Intertemporal Cost Allocation and Managerial Investment Incentives: A Theory Explaining the Use of Economic Value Added as a Performance Measure

William P. Rogerson

Northwestern University

This paper provides a formal analysis of how managerial investment incentives are affected by alternative allocation rules when managerial compensation is based on accounting measures of income that include allocations for investment expenditures. The main result is that there exists a unique allocation rule that always induces the manager to choose the efficient investment level. The income measure created by this allocation rule is usually referred to as residual income or economic value added.

I. Introduction

An important aspect of many managers' jobs is making investment decisions that will affect cash flows in multiple future periods. Since managerial compensation is typically based on accounting income (Antle and Smith 1986; Lambert and Larcker 1987; Rosen 1992), managers can generally affect their future compensation by altering investment levels. The natural question that arises in this context is whether managers' private incentives to choose investment levels result in efficient investment levels from the perspective of shareholders. A frequently expressed concern is that managers may be

I would like to thank Ron Dye, Kathleen Hagerty, Bob Magee, Stefan Reichelstein, Sherwin Rosen, and an anonymous referee for helpful comments and discussions.

[*Journal of Political Economy*, 1997, vol. 105, no. 4]

too impatient and thus may underinvest relative to the efficient level, either because their personal cost of capital is higher than the firm's or because they have a shorter time horizon than the firm (i.e., they plan to leave or retire before all the benefits of the investment are realized).

One technique that firms use to help combat this potential distortion is to base managerial compensation on accounting measures of income created by allocating investment expenditures to the future periods that benefit from the investment. The intuitive justification for this procedure is that matching costs to benefits creates a more "accurate" measure of income on a period-by-period basis and thus reduces distortions caused by the fact that managers may not compare cash flows across time correctly (Dechow 1994). Although this intuition is appealing, it is obviously incomplete. The intuition does not precisely explain why such a procedure would work. Nor does it explain what allocation rule should be used and how the choice of allocation rule should depend on factors such as the time pattern of benefits from the investment, shareholders' discount rate, the manager's discount rate, or the nature of wage contracts in place across various periods. It is intuitively clear that all these factors might enter the analysis.

Firms typically think of themselves as choosing an allocation method for investment expenditures by choosing a depreciation rule and an interest imputation rate. A depreciation rule is simply a rule that assigns a share of the original investment cost to each period of the asset's life with the property that the shares sum to the total investment cost. The share assigned to a period is referred to as that period's depreciation. The total investment cost allocated to any period is set equal to that period's depreciation plus an imputed interest cost calculated by multiplying the interest imputation rate by the remaining (nondepreciated) book value of the investment.

Many firms have traditionally used "operating income" as a performance measure for management. This amounts to using an interest imputation rate of zero; that is, no interest is imputed. There are a small number of commonly used depreciation rules. Some firms assign an equal share of depreciation to each period of the asset's life. This is called the straight-line method. Most other commonly used depreciation rules are accelerated relative to the straight-line rule, in the sense that depreciation occurs more quickly.

An alternative performance measure used by some firms is "residual income" (Kaplan 1982; Horngren and Foster 1987). This amounts to using an interest imputation rate equal to the firm's cost of capital. The depreciation rule is generally still selected from the same small group of commonly used rules used to create operating income. In the last three or four years, there has been an explosion of interest in this method and a great increase in the extent to which it is used. Management consulting companies have renamed this performance measure "economic value added" (EVA) and have quite successfully marketed it as an important new way of creating better investment incentives for managers. *Fortune,* for example, has run a cover story on EVA, extolling its virtues and listing a long string of major companies that have adopted it (Tully 1993).[1]

From the standpoint of real firms, then, the important questions regarding the effect of investment allocation rules on investment incentives appear to be the following: (1) How does the choice of depreciation rule and interest imputation rate affect managerial investment incentives? (2) Is there an "optimal" depreciation rule and interest imputation rate, and how is this choice affected by factors such as the time pattern of benefits from the investment, shareholders' discount rate, the manager's discount rate, the manager's level of risk aversion, and so forth? The purpose of this paper is to provide a theory that answers these questions.

This paper constructs a model in which the manager is better informed than shareholders about investment opportunities, and shareholders therefore delegate the investment choice to the manager. The manager also exerts an unobservable level of effort each period that increases the firm's cash flows. The "problem" with this situation is that the two incentive problems generally interfere with one another. That is, wage contracts designed to deal with the moral hazard problem will generally distort the agent's investment decision. The main result of this paper is to show that a very large class of contracts exist that dramatically simplify this problem but still allow shareholders to achieve a high level of expected utility. Suppose that, instead of basing the manager's wage contract on completely disaggregated accounting data, the firm calculates period-by-period income for itself by allocating the investment cost to periods that benefit from the investment and then bases the manager's wage contract on the firm's accounting income. It is shown that a unique allocation rule exists that always induces the manager to make efficient investment decisions, as long as the wage contract is weakly increasing in income. Thus the investment delegation problem is completely solved, and shareholders are left with an enormous num-

[1] See the roundtable discussion in the *Continental Bank Journal of Applied Corporate Finance* (Stern and Stewart 1994) and the associated articles (Sheehan 1994; Stewart 1994) for more complete descriptions and discussions and further references.

ber of degrees of freedom to attempt to deal with the moral hazard problem.

Shareholders require essentially no information about the manager's preferences in order to construct this allocation rule. In particular, they do not need to know the manager's own personal discount rate, nor do they need to know anything about his attitude toward risk. The result does not depend on particular functional form assumptions or on the existence of a very structured environment in which a one-dimensional "type" describes the nature of uncertainty. Therefore, unlike many theoretical agency models, this model yields a very robust result that one could imagine being used by real firms in real situations, without any further alteration or adaption.

This allocation rule is created by choosing an interest imputation rate equal to the firm's cost of capital and choosing the depreciation rule so that the *total* investment cost allocated to each period (i.e., depreciation plus imputed interest on remaining book value) remains constant across periods. Thus the current wave of enthusiasm for using an interest imputation rate equal to the firm's cost of capital seems to be justified. However, as will be shown, insufficient attention has been paid to the issue of what depreciation rule to use.

The result that the depreciation rule discussed above induces efficient investment is derived in a model in which the investment is assumed to remain equally productive over its lifetime. This assumption is also relaxed to allow the productivity of the investment to vary over its lifetime. In this case there is still a unique allocation rule that always induces the manager to make efficient investment decisions. The interest imputation rate is still set equal to the firm's cost of capital. The depreciation rule is set so that the total cost allocated to each period is proportional to the relative productivity of the asset in each period. This rule can therefore be viewed as being consistent with a version of the "matching principle" from accounting, which states that costs should be allocated across objectives in proportion to the benefits that the costs create across objectives.

The basic economic idea underlying this paper can be understood from this viewpoint. It is shown that by using the matching principle to allocate investment costs, the firm can essentially "annuitize" the manager's problem: The firm can create a situation in which every period creates the same investment incentive; that is, the firm can create a situation in which, even if the manager cared only about wages in a single period, he would choose the efficient investment level, and this is true for every period. In such a case, the way the manager values cash flows across periods becomes completely irrelevant to determining his investment choice. In particular, the manager makes the efficient investment decision regardless of his own personal discount rate.

Therefore, this paper provides a theory of both why income may be used as a performance measure for management and how income should be calculated for this purpose. Income is used as a performance measure to guarantee in a simple robust way that managers will make efficient input decisions. When the input is an investment good and benefits multiple future periods, it is important that the costs be allocated across periods in proportion to the benefits they produce and that the discounted sum of the cost allocations, using the shareholders' cost of capital, be equal to the total investment cost. This essentially annuitizes the problem from the manager's perspective and creates an incentive for the manager to choose the efficient investment level, no matter how he values wage payments across periods.

The result of this paper is also very relevant to the large ongoing debate in the economics, finance, and accounting literatures on whether, from a theoretical perspective, managerial compensation ought to be tied more closely to accounting income or stock market price. A large empirical literature has documented the fact that managerial compensation is closely tied to accounting measures of income and, in fact, that managerial compensation is probably more closely tied to accounting measures of performance than to stock market measures of performance (Antle and Smith 1986; Lambert and Larcker 1987; Jensen and Murphy 1990; Rosen 1992). This result has been viewed as somewhat puzzling and counterintuitive by many economists. One of the main reasons for this is the intuition that, by basing managerial compensation on the firm's stock market value, shareholders can clearly solve the investment incentive problem in a simple robust way. Furthermore, they should still be able to address the moral hazard problem of inducing managerial effort by basing managerial compensation on stock market value. If shareholders can completely solve the investment incentive problem in a simple robust way and are still left with a large number of degrees of freedom to address the moral hazard problem, why don't we observe compensation contracts in the real world that are much more closely tied to stock market performance than to accounting measures of performance? The answer suggested by this paper's result is that basing managerial compensation on accounting income can provide an equally simple and robust solution to the investment incentive problem. Therefore, from a theoretical perspective, consideration of the investment incentive problem does not necessarily suggest anything about the relative desirability of basing managerial compensation on stock market versus accounting measures of performance. In particular, then, if basing managerial compensation on accounting measures of performance had some other advantage, we might expect to observe in the real world that managerial compensation is more closely tied to accounting measures of performance than to stock market measures of performance. The literature has, in fact, suggested that such advantages may exist.[2]

Section II of the paper introduces the basic model and Section III analyzes it. In these early sections, the firm is viewed as directly choosing an allocation rule rather than directly choosing a depreciation rule and interest imputation rate (which in turn generate an allocation rule). Section IV reinterprets the results when the firm is viewed as directly choosing a depreciation rule and interest imputation rate. Section V generalizes the model to allow the productivity of the investment to vary over time. Section VI relates this paper's results to other papers exploring investment incentives and the use of residual income as a performance measure. Finally, Section VII draws brief conclusions.

II. The Model

A. *The Basic Model*

The relationship between the owners of the firm and the manager will be modeled as a principal-agent relationship. The terms "owners of the firm" and "principal" will be used interchangeably. Similarly, the terms "manager" and "agent" will be used interchangeably.

Suppose that there are $T + 1$ periods indexed by $t \in \{0, 1, \ldots, T\}$. The firm will conduct business and realize cash flows from conducting business during periods $1, \ldots, T$. Let $\mathbf{z} = (z_1, \ldots, z_n)$ denote the vector of cash flows received by the firm from conducting business. Before beginning business, the firm must choose a level of investment, x, in period 0. The level of investment chosen in period 0 will affect the value of cash flows in future periods. For example, purchasing a machine may reduce per period expenditures on labor. The accounting system of the firm is able to directly measure x and $\mathbf{z}$. It is also assumed that, in each of periods $1, \ldots, T$, the agent exerts an unobservable level of effort that affects the firm's cash flow during that period. Formally, let e_t denote the agent's ef-

[2] A number of recent papers have suggested that basing managerial compensation contracts on accounting income may provide a superior solution to the moral hazard problem of inducing effort, in some cases (Paul 1992; Bushman and Indjejkian 1993; Kim and Suh 1993; Lambert 1993; Sloan 1993). The basic idea is that accounting income may be a less noisy signal of managerial effort than stock market value is.

fort choice in period t, and let $\mathbf{e} = (e_1, \ldots, e_T)$ denote the vector of all the agent's effort choices.

Assume that the manager is potentially better informed than shareholders about both his own preferences and the marginal productivity of investment. Formally, assume that, before the beginning of the relationship, a state of nature, θ, is drawn from some set Θ according to the density $g(\theta)$. The agent directly observes θ but the principal does not. For purposes of thinking about the model, one would generally expect θ to be multidimensional. It contains information about both the marginal productivity of capital and the agent's preferences, and information about either of these could be very complex.

Period t cash flow is therefore affected by the state of nature, the investment level, and the agent's effort choice in period t. It will be initially assumed that the investment lasts all T periods and remains equally productive over its entire lifetime.[3] Formally, assume that period t cash flow is determined by

$$z_t = \delta(x, \theta) + \epsilon_t, \tag{1}$$

where $\delta(x, \theta)$ is an increasing function of x for every θ, and ϵ_t is a random variable affected by effort according to the density $f_t(\epsilon_t / e_t)$.

Assume that the principal is risk-neutral and has a cost of capital of $r^* \in [0, \infty)$. Since ϵ_t and x are additively separable in (1), the investment level that maximizes expected discounted cash flows can be determined independently of effort levels. The investment level that maximizes expected discounted cash flows for the firm is the level that maximizes

$$\alpha(r^*)\delta(x, \theta) - x, \tag{2}$$

where $\alpha(r)$ denotes the discounted value of receiving \$1.00 per period over periods $1, \ldots, T$, using the interest rate r, and is given by

$$\alpha(r) = \sum_{t=1}^{T} \frac{1}{(1 + r)^t}. \tag{3}$$

Assume for every $\theta \in \Theta$ that $\delta(x, \theta)$ is continuously differentiable in x, strictly increasing in x, and strictly concave in x and that its first derivative with respect to x assumes all values in the range $(0, \infty)$ as x varies over $[0, \infty)$. These assumptions are sufficient to guarantee

[3] Section V will generalize the model to allow the productivity of the asset to vary over time.

that for every θ there exists a unique value of x that maximizes (2) and that it is determined by the first-order condition

$$\delta_x(x, \theta) = \frac{1}{\alpha(r^*)}. \tag{4}$$

This will be called the efficient investment level given θ and will be denoted by $x^*(\theta)$.

Let $\mathbf{w} = (w_1, \ldots, w_T)$ denote a vector of wage payments the agent receives in periods $1, \ldots, T$. Let $u(\mathbf{w}, e, \theta)$ and $\bar{u}$ denote the agent's expected utility function and reservation utility.

The principal hires the agent at the beginning of period 0 to choose a level of investment in period 0 and then exert effort in each of periods $1, \ldots, T$. The principal delegates the investment decision to the agent because the agent has better information regarding the level of investment that would be efficient. A contract specifies the wage the agent will be paid in each of periods $1, \ldots, T$ as a function of the agent's investment choice in period 0 and all cash flows that have been observed through the end of each period. Such a contract will be called a disaggregated data–based contract, to connote the fact that it is based on all available accounting data in a disaggregated form. Therefore, a period t disaggregated data–based contract is a real-valued function $\phi_t(x, z_1, \ldots, z_t)$, giving the wage the agent will be paid conditional on observing $(x, z_1, \ldots, z_t)$. A disaggregated data–based contract is a function from $(x, \mathbf{z})$ to R^T denoted by $\phi(x, \mathbf{z}) = (\phi_1, \ldots, \phi_T)$.[4]

To complete the description of the basic model, the order of play and the information of each player at each stage will now be briefly reviewed. At the beginning of period 0, nature has already drawn θ. Only the agent is able to directly observe θ. The principal and agent both know the entire structure of the model, including $\delta(x, \theta)$, $f_t(\epsilon_t/e_t)$, $u(\mathbf{w}, e, \theta)$, $\bar{u}$, and $g(\theta)$. The principal offers the agent a disaggregated data–based contract $\phi(x, \mathbf{z})$. If the agent rejects the contract, the relationship is over and the agent receives $\bar{u}$ utils. If the agent accepts the contract, the agent then chooses x in period 0. For each of periods $1, \ldots, T$, the agent chooses the

[4] It would be potentially more general to allow the principal to choose a mechanism in which the agent announces his observation of θ and the investment level and the wage contract are functions of the agent's announcement of θ. This is potentially more general than simply allowing delegation of the investment choice, because θ may be multidimensional and it may be possible for the principal to obtain incentive-compatible revelation of more than one dimension of information. However, such contracts would be extremely complex, especially when the agent is risk-averse, and theorists have not been able to make much progress in describing the nature of the optimal contract in such a case (Melumad and Reichelstein 1989). It seems unlikely that such contracts would ever be seen in practice.

effort level that he will exert at the beginning of the period, and then that period's cash flow is determined according to (1). The agent is paid a wage at the end of each period as specified by the contract.

An optimal contract is defined as follows. For every contract, the principal is able to predict the agent's behavior conditional on θ ("behavior" includes whether the agent will accept the contract or not, as well as the agent's investment and effort decisions conditional on accepting the contract). Therefore, for any contract, the principal can calculate his expected discounted cash flow, taking the agent's predicted behavior into account. The optimal contract is the contract that maximizes the principal's expected discounted cash flow.

B. *Income-Based Contracts and Allocation Rules*

In the model above, a contract can be made a function of completely disaggregated accounting data. That is, the agent's wage payment each period can be made to depend on the agent's investment choice and all cash flows observed up until the end of that period, and each of these variables can enter as a separate argument in the wage function. In reality, firms do not typically consider such a broad class of contracts. Typically, they will aggregate accounting data to calculate income on a period-by-period basis. Then wage payments are based only on current and possibly historic income levels. In the context of this model, completely disaggregated accounting data are a vector $(x, \mathbf{z})$ in R^{T+1}. An income measure would be a vector $\mathbf{y} = (y_1, \ldots, y_T)$ in R^T, where y_t denotes the firm's income in period t. The $T + 1$ dimensions of information are aggregated into T dimensions by allocating the investment cost to the periods that benefit from it. Notation to formally describe this will now be introduced.

Define an allocation rule to be a vector of real numbers $\mathbf{a} = (a_1, \ldots, a_T)$, where a_t denotes the investment cost allocated to period t for every dollar of investment. That is, if x dollars are invested, then a cost of $a_t x$ dollars is allocated to period t.[5] Formally, let $I_t(x, \mathbf{z},$

[5] Firms do not typically think of themselves as directly choosing an allocation rule. Rather, they think of themselves as directly choosing a depreciation rule and an interest imputation rate. They in turn generate a cost allocation rule. (The cost allocated to any period equals depreciation plus imputed interest charges on the remaining book value of the investment.) To keep the analysis as clear and simple as possible, the principal will initially be modeled as directly choosing an allocation rule. Consideration of depreciation rules and interest imputation rates will be delayed until Sec. IV.

a) denote the function determining the firm's period t accounting income conditional on the investment level x, cash flows $\mathbf{z}$, and allocation rule $\mathbf{a}$. It is given by

$$I_t(x, \mathbf{z}, \mathbf{a}) = z_t - a_t x. \tag{5}$$

Let $I(x, \mathbf{z}, \mathbf{a}) = (I_1, \ldots, I_t)$ denote the function determining the entire vector of incomes.

An income-based contract specifies the wage the agent will be paid each period as a function of current and possibly historic accounting incomes. Therefore, a period t income-based contract is a function $\psi_t(y_1, \ldots, y_t)$ giving the wage the agent will be paid if the firm's income in periods 1, . . . , t is given by $(y_1, \ldots, y_t)$. An income-based contract is then a function from R^T to R^T denoted by $\psi(\mathbf{y}) = (\psi_1, \ldots, \psi_T)$.

It is clear that the principal can create a disaggregated data–based contract by choosing an allocation rule to define income and an income-based contract. Formally, a disaggregated data–based contract will be said to be created by $(\mathbf{a}, \psi)$ if

$$\phi(x, \mathbf{y}) = \psi(I(x, \mathbf{y}, \mathbf{a})). \tag{6}$$

In the context of this paper's model, the practice of real firms is to choose an allocation rule for investment expenditures based on observable characteristics of the investment such as its useful lifetime and to restrict themselves to choosing a disaggregated data–based contract that can be created by this allocation rule and some income-based contract. The goal of this paper is to explain why such a practice might be desirable and to explain how the allocation rule should be chosen. This will provide a theory of why income is used as a performance measure and explain how the allocation rule should be selected to calculate income.

Before I begin the analysis, it will be useful to describe one property of allocation rules. In the single-period context, where costs are allocated between multiple products produced in the same period, one usually thinks of an allocation rule as "completely" allocating a cost if the allocation shares sum to one. In the multiperiod case considered by this paper, the natural analogue is having the discounted allocation shares sum to one. For an interest rate, r, an allocation rule will be said to be complete with respect to r if the discounted values of the allocation shares sum to one. Formally, $\mathbf{a}$ is complete with respect to r if

$$\sum_{t=1}^{T} \frac{a_t}{(1 + r)^t} = 1. \tag{7}$$

Straightforward algebra shows that, for every r, there is a unique allocation rule such that it is complete with respect to r and the allocation share remains constant across periods. This will be called the r-annuity allocation rule and will be denoted by $\mathbf{a}^r = (a_1^r, \ldots, a_T^r)$. Formally, the r-annuity allocation rule is given by

$$a_t^r = \frac{1}{\alpha(r)}, \tag{8}$$

where, recall, $\alpha(r)$ is defined by (3).

III. Income-Based Contracts and Inducing Efficient Investment

The standard approach of the formal incentives literature to analyzing the problem described above is to calculate the optimal contract and then attempt to say something interesting about it. The major problem that economists have experienced when employing this approach is that, from an applied standpoint at least, it is often the case that nothing of much interest can be said. In problems such as this in which the agent makes decisions based on private information, in order to be able to analytically solve the problem with existing methods, it must generally be assumed that the agent's private information is one-dimensional and that some type of single crossing condition is satisfied so that the various "types" can be induced to sort themselves. Even given all the structure that is generally assumed, the nature of the calculations is still extremely complex. Furthermore, the nature of the optimal contract is highly dependent on the particular functional form assumptions made about preferences, the nature of uncertainty, and so forth. Small changes in any of these assumptions might cause quite large changes in the nature of the optimal contract. In the real world, the principal's information is always somewhat "fuzzy," uncertainty occurs over more than a single dimension of information, and the principal has limited computational abilities. The type of solution provided by the standard approach therefore often does not seem to shed much light on real behavior and practices.

This paper will adopt a different approach to analyzing this incentive contracting problem that is more consistent with the view that simplicity, robustness, and ease of calculation play an important role in determining the types of contracts that principals and agents actually use. The nature of asymmetric information will be left perfectly general. In particular, then, the possibility that the principal has poor information about the agent's preferences as well as poor information about the marginal productivity of investment will be allowed for. The main result is that there exists a large class of very simple contracts that always induce the agent to choose the efficient investment level. Thus by restricting himself to this set of contracts, the principal can guarantee in a simple robust way that the investment problem is completely solved, and he is still left with an enormous number of degrees of freedom to attempt to solve the moral hazard problem.

More specifically, the main result is that if the principal uses the r^*-annuity allocation rule to define income, the agent will *always* (i.e., for every state of nature θ) choose the efficient investment level for any income-based wage contract such that wages are weakly increasing in income. Furthermore, the r^*-annuity allocation rule is the unique allocation rule that exhibits this property.

The result therefore can be interpreted as a theory that explains why firms might choose to base managerial compensation on an accounting measure of income and how the allocation rule should be chosen for calculating accounting income. By restricting himself to considering contracts that can be implemented by using the r^*-annuity allocation rule and a weakly monotone income-based contract, the principal automatically guarantees in a very robust way with no further calculations that the investment decision problem is completely solved. Then he can select an income-based wage contract from the entire class of monotone income-based contracts to find the best possible solution to the moral hazard problem. Such an approach might be particularly natural in a world of bounded rationality, where the principal was constantly monitoring the performance of existing contractual arrangements and then attempting to make incremental improvements. It might be very sensible for such a principal to restrict himself to using the r^*-annuity allocation rule and income-based wage contracts. He would always induce the agent to invest efficiently and could adjust the sharing ratio of the wage contract over time to induce more or less effort as seemed appropriate.

Of course simplicity, robustness, and ease of calculation are not sufficient ends in and of themselves. It is also important to consider the level of welfare that the principal can achieve by restricting himself to this set of contracts. On an intuitive level, it seems that the main constraint placed on the principal by restricting himself to this set of contracts is that he must select a contract that induces the agent to select the efficient investment level. (Recall that all contracts in this set induce the agent to select the efficient investment level.) In simplified versions of this model in which the agent is assumed to have a one-dimensional type and the standard techniques can be used to solve for the optimal contract, in general, it may be optimal for the principal to induce at least some distortion in the agent's investment decision in order to gain extra leverage on the moral hazard problem. However, this is precisely the type of contract that is nonrobust to slight changes in the environment and is extremely complex. In a wide variety of circumstances, it may be that "settling" for inducing the efficient investment choice may be a relatively small price to pay for achieving a robust simple solution to the investment incentive problem. Whether it can be formally shown in some sense that the optimal contract lies within this set of simple contracts if the principal's information is imprecise enough is an interesting question for future research that is beyond the scope of this paper.[6] This paper will restrict itself to simply showing that all contracts within this set induce the efficient investment level.

Notation and definitions necessary to formally state the main result will now be introduced. Recall that an income-based contract, ψ, determines each period's wage as a function of current and historic periods' accounting incomes. An income-based contract ψ will be called weakly increasing if every period's wage is weakly increasing in current and historic accounting incomes. Formally, ψ is weakly increasing if $\psi_t(y_1, \ldots, y_t)$ is weakly increasing in y_i for every $t \in \{1, \ldots, T\}$ and $i \in \{1, \ldots, t\}$.

For any disaggregated data–based contract, ϕ, it will be said that ϕ induces efficient investment if, for every possible θ and every possible strategy for effort choice, the agent maximizes his expected utility by choosing the efficient investment level. Some extra notation needs to be introduced to formally define this concept. The effort level chosen by the agent in any period can be made a function of observed cash flows in all preceding periods. Thus an effort strategy for the agent can be denoted by a vector of functions $\mathbf{s} = (s_1, \ldots, s_T)$, where s_1 is a constant function and s_t is a function of $(z_1, \ldots, z_{t-1})$ for every $t \in \{2, \ldots, T\}$. Let $U(x, \mathbf{s}, \theta, \phi)$ denote the agent's expected utility given that nature has drawn θ and the agent accepts the contract ϕ, chooses the investment level x, and makes the effort decision $\mathbf{s}$.[7] Formally, a contract ϕ will be said to induce

[6] An earlier version of this paper (Rogerson 1996) begins to develop the idea that a sufficient condition for this set of contracts to "perform well" is that observation of the efficient investment level be uninformative about the firm's future cash flows.

[7] Formally,

$$U(x, \mathbf{e}, \theta, \phi) = \int u(\phi(x, \mathbf{z}), \mathbf{e}, \theta) f(\epsilon / e)\, d\epsilon,$$

where $\mathbf{z}$ is defined by (1).

efficient investment if

$$x^*(\theta) \in \underset{x}{\operatorname{argmax}}\ U(x, \mathbf{s}, \theta, \phi) \quad \text{for every } \mathbf{s} \text{ and } \theta. \tag{9}$$

Now the main property of interest will be defined. An allocation rule will be said to induce efficient investment if the disaggregated data–based contract created by using any weakly increasing income-based contract induces efficient investment. Formally, an allocation rule, **a**, induces efficient investment if, for every weakly increasing income-based contract ψ, the disaggregated data–based contract created by (**a**, ψ) induces efficient investment.

Proposition 1 now presents the result that the r^*-annuity allocation rule is the unique allocation rule that always induces efficient investment.

PROPOSITION 1. (i) Suppose that $u(\mathbf{w}, \mathbf{e})$ is weakly increasing in w_t for every $t \in \{1, \ldots, T\}$. Then the r^*-annuity allocation rule induces efficient investment. (ii) The r^*-annuity allocation rule is the only allocation rule that induces efficient investment for every $u(\mathbf{w}, \mathbf{e})$ such that u is weakly increasing in w_t for every $t \in \{1, \ldots, T\}$.

Proof. First, part i will be proved. For any allocation rule **a**, period t accounting income for the firm is defined by

$$y_t = \delta(x, \theta) - a_t x + \epsilon_t. \tag{10}$$

The r^*-annuity allocation is defined by (8). Substitution of (8) into (10) yields

$$y_t = \left[\delta(x, \theta) - \frac{x}{\alpha(r^*)}\right] + \epsilon_t. \tag{11}$$

Note that the choice of x has exactly the same effect on each period's accounting income, which is given by the bracketed term in (11). Recall that $x^*(\theta)$ is the unique maximizer of the bracketed term. This means that, for every θ, the distribution over **y** induced by $x^*(\theta)$ first-order stochastic dominates the distribution over **y** induced by any other choice of x. By assumption, the agent's expected utility function is weakly increasing in wage income. Because the wage function is assumed to be weakly increasing, the agent will always prefer one distribution of **y** over another if the former first-order stochastic dominates the latter. In particular, then, the agent weakly prefers the income distribution generated by choosing $x^*(\theta)$ to the income distribution generated by any other choice of x.

Now part ii will be proved. Suppose that an allocation rule, **a**, induces efficient investment for every utility function that is weakly increasing in wage income. In particular, choose a utility function that is strictly increasing in every period's wage income. Now choose any $t \in \{1, \ldots, T\}$. Consider an income-based wage contract such that the wage in all periods except period t is constant and the period t wage depends only on the firm's period t accounting income and is strictly increasing in period t accounting income. Period t accounting income for the firm is given by (10). Just as argued above, the investment choice given by

$$\delta_x(x, \theta) - a_t = 0 \tag{12}$$

produces a distribution over y_t that first-order stochastic dominates the distribution over y_t produced by any other x. Therefore, the unique optimal investment choice for the agent is given by (12). However, by assumption, the allocation rule **a** induces the efficient investment choice given by (4). Equations (4) and (12) imply that **a** must be the r^*-annuity allocation rule. Q.E.D.

The intuition for this proposition is very simple. The r^*-annuity allocation rule essentially annuitizes the problem from the agent's perspective. When costs are matched to benefits, the effect of investment on each period's income is the same. For any period, the agent causes the distribution of income to shift maximally to the right by choosing the efficient investment level. Since this is true for any period, it is optimal for the agent to choose the efficient investment level regardless of how he compares cash flows across periods.

It is straightforward to show that the uniqueness result in part ii of proposition 1 can be considerably strengthened. Part ii states that the r^*-annuity allocation rule is the unique allocation rule that induces efficient investment over the set of all managerial utility functions such that utility is weakly increasing in each period's wage. This is a very large set. As formally stated, part ii of proposition 1 therefore leaves open the possibility that there are other allocation rules that induce efficient investment over sets of managerial utility functions that are still quite large. In fact, the uniqueness result can be proved for much smaller sets of managerial utility functions. An earlier version of this paper (Rogerson 1993) defines a property called the "full spanning condition" and shows that the r^*-annuity allocation rule is the unique allocation rule that induces efficient investment over any set of managerial utility functions satisfying the full spanning condition. This condition is very weak. For example, it is satisfied by the set of utility functions corresponding to the case in which the manager is risk-neutral and his discount rate is known to be chosen from some interval. Thus, in real situations, one would generally expect that the set of possible utility functions for the agent is large enough that the r^*-annuity allocation rule is the only allocation rule that induces efficient investment for every possible utility function.

IV. Depreciation Rules and Interest Imputation Rates

As previously mentioned, firms typically think of themselves as choosing an allocation rule by directly choosing a depreciation rule and interest imputation rate. This section will now reinterpret the paper's results from this viewpoint. Subsection *A* will introduce notation to describe depreciation rules and interest imputation rates. Subsection *B* will then identify the unique depreciation rule and interest imputation rate that generate the r^*-annuity allocation rule. Subsection *C* will compare this solution to actual practices of firms. Subsection *D* will report comparative statics results that show whether current practices generally induce overinvestment or underinvestment.

A. *Notation*

A depreciation rule is defined to be a vector $\mathbf{d} = (d_1, \ldots, d_T) \in D$, where D is the set of all vectors in R^T that sum to one. Interpret d_t as the share of depreciation allocated to period t. That is, if x dollars are invested in period 0, then $d_t x$ dollars of depreciation are assigned to period t. Let $r \in [0, \infty)$ denote the interest imputation rate. Therefore, the set $D \times [0, \infty)$ is the set of all depreciation rule/interest rate pairs. Let $\boldsymbol{\eta}(\mathbf{d}, r) = (\eta_1(\mathbf{d}, r), \ldots, \eta_T(\mathbf{d}, r))$ denote the allocation rule generated by $(\mathbf{d}, r)$. This is formally given by

$$\eta_t = d_t + rb_t, \tag{13}$$

where

$$b_1 = 1 \tag{14}$$

and

$$b_t = 1 - \sum_{j=1}^{t-1} d_j, \quad t > 1. \tag{15}$$

According to (14) and (15), b_t can be interpreted as the book value in period t. Therefore, (13) states that the cost allocated to any period equals depreciation plus interest on book value.

For any $r \in [0, \infty)$, let A^r denote the set of allocation rules that are complete with respect to r.[8] It is straightforward to see that, for any

[8] Recall that an allocation rule is r-complete if the discounted sum of the allocation shares (when the interest rate r is used) equals one.

fixed $r \in [0, \infty)$, $\boldsymbol{\eta}(\mathbf{d}, r)$ is a one-to-one mapping from D onto A^r. That is, the allocation rule generated by $(\mathbf{d}, r)$ is always r-complete, and every r-complete allocation rule can be generated by a unique $(\mathbf{d}, r)$ pair for some $\mathbf{d} \in D$. Let $\boldsymbol{\lambda}(\mathbf{a}, r) = (\lambda_1(\mathbf{a}, r), \ldots, \lambda_T(\mathbf{a}, r))$ denote the inverse of $\boldsymbol{\eta}$. That is, for any $r \in [0, \infty)$ and $\mathbf{a} \in A^r$, the unique $\mathbf{d}$ such that $(\mathbf{d}, r)$ generates $\mathbf{a}$ is given by $\boldsymbol{\lambda}(\mathbf{a}, r)$. It is also straightforward to see that $\boldsymbol{\lambda}(\mathbf{a}, r)$ is given by

$$\lambda_1(\mathbf{a}, r) = a_1 - r \tag{16}$$

and

$$\lambda_t(\mathbf{a}, r) = a_t - (1 + r)^{t-1} r \left[1 - \sum_{i=1}^{t-1} \frac{a_i}{(1 + r)^i}\right], \quad t > 1. \tag{17}$$

This result is summarized as proposition 2.

PROPOSITION 2. For any fixed $r \in [0, \infty)$, the function $\boldsymbol{\eta}(\mathbf{d}, r)$ is a one-to-one mapping from D onto A^r. The inverse of $\boldsymbol{\eta}$ is given by $\boldsymbol{\lambda}(\mathbf{a}, r)$ defined by (16) and (17).

Proof. Straightforward algebra. Q.E.D.

Proposition 2 states that every allocation rule in A^r can be generated by one and only one depreciation rule using the interest rate r. One would normally expect an allocation rule to be complete with respect to only one nonnegative interest rate. For example, this is true if all the allocation shares are nonnegative. In this case it is straightforward to see that proposition 2 implies that an allocation rule in A^r cannot be generated using any other interest rate. Therefore, for the normal case of an allocation rule that is complete with respect to a single interest rate, there is a unique depreciation rule/interest rate pair that generates the allocation rule. This result is formally presented as corollary 1.

COROLLARY 1. Suppose that $\mathbf{a}$ is an allocation rule that is complete with respect to the nonnegative interest rate r^{**}. Suppose that $\mathbf{a}$ is not complete with respect to any other nonnegative interest rate. Let $\mathbf{d}^{**}$ denote the depreciation rule $\boldsymbol{\lambda}(\mathbf{a}, r^{**})$. Then $(\mathbf{d}^{**}, r^{**})$ is the unique $(\mathbf{d}, r)$ pair that generates $\mathbf{a}$.

Proof. Proposition 2 directly shows that $(\mathbf{d}^{**}, r^{**})$ generates $\mathbf{a}$. It remains to show that $(\mathbf{d}^{**}, r^{**})$ is the unique such pair. This will now be done. Suppose that $(\mathbf{d}, r)$ is a depreciation rule/interest rate pair that generates $\mathbf{a}$. It will be shown that $(\mathbf{d}, r)$ must be equal to $(\mathbf{d}^{**}, r^{**})$. First suppose that $r = r^{**}$. Then proposition 2 directly shows that $\mathbf{d}$ must be equal to $\mathbf{d}^{**}$. Now suppose that $r \neq r^{**}$. Proposition 2 states that the allocation rule generated by $(\mathbf{d}, r)$ must be complete with respect to r. Therefore, $\mathbf{a}$ is complete with respect to

r. If $r \neq r^{**}$, this contradicts the assumption that **a** is not complete with respect to any nonnegative interest rate other than r^{**}. Q.E.D.

B. *Generating the* r*-*Annuity Allocation Rule*

For any $r \in [0, \infty)$, the r-annuity allocation rule is complete with respect to only the interest rate r. Therefore, by corollary 1, there is a unique depreciation rule/interest rate pair that generates the r-annuity allocation rule for any $r \in [0, \infty)$. The interest imputation rate must be set equal to r. Then the depreciation rule is given by $\boldsymbol{\lambda}(\mathbf{a}^r, r)$. This depreciation rule will be called the r-annuity depreciation rule and denoted by $\mathbf{d}^r$. Substitution of (8) into (16) and (17) yields

$$d_t^r = \frac{(1 + r)^{t-1}}{\alpha(r)(1 + r)^T}. \qquad (18)$$

This result is formally stated as proposition 3.

PROPOSITION 3. There is a unique $(\mathbf{d}, r)$ pair that generates the r^*-annuity allocation rule. It is given by $(\mathbf{d}^{r^*}, r^*)$.

Proof. As above. Q.E.D.

Note that the r-annuity depreciation rule is strictly increasing over time as long as r is positive. That is, more depreciation is assigned to later periods than to early periods. Under the r-annuity allocation rule, the total cost allocated to each period remains constant. Total cost equals depreciation plus the imputed interest cost. Imputed interest is calculated by multiplying the interest imputation rate by the book value. Since the book value of the investment falls over time, the imputed interest cost also falls over time. Therefore, the only way to make total cost constant over time is to have depreciation rise over time.

C. *Implications for Real Practices*

The unique way to generate the r^*-annuity allocation rule is to set the interest imputation rate equal to r^* and to use the r^*-annuity depreciation rule as defined above. This has two implications for the real practices of firms. First, it is correct to impute interest costs at the firm's cost of capital when using income as a performance measure for management. Therefore, the current wave of enthusiasm for residual income and EVA measures seems justified. Second, the depreciation rules typically used by firms are not correct. Firms typically use either the straight-line method or methods that are more accelerated than this in the sense that more depreciation is recorded in earlier periods so that depreciation shares fall over time. Under the correct rule, precisely the reverse should occur. More depreciation should be allocated to later periods than to early periods so that depreciation shares rise over time.

D. *Comparative Statics*

In an earlier version of this paper (Rogerson 1993), more structure is added to the model to develop comparative statics results to predict how variations in the interest imputation rate and depreciation rule will affect the agent's investment choice. Since the results are very intuitive but formally presenting them requires a significant amount of extra notation, the results will be only briefly summarized here.

Increasing the interest imputation rate, quite intuitively, causes the agent to invest less; that is, the agent invests less when he is told that capital has a higher cost. The effect of using a more accelerated depreciation rule depends on whether the agent is more or less patient than the principal. The most plausible case is one in which the agent is less patient than the principal, either because the agent expects to leave the firm before the full effects of the investment are realized or because the agent has a higher personal cost of capital than the firm does. In this case, using a more accelerated depreciation rule causes the manager to invest less. This result is also quite intuitive. Using a more accelerated depreciation rule pushes more costs into the early periods that the manager cares too much about. This causes him to view investment as being more costly and thus causes him to invest less.

For tangible assets, the traditional practice used by firms is to depreciate the asset over time but impute no interest costs. Since no interest is imputed, the manager overinvests. However, since the depreciation rule used is too accelerated, the manager underinvests. Since the two effects work in opposite directions, no unambiguous prediction is possible. Firms that currently use residual income or EVA as a performance measure create only the latter effect. Therefore, the manager should underinvest relative to the efficient level. It is also unambiguously the case that if a firm switches from using operating income as a performance measure to using residual income, the manager should respond by investing less than before. This latter prediction is consistent with the stylized facts reported in the practitioner-oriented literature (Sheehan 1994; Stern and Stewart 1994; Stewart 1994).

Firms generally expense intangible assets such as expenditures on research and development. In terms of the formal model, this is simply an extremely accelerated form of depreciation. (Since the expense is charged to the period in which it is incurred, no interest needs to be imputed.) Therefore, the comparative statics results above predict that current practice creates incentives for managers to underinvest in intangible assets relative to what would be efficient.

V. Variable Productivity across Periods

Instead of assuming that cash flows across periods are determined by (1), assume that they are determined by

$$z_t = \rho_t \delta(x, \theta) + \epsilon_t, \tag{19}$$

where $\boldsymbol{\rho} = (\rho_1, \ldots, \rho_T)$ is a vector of nonnegative numbers that will be called the relative productivity profile of the investment. Without loss of generality, assume that $\rho_1 = 1$. The variable ρ_t will be called the relative productivity of the asset in period t. Assume that the principal and agent both know $\boldsymbol{\rho}$. The model is unchanged in all other respects.

Some examples may be helpful. In the basic model, it was assumed that $\rho_t = 1$ for every t. If the asset's usefulness declined at some rate β per period, then $\boldsymbol{\rho}$ would be given by

$$\rho_t = (1 - \beta)^{t-1}. \tag{20}$$

If there was an inflation rate of γ and the real productivity of the asset remained constant, then $\boldsymbol{\rho}$ would be given by

$$\rho_t = (1 + \gamma)^{t-1}. \tag{21}$$

Two remarks should be noted about assumption (19). First, even though the principal knows the time pattern of the investment's relative productivity as given by $\boldsymbol{\rho}$, he does not know enough to calculate the optimal level of investment himself. For this, he would have to know the absolute level of productivity given by the function $\delta(x, \theta)$. Second, the formulation in (19) has the productivity parameter enter in a multiplicatively separable way. The consequence of this is that the relative marginal productivity of investment across periods i and j is simply given by the ratio ρ_i/ρ_j and is *not* affected by the level of investment. The assumption that the relative marginal productivity of the investment is not affected by the level of investment is important for the derivation of the result. In an earlier version of this paper (Rogerson 1993), it is shown that this is a necessary condition for there to exist an allocation rule that always induces efficient investment.

For the generalized problem, the efficient level of investment is the level that maximizes

$$\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta)}{(1 + r^*)^t} - x. \tag{22}$$

Given the regularity assumptions made about $\delta(x, \theta)$, there is a unique level of efficient investment characterized by the first-order condition

$$\delta_x(x, \theta) - \frac{x}{\sum_{i=1}^{T} \frac{\rho_i}{(i + r^*)^i}} = 0. \tag{23}$$

As before, let $x^*(\theta)$ denote the efficient investment level.

Consider any productivity profile, $\boldsymbol{\rho}$. An allocation rule, $\mathbf{a}$, allocates costs in proportion to benefits as defined by $\boldsymbol{\rho}$ if

$$\frac{a_i}{a_j} = \frac{\rho_i}{\rho_j} \quad \text{for every } i, j. \tag{24}$$

Recall that an allocation rule is r-complete if it satisfies (7). Simple algebra shows that, for every $\boldsymbol{\rho}$ and r, there is a unique allocation rule that satisfies (24) and (7). This will be called the relative marginal benefits (RMB) allocation rule given $(\boldsymbol{\rho}, r)$ and be denoted by $\mathbf{a}^{\rho,r} = (a_1^{\rho,r}, \ldots, a_T^{\rho,r})$. It is given by

$$a_t^{\rho,r} = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1 + r)^i}}. \tag{25}$$

For the basic model, where $\rho_t = 1$ for every t, $\mathbf{a}^{\rho,r}$ is simply the r-annuity allocation rule. In the basic model it was shown that the r^*-annuity allocation rule was the unique rule that induces efficient investment. Therefore, the generalization of this result would be to show that the $(\boldsymbol{\rho}, r^*)$–RMB allocation rule is the unique allocation rule that induces efficient investment. This is stated and proved as proposition 4.

PROPOSITION 4. Suppose that the relative productivity profile of the investment is $\boldsymbol{\rho}$ and the principal's cost of capital is r^*. (i) Suppose that $u(\mathbf{w}, \mathbf{e})$ is weakly increasing in w_t for every $t \in \{1, \ldots, T\}$. Then the $(\boldsymbol{\rho}, r^*)$–RMB allocation rule induces efficient investment. (ii) The $(\boldsymbol{\rho}, r^*)$–RMB allocation rule is the only allocation rule that induces efficient investment for every $u(\mathbf{w}, \mathbf{e})$ such that u is weakly increasing in w_t for every t.

Proof. First part i will be proved. For any allocation rule **a**, period t accounting income for the firm is defined by (5). Substitution of (25) and (19) into (5) yields

$$y_t = \rho_t \left[\delta(x, \theta) - \frac{x}{\sum_{i=1}^{t} \frac{\rho_i}{(1 + r^*)^i}} \right] + \epsilon_t. \qquad (26)$$

Note that the term in brackets is the same for every t. Furthermore, $x^*(\theta)$ maximizes this term. The proof now follows the same steps as the proof of part i of proposition 1.

The proof of part ii parallels the proof of part ii of proposition 1, with the same type of modification as above, so it will not be presented. Q.E.D.

Therefore, there is a unique allocation rule that always induces efficient investment, and it is the unique rule that satisfies two properties. The first property is that it is r^*-complete. The second property is that it allocates costs across periods in proportion to the benefits the asset creates across periods. For the special case in which benefits across periods are constant, the allocation rule is the r^*-annuity allocation rule. For any profile of relative benefits across periods given by $\boldsymbol{\rho}$, the allocation rule is the $(\boldsymbol{\rho}, r^*)$–RMB allocation rule.

This result can be interpreted as being consistent with a version of the "matching principle" from accounting, which states that the correct way to allocate a joint cost across objectives is to allocate the cost in proportion to the benefits it creates across objectives. The basic idea explaining this paper's result is that the effect of matching costs to benefits is to annuitize the problem from the agent's point of view, in the sense that every period creates the same incentive for the agent. In particular, the agent has the incentive to choose the efficient investment level, if he considers any single period's results. Therefore, the manner in which the agent compares cash flows across periods becomes irrelevant to predicting the agent's behavior.

Proposition 4 and corollary 1 show that, for every $r \in [0, \infty)$, there is a unique depreciation rule/interest imputation rate pair that generates the $(\boldsymbol{\rho}, r)$–RMB allocation rule. The interest imputation rate must be set equal to r. The depreciation rule is given by $\boldsymbol{\lambda}(\mathbf{a}^{\boldsymbol{\rho}, r}, r)$. This depreciation rule will be called the $(\boldsymbol{\rho}, r)$–RMB depreciation rule and be denoted by $\mathbf{d}^{\boldsymbol{\rho}, r}$. This result is formally stated as proposition 5.

PROPOSITION 5. There is a unique (**d**, r) pair that generates the ($\boldsymbol{\rho}$, r^*)–RMB allocation rule. It is given by ($\mathbf{d}^{\rho, r^*}$, r^*).

Proof. As above. Q.E.D.

VI. Relationship to the Literature

This paper's results are most closely related to those of two previous papers by Ramakrishnan (1988) and Rogerson (1992). They both consider principal-agent models in which an investment decision must be made at the start of the relationship and the agent has better information than the principal about the productivity of the investment. Both papers assume that the productivity of the investment remains constant across future periods and show that the r^*-annuity allocation rule (where r^* is the principal's discount rate) induces the agent to make an efficient investment decision. Thus one difference between this paper and these two previous papers is that the case of variable productivity across time periods is considered in this paper. The extension of the result to the variable productivity case makes it clear that the result is a version of the matching principle. However, the major difference is that both previous papers make significant special assumptions, so that the generality of the results is not apparent. Ramakrishnan (1988) assumes that the agent is risk-neutral and that the principal restricts himself to using wage contracts in which each period's wage is a linear function of that period's income and the same linear function is used every period. It is also assumed that the stochastic effect of investment on future cash flows is determined by a simple two-point distribution function (i.e., investment will increase cash flows by one of two amounts, a high amount or a low amount). Rogerson (1992) makes similar types of special assumptions. The structure of the model in that paper also differs because Rogerson analyzes a public utility regulation problem, where the principal is the regulator and the agent is the regulated firm. (The incentive effects created by the wage function are replaced by incentive effects due to the existence of regulatory lag.)

Reichelstein (1996) has recently extended the results of this paper to show that they also hold when there is a series of overlapping investment problems. Reichelstein also considers a slightly different formulation of the investment problem. Recall that this paper creates a continuum of possible investment choices for the manager by assuming that the manager chooses a scalar level of investment. Reichelstein assumes that the manager makes a simple yes/no decision regarding whether or not to invest but that, ex ante, there is a continuum of possible investment projects. He requires that the allocation rule induce the efficient choice for all possible projects.

This alternate formulation turns out to generate the same mathematical structure.

A series of papers by Jordan (1990), Anctil (1996), and Jordan, Anctil, and Mukherji (1996) have shown that, in a dynamic model, a firm attempting, each period, to myopically maximize next period's residual income will in the limit converge to the optimal investment path. Although these models are extremely different from the one in this paper, they yield the same general type of conclusion that residual income is a desirable performance measure.

VII. Conclusion

This paper considers a principal-agent model of the relationship between the shareholders and manager of a firm in which there are two incentive problems. Shareholders delegate an investment decision to the manager because he has better information than shareholders to base this decision on. The manager also exerts an unobservable level of effort each period that increases the firm's cash flows. The "problem" with this situation is that the two incentive problems generally interfere with one another. That is, wage contracts designed to deal with the moral hazard problem will generally distort the agent's investment decision.

The main result of this paper is to show that a very large class of contracts exist that dramatically simplify this problem but still allow shareholders to achieve a high level of expected utility. Suppose that, instead of basing the manager's wage contract on completely disaggregated accounting data, the firm calculates period-by-period income for itself by allocating the investment cost to periods that benefit from the investment and then bases the manager's wage contract on the firm's accounting income. The result is that there exists a unique allocation rule such that it is *always* the case that the manager will make the efficient investment decision for *any* income-based wage contract that shareholders choose as long as the wage contract is weakly increasing in income. Thus the investment delegation problem is completely solved in a very robust and simple manner, and shareholders are left with an enormous number of degrees of freedom to attempt to deal with the moral hazard problem.

Therefore, this paper provides a theory of both why income may be used as a performance measure for management and how income should be calculated for this purpose. Income is used as a performance measure to guarantee in a simple robust way that managers will make efficient input decisions. When the input is an investment good and benefits multiple future periods, it is important that the costs be allocated across periods in proportion to the benefits they produce and that the discounted sum of the cost allocations, using the shareholders' cost of capital, be equal to the total investment cost. This essentially "annuitizes" the problem from the manager's perspective and creates an incentive for the manager to choose the efficient investment level, no matter how he values wage payments across periods.

References

Anctil, Regina M. "Capital Budgeting Using Residual Income Maximization." *Rev. Accounting Studies* 1 (March 1996): 9–50.

Antle, Rick, and Smith, Abbie. "An Empirical Investigation of the Relative Performance Evaluation of Corporate Executives." *J. Accounting Res.* 24 (Spring 1986): 1–39.

Bushman, Robert M., and Indjejikian, Raffi J. "Accounting Income, Stock Price, and Managerial Compensation." *J. Accounting and Econ.* 16 (January–April–July 1993): 3–23.

Dechow, Patricia M. "Accounting Earnings and Cash Flows as Measures of Firm Performance: The Role of Accounting Accruals." *J. Accounting and Econ.* 18 (July 1994): 3–42.

Horngren, Charles T., and Foster, George. *Cost Accounting: A Managerial Emphasis.* 6th ed. Englewood Cliffs, N.J.: Prentice-Hall, 1987.

Jensen, Michael C., and Murphy, Kevin J. "Performance Pay and Top-Management Incentives." *J.P.E.* 98 (April 1990): 225–64.

Jordan, J. S. "Accounting Based Divisional Performance Measurement: Incentives for Investment." Manuscript. Minneapolis: Univ. Minnesota, Dept. Econ., 1990.

Jordan, J. S.; Anctil, Regina M.; and Mukherji, Arijit. "Activity-Based Costing for Economic Value Added." Manuscript. Minneapolis: Univ. Minnesota, Dept. Econ. and Carlson School Management, 1996.

Kaplan, Robert S. *Advanced Management Accounting.* Englewood Cliffs, N.J.: Prentice-Hall, 1982.

Kim, Oliver, and Suh, Yoon. "Incentive Efficiency of Compensation Based on Accounting and Market Performance." *J. Accounting and Econ.* 16 (January–April–July 1993): 25–53.

Lambert, Richard A. "The Use of Accounting and Security Price Measures of Performance in Managerial Compensation Contracts: A Discussion." *J. Accounting and Econ.* 16 (January–April–July 1993): 101–23.

Lambert, Richard A., and Larcker, David F. "An Analysis of the Use of Accounting and Market Measures of Performance in Executive Compensation Contracts." *J. Accounting Res.* 25 (suppl., 1987): 85–125.

Melumad, Nahum D., and Reichelstein, Stefan. "Value of Communication in Agencies." *J. Econ. Theory* 47 (April 1989): 334–68.

Paul, Jonathan M. "On the Efficiency of Stock-Based Compensation." *Rev. Financial Studies* 5, no. 3 (1992): 471–502.

Ramakrishnan, R. "Accrual Accounting and Incentives: Depreciation Methods for Investment Centers." Manuscript. New York: Columbia Univ., Grad. School Bus., 1988.

Reichelstein, Stefan. "Investment Decisions and Managerial Performance Evaluation." Manuscript. Berkeley: Univ. California, Haas School Bus., 1996.

Rogerson, William P. "Optimal Depreciation Schedules for Regulated Utilities." *J. Regulatory Econ.* 4 (March 1992): 5–33.

———. "Inter-temporal Cost Allocation and Managerial Investment Incentives: Version 1." Discussion Paper no. 1060. Evanston, Ill.: Northwestern Univ., Center Math. Studies Econ. and Management Sci., 1993.

———. "Inter-temporal Cost Allocation and Managerial Investment Incentives: Version 2." Manuscript. Evanston, Ill.: Northwestern Univ., Dept. Econ., 1996.

Rosen, Sherwin. "Contracts and the Market for Executives." In *Contract Economics,* edited by Lars Werin and Hans Wijkander. Cambridge, Mass.: Blackwell, 1992.

Sheehan, T. "To EVA or Not to EVA: Is That the Question?" *Continental Bank J. Appl. Corporate Finance* 7 (Summer 1994): 85–87.

Sloan, Richard G. "Accounting Earnings and Top Executive Compensation." *J. Accounting and Econ.* 16 (January–April–July 1993): 55–100.

Stern, J., and Stewart, B., moderators. "Stern Stewart EVA Round Table." *Continental Bank J. Appl. Corporate Finance* 7 (Summer 1994): 46–70.

Stewart, B. "EVA: Fact and Fantasy." *Continental Bank J. Appl. Corporate Finance* 7 (Summer 1994): 71–84.

Tully, Shawn. "The Real Key to Creating Wealth." *Fortune* 128 (September 20, 1993).