. However, from Equation (13), we get that the β_i coefficients are increasing in both Var (r_i) and σ_i^2.

6. The Threat of Takeover as an Incentive for Good Management

Takeovers and the threat of takeovers can be an important mechanism providing incentives for the operation of the firm [Marris (1963), Manne (I965), Fama (1980), Jensen (1986), Scharfstein (1988)]. In a stock market with few impediments to takeovers, firms whose stock price is low relative to their value if run efficiently are vulnerable to takeover and to having new management installed. Regardless of the nature of their compensation package, managers who obtain rents (or quasi-rents) from their position in control of the firm will have an incentive to operate the firm so as to enhance its current stock price in order to ward off the possibility of takeover. Let $w(P)$ be the certainty equivalent of the rents the manager receives from the firm when the stock price is P. Suppose the probability of takeover is decreasing in the firm's stock price relative to its stock price under efficient operation and, therefore, that the rents management can extract from the firm are increasing in the stock price. In this case, $w(P)$ will be increasing in P. The manager's incentives are the same as if he faces a wage function $w(P)$ which is increasing in P. From Section 5.3, we have that Propositions 1, 2, and 3 hold in this case. There is no sense in which an active market for corporate control provides efficient incentives for the operation of the firm.

The inefficiencies arising from stock price incentives can exist even if management acts completely on behalf of the shareholders with no agency conflicts. In an economy with an active takeover market, the only firms which will survive are the ones whose governance structures are such that the firm is operated so as to keep its current stock price high. Consider the case in which each shareholder owns one share in the firm, and a small fraction (proportion zero) of the shareholders (the board of directors) can perfectly observe the manager's effort levels. In this case there is no agency conflict between the manager and the shareholders. The board will force the manager to maximize the payoff from their shares which, in turn, will maximize the wealth of all shareholders.

Now suppose there is a possibility of takeover. In a Grossman-Stiglitz (1980) model, the equilibrium stock price will be $E[X_0 - w | Y_1,\ldots,Y_n]$. The shareholders who are not on the board of directors will be willing to sell their shares for any price above this level. In order to maximize their payoff from the takeover, the board will instruct the manager to maximize the current share price.[22] The manager could maximize the current stock price P by convincing the market that he was operating the firm at first-best, $f_1' = \cdots = f_n'$. However, the board would then have an incentive to deviate and (secretly) instruct the manager to operate the firm so as to maximize $\beta_1 Y_1 + \cdots + \beta_n Y_n$. The stock market realizes this incentive. So in equilibrium, the market will only believe that the firm will operate so as to maximize $\beta_1 Y_1 + \cdots + \beta_n Y_n$; and the firm will indeed operate so as to maximize $\beta_1 Y_1 + \cdots + \beta_n Y_n$.

Thus, in this case in which there is no agency conflict between shareholders and the manager, the threat of takeover will cause the firm to maximize $\beta_1 Y_1 + \cdots + \beta_n Y_n$. However, as we have seen from Propositions 1, 2 and 3, this does not provide for the efficient operation of the firm.[23] In this case, the firm would operate more efficiently if there were no possibility of takeovers. Without the threat of takeover,

[22] If the takeover is successful, then all the target firm's shares will be redeemed at the takeover price.

[23] Suppose that with probability a, the firm will be taken over when the market observes $(Y_1,\ldots,Y_n)$. Then, with probability a,. the owners of the firm receive P, and, with probability $(1 - a_1)$, they receive X_0. In this case, the firm's objective function is to maximize $a_1 P + (1 - a_1) X_0$ and the results in Section 5.1 apply.

the board would operate the firm at the first-best level, maximizing terminal payoff X_0.

7. Conclusion

An efficient market weights information according to its informativeness about asset value in determining asset price. For optimal incentives in a principal-agent problem, information should be weighted according to its informativeness about the *value-added* of the manager. The asset price in an efficient market measures the asset's *value*-not the *value-added* of the individual managing the asset. Therefore, the asset price is not an optimal aggregator of information for the firm's principal-agent problem.

When the manager's incentives are determined by the stock price due to either stock-based compensation or the threat of takeover:

(i) The weight on any given project in managerial compensation is independent of the marginal productivity of effort in the project.

(ii) There is a systematic bias for the projects that are the noisiest indicators of managerial effort to receive the most weight in compensation.

(iii) Investors tend to have the greatest incentive to collect information about the projects that are the noisiest indicators of managerial effort.

Points (ii) and (iii) hold without qualification in the base case in which the profitability of all projects can be measured with equal precision. There is no sense in which the stock market aggregates information efficiently for principal-agent problems.

The theory of stock-based incentives proposed in this article is consistent with the vast empirical literature documenting the importance of accounting earnings in addition to stock returns in determining CEO compensation. In an efficient market, accounting earnings are superfluous in determining firm value given security prices, but accounting earnings are not superfluous in determining the value-added contributed by the manager.

Both accounting earnings and stock values are imperfect measures for use in managerial compensation. Accounting earnings put equal weight on each accounting entry, and, therefore, overemphasize entries that contain large amounts of measurement error (high w_i). As we have seen in this article, stock valuation overemphasizes information about risky projects (high σ_i). Neither measure dominates the other for use in the compensation problem, and thus we would expect to see both measures used to determine management compensation. This is consistent with the empirical literature on management compensation. Ideally, compensation would be based directly on the various components of the accounting statement. There is some evidence of this [Ely (1991), Natarajan (1991)]. However, it seems that CEO pay is often based on aggregate accounting earnings rather than the individual components of the accounting statement. This may be due to CEOs having much greater latitude in allocating revenues and expenses to various accounts than in manipulating the aggregate level of accounting earnings.

The stock price can only reflect the information available to the stock market. If the market's information is inferior to the manager's, actions that maximize the current stock price will not, in general, be the ones that lead to efficient operation of the firm. Thus, a rational, efficient market will lead to inefficient operation of the firm when the manager's objective function contains the current stock price.[24] In the case in which the market has superior information about the near future as opposed to the distant future, the manager will have an incentive to allocate excessive (unobservable) resources to boost the firm's short-term performance and neglect long-term performance. Thus, rational, nonmyopic financial markets and rational, nonmyopic managers will lead to inefficient "myopic" behavior when the current stock price affects managerial incentives and the financial market's information about short-term performance is superior to its information about long-term performance. This is consistent with the empirical findings of Bizjak, Brickley, and Coles (1991), who find that firms whose projects involve substantial long-term uncertainty are less likely to base managerial compensation on the current stock price than firms whose projects involve little long-term uncertainty.

The conflict between aggregating information to assess value and aggregating information to provide incentives has important effects on the operation of the firm. With stock-based incentives: (i) the productivity of effort in the various projects plays no role in the allocation of the manager's effort across projects; (ii) the manager will allocate excessive effort to projects whose cash flows have high variability (high σ_i) relative to the projects whose cash Bows have low variability (low σ_i); and (iii) the risk premium paid to the manager is in excess of the amount paid in the second-best optimum (in which the firm could contract directly on the information observed by the market). As shown in Equation (5) and Section 3.3, this leads to inefficient operation of the firm relative to the second-best optimum.

If all of the individual signals contained in the stock price can be directly contracted upon, the firm should leave the stock price out of its managerial compensation contracts and, instead, write compensation contracts directly on these signals themselves. If the stock

[24] Natayanan (1985) and Stein (1989) also show that myopic firm behavior can persist under efficient markets.

price aggregates individual pieces of information that cannot be directly contracted upon, the firm has no choice but to include the stock price in management compensation. However, it cannot rely on the stock market to aggregate information optimally for the compensation problem. In this case, the firm will have an incentive to create other non-stock-based mechanisms for corporate governance to try to offset some of the deficiencies of stock-based compensation. Research into these areas may lead to a better understanding of the exact role of many features of corporate governance.

The applicability of the ideas described in this article are not limited to large corporations. An entrepreneur creating a start-up firm will know more than others about his ability and effort. To the extent his incentives are determined by the price his firm's shares will bring at a future public offering, his incentives will suffer from the inefficiencies described in Propositions 1, 2, and 3. The basic ideas discussed here will hold outside of financial markets as well. They will hold whenever market prices are used to aggregate information for a principal-agent problem.

Appendix: Derivation of Equation (12)

In this appendix, I derive Equation (12) in Section 5.6. Recall that $X_i = a_i\mu_i + \theta_i$, and a type **r** manager has cost of effort function:

$$C_{\mathbf{r}}(\mu_1,\ldots,\mu_n) = \sum_i c_i(\mu_i;\, r_i),$$

where

$$c_i(\mu_i;\, r_i) = \begin{cases} k_i(\mu_i - r_i)^2/2, & \text{if } \mu_i > r_i, \\ 0, & \text{otherwise,} \end{cases}$$

with $k_i > 0$ for all i. The random vector $(r_1,\ldots,r_n,\theta_1,\ldots,\theta_n,\epsilon_1,\ldots,\epsilon_n)$ has a joint normal distribution and all its elements are mutually independent. Without loss of generality, assume $\mu_i > r_i$.. Since the manager has exponential utility, a type **r** manager's certainty equivalent from choosing effort levels $(\mu_1,\ldots,\mu_n)$ is

$$\gamma_0 + \sum_i \gamma_i a_i \mu_i - \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) - \sum_i \frac{k_i(\mu_i - r_i)^2}{2}. \quad \text{(A1)}$$

Note that this objective function is concave in $(\mu_1,\ldots,\mu_n)$. The manager's utility-maximizing effort levels are given by the first-order condition:

$$\mu_i = a_i\gamma_i/k_i + r_i. \quad \text{(A2)}$$

From Equations (A1) and (A2), a type **r** manager's certainty equivalent is

$$\gamma_0 + \sum_i \gamma_i a_i\left(\frac{a_i\gamma_i}{k_i} + r_i\right) - \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) - \sum_i \frac{(a_i\gamma_i)^2}{2k_i}. \quad \text{(A3)}$$

In Section 5.6, the manager does not know his type at the time he must decide whether to accept the contract. Thus, at the time the manager must decide whether to accept the contract, he faces this additional uncertainty because of his unknown type. Since the manager has exponential utility, at the time he must decide whether to accept the contract, his certainty equivalent is

$$\gamma_0 + \sum_i \frac{(a_i\gamma_i)^2}{2k_i} + \sum_i \gamma_i a_i E[r_i] - \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2)$$
$$- \frac{\rho}{2}\sum_i (a_i\gamma_i)^2 \mathrm{Var}(r_i). \quad \text{(A4)}$$

The manager's wage contract must yield him a certainty equivalent of at least his reservation wealth W_0 at the time he accepts the contract or else the manager will refuse the contract and work elsewhere in the economy. For the contract that maximizes ex ante firm value, this constraint will be binding. Setting γ_0 so that the manager's certainty equivalent at the time he must decide whether to accept the contract (A4) equals W_0 yields

$$\gamma_0 = W_0 + \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) + \frac{\rho}{2}\sum_i (a_i\gamma_i)^2 \mathrm{Var}(r_i)$$
$$- \sum_i \frac{(a_i\gamma_i)^2}{2k_i} - \sum_i \gamma_i a_i E[r_i]. \quad \text{(A5)}$$

The firm wants to set the contract that maximizes the ex ante value of the firm subject to conditions (A2) and (A5). The firm's objective function is

$$\sum_i a_i\left(\frac{a_i\gamma_i}{k_i} + E[r_i]\right) - \left[W_0 + \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2) + \frac{\rho}{2}\sum_i (a_i\gamma_i)^2 \mathrm{Var}(r_i)\right.$$
$$\left. - \sum_i \frac{(a_i\gamma_i)^2}{2k_i} - \sum_i \gamma_i a_i E[r_i]\right]$$
$$- \sum_i \gamma_i a_i\left(\frac{a_i\gamma_i}{k_i} + E[r_i]\right).$$

This reduces to

$$\sum_i a_i\left(\frac{a_i\gamma_i}{k_i} + E[r_i]\right) - W_0 - \frac{\rho}{2}\sum_i \gamma_i^2(\sigma_i^2 + \omega_i^2)$$
$$-\frac{\rho}{2}\sum_i (a_i\gamma_i)^2\operatorname{Var}(r_i) - \sum_i \frac{(a_i\gamma_i)^2}{2k_i},$$

which is concave in $(\gamma_1,...,\gamma_n)$. The following first-order condition describes the wage coefficients that maximize ex ante firm value:

$$\gamma_i = a_i^2/(a_i^2 + \rho k_i[a_i^2\operatorname{Var}(r_i) + \sigma_i^2 + \omega_i^2]).$$

References

Antle, R., and A. Smith, 1986, "An Empirical Investigation of the Relative Performance Evaluation of Corporate Executives," *Journal of Accounting Research,* 24, l-39.

Bizjak, J., J. Brickley. and J. Coles, 1991, "Stock-Based Incentive Compensation, Asymmetric Information, and Investment Behavior," Working Paper MR 91-11, Bradley Policy Research Center. University of Rochester.

Bresnahan. T., P. Milgrom. and J. Paul, 1992, "The Real Output of the Stock Exchange," in Z. Griliches (ed.), Output Measurement in *the Services Section,* University of Chicago Press (for NBER), Chicago, in press.

Bushman, R., and R. Indjejikian. 1991, "Accounting Income, Stock Price, and Managerial Compensation," forthcoming in *Journal of Accounting and Economics.*

Clinch, G., and J. Magliolo, 1991, "Executive Compensation Effects of Accounting-Oriented Discretionary Transactions in Commercial Banks," forthcoming in *Journal of Accounting and Economics.*

DeAngelo, L., 1988, "Managerial Competition, Information Costs, and Corporate Governance." *Journal of Accounting and Economics,* 10, 3-36.

Dechow, P. M., and R. G. Sloan, 1990, "Executive Incentives and the Horizon Problem," working paper, University of Rochester.

Defeo. V. J., R. A. Lambert, and D. F. Larcker, 1989, "The Executive Compensation Effects of Equity for-Debt Swaps," *Accounting Review,* 64, 201-227.

Diamond, D. W., and R. E. Verrecchia, 1982, "Optimal Managerial Contracts and Equilibrium Security Prices," *Journal of Finance,* 37, 275-287.

Ely, K., 1991, "Interindustry Differences in the Relation Between Compensation and Firm Performance Variables," *Journal of Accounting Research,* 29, 37-58.

Fama, E. F., 1980, "Agency Problems and the Theory of the Firm," *Journal of Political Economy,* 88,200-307.

Gibbons. R., and K. J. Murphy, 1990, "Relative Performance Evaluation for Chief Executive Officers," *Industrial and Labor Relations Review,* 43, 30-51.

Gibbons, R., and K. J. Murphy, 1992, "Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence," *Journal of Political Economy,* 100,468-505.

Gjesdal, F., 1981. "Accounting for Stewardship," *Journal of Accounting Research,* 19, 208-231

Grossman, S., and J. Stiglitz, 1980. "On the Impossibility of Informationally Efficient Markets," *American Economic Review,* 70, 81-101.

Hagerty, K., A. Ofer, and D. Siegel, 1991, "Managerial Compensation and Incentives to Engage in Far-Sighted Behavior," working paper, Northwestern University.

Haugen, R. A., and L. Senbet, 1981, "Resolving Agency Problems of External Capital through Options," *Journal of Finance,* 36, 629-647.

Healy, P. M., 1985, "The Effect of Bonus Schemes on Accounting Decisions," *Journal of Accounting and Economics,* 7, 85-107.

Holmstrom, B., and P. Milgrom. 1987, "Aggregation and Linearity in the Provision of Intertemporal Incentives," *Econometrica,* 55, 303-328.

Holmstrom. B., and P. Milgrom, 1991, "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design," *Journal of Law, Economics, & Organization,* 7(Sp), S24-S52.

Holmstrom, B., and J. Tirole, 1990, "Corporate Control and the Monitoring Role of the Stock Market," Working Paper 48, Yale School of Management.

Jackson, M., and E. Lazear, 1988, "Stock, Options, and Deferred Compensation," forthcoming in *Research in Labor Economics.*

Janakiraman, S., R. Lambert, and D. Larcker, 1991, "An Empirical Investigation of the Relative Performance Evaluation Hypothesis," mimeo, Wharton School, University of Pennsylvania.

Jensen, M. C., 1986, "Agency Costs of Free Cash Flows, Corporate Finance, and Takeovers," *American Economic Review,* 76, 323-329.

Jensen, M. C., and W. H. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure," *Journal of Financial Economics,* 3, 305-360.

Jensen, M. C., and K. J. Murphy, 1990, "Performance Pay and Top-Management Incentives," *Journal of Political Economy,* 98, 225-264.

Kihlstrom, R. E., and S. A. Mathhews, 1990, "Managerial Incentives in an Entrepreneurial Stock Market Model," *Journal of Financial Intermediation,* 1, 57-79.

Kim, O., and Y. Suh, 1991, "Incentive Efficiency of Compensation Based on Accounting and Market Performance," forthcoming in *Journal of Accounting and Economics.*

Lambert, R. A., and D. F. Larcker, 1987, "An Analysis of the Use of Accounting and Market Measures of Performance in Executive Compensation Contracts," *Journal of Accounting Research,* 25, 85-129.

Manne, H. G., 1965, "Mergers and the Market for Corporate Control," *Journal of Political Economy,* 73, 110-120.

Marris, R., 1963, "A Model of Managerial Enterprise," *Quarterly Journal of Economics,* 77, 185-209.

McNichols, M., and G. P. Wilson, 1988, "Evidence of Earnings Management from the Provision for Bad Debts," *Journal of Accounting Research,* 26, 1-31.

Narayanan, M. P., 1985, "Managerial Incentives for Short-Term Results," *Journal of Finance,* 40, 1469-1484.

Natarajan. R., 1991, "The Use of Accruals in Management Compensation Contracts," working paper, Wharton School, University of Pennsylvania.

Ramakrishnan. R., and A. Thakor, 1984, "The Valuation of Assets under Moral Hazard," *Journal of Finance,* 39, 229-238.

Scharfstein, D., 1988, "The Disciplinary Role of Takeovers," *Review of Economic Studies,* 55, 185-199.

Scholes, M., 1991, "Stock and Compensation," *Journal of Finance,* 46, 803-823.

Sloan. R. G., 1991, "An Empirical Examination of the Role of Accounting Earnings in Top Executive Compensation Contracts," working paper. University of Rochester.

Stein, J. C., 1989, "Efficient Capital Markets, Inefficient Firms: A Model of Myopic Corporate Behavior." *Quarterly Journal of Economics,* 104, 655-669.

Stoughton. N. M., and E. Talmor. 1991, "Managerial Bargaining Power in the Determination of Compensation Contracts and Corporate Investment," working paper, University of California at Irvine.