AN EVALUATION OF THE USEFULNESS OF ALTERNATIVE MEASURES OF PERFORMANCE IN MANAGER'S BONUS CONTRACTS

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ABSTRACT

In designing an executive bonus compensation contract, a compensation committee, usually with help from a professional executive compensation consulting firm, uses measures of short–term accounting performance as proxies for executive cash bonuses [Foulks, 1991]. Two measures commonly used are cash flows (CF) and accrual accounting income (INC). We show, analytically, that an implication of the Feltham, Ohlson framework is that the relationship between CF and INC differs depending on whether cash investment is growing, constant or declining over some time period. Through simulation, we provide evidence of this differential relationship. We also provide evidence through simulation that the relationship between CF and INC differs depending on whether the variance of the shocks is low, medium or high. We argue that executive cash bonuses can be excessive depending on these properties. Finally, we find evidence suggesting that economic income (E) may be a poor measure of earnings for which to base executive cash bonuses.

Keywords: cash flows, earnings, economic income, executive bonuses

I. INTRODUCTION

Typically, firms attempt to link their performance to executive cash bonus payouts using measures of short-term accounting performance (Foulks, 1991). The reasoning is that in order to judge executive performance, it would seem reasonable to use a measure over which the executive has significant control. Using firm share price as the basis for the bonus payout is criticized because of the lack of control executives have over the markets setting of prices. On the other hand, plans based on traditional accounting measures are criticized because executive bonuses have been high in periods of high earnings despite declining share prices (Foulks, 1991).

In theory, it would seem reasonable that the firm would want to base the manager's bonus on the firm's economic income for the period. That is, the portion of discounted expected future earnings that this year's earnings predict. However economic income defined as such is forward looking and based on expectations that may or may not be realized. Both accrual income (net income) and cash flows[1] for the period have properties more closely tied to realization. Cash flows are realized and accrual income is much closer to realized than economic income. Thus they may be better firm summary performance measures. Therefore it seems a mismatch to use economic income as the basis for determining the manager's bonus for this period's performance since economic income is driven by future expectations and not past realizations. Economic income in this sense then seems to be inferior to accrual income and cash flows as a measure of shortterm accounting performance on which to base a manager's bonus.

Our intent is to demonstrate conceptually, analytically, and with simulation that attributes of alternative earnings metrics impact the potential desirability for using the earnings measure in management compensation determination. We intend to also investigate whether it is appropriate and useful to adjust the weights placed upon the more realized or realizable measures (accrual earnings and cash flows) in response to observable attributes.

Consider that one might wish to 'engineer' the best measure of earnings to be used in compensation determination based solely on the attributes of the alternative earnings measures. In essence, we focus solely on the attributes of the 'accounting' measures and do not attempt to engage in trying to match the choice of earnings measure with personal incentives and motives of the managers. It would seem plausible that one would desire an earnings measure that is predictable, that reflects volatility in the true earnings (risk), that captures management's efforts, that has less noise, and that better reflects actual realizations rather than future expectations that may never occur. Given this reasoning, one of the questions we ask in this study follows. Given an earnings process, what (if any) properties of economic income render this measure inferior to cash flows and accrual income as a performance measure on which to base bonuses?

We find through simulation of the Feltham & Ohlson earnings process that economic earnings has a much larger variance and level than cash flows and accrual income across all variations in the parameters of the process and over time. This provides some evidence to support the notion that economic income is an inferior measure on which to base bonuses (compensation). Economic income fluctuates much more and can be much larger than both cash flows and accrual income. A manager therefore has much less inherent control over economic income than the other two measures and bonuses will inherently be much larger if based on economic income, ceteris paribus.

Next we assume that a manager's cash bonus is based on CF and INC as has been documented in prior research. We also assume that the CF and INC are an increasing function of the manager's effort. Thus if a manager puts forth effort level $b > a$ then they can expect $CF_b > CF_a$ and $INC_b > INC_a$. Furthermore there is a range of bonuses $[a_1, a_2], [b_1, b_2]$ the manager can expect to receive given they put forth effort level

a and b respectively. We assume that $a_2 < b_1$. That is, the highest bonus the manager could possibly receive when putting forth effort level a is smaller than the lowest bonus they could possibly receive while putting forth effort level b.[2] The actual bonus the manager receives given they put forth effort level b or a depends on the relative weights placed on CF and INC in the bonus formula and of course the realizations for CF and INC in a given year.

With these assumptions in mind and exploiting the convergence properties[3] of cash flows and accrual income, the second question we ask in this study follows. Are their certain periods and properties of the earnings process for which the sum and variance of cash flows over a given time period is greater (less) than the sum and variance of accrual accounting income? If the answer is yes, then assuming the bonus formula is a linear combination of CF and INC and increasing in both, the relative weights placed on each will determine the total compensation and one would want to place differential weights on CF or INC depending upon potentially observable attributes of the earnings process.

Much prior literature has focused on an 'optimal' incentive scheme. Such exercises use particular objective functions, owner and agent utility functions and search for an optimal solution to reduce information asymmetry, reduce agency costs, and maximize owner wealth. Our analysis is substantially different since it focuses on inherent properties of the accounting system and the attributes of the three earnings measures over time. Accordingly, our inferences are not bounded by assumptions regarding utility functions, objective functions, or levels of information asymmetry. Instead, we focus on the inherent properties of alternate accounting measures of earnings.

It has been documented (e.g. Dechow 1994) that INC generally has less variance than CF (i.e. earnings are smoother than cash flows) implying Figure 1.

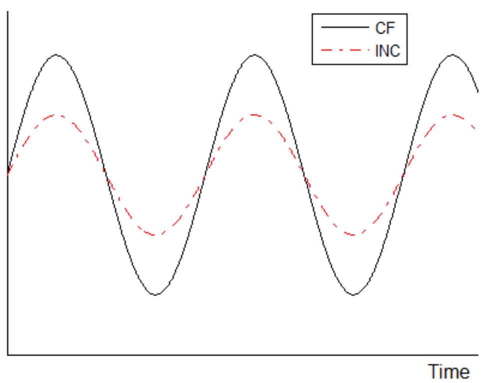

Figure 1: Earnings Smooth Cash Flows

We ask whether there are periods and (or) properties of the earnings process where cash flows are smoother than accrual earnings leading us to observe Figure 2. Using the Feltham, Ohlson framework we show analytically that the relationship between CF and INC, and the convergence between the two, could differ depending on whether cash investment is growing, constant or declining over some time period. We use simulation to determine for which parameter sets (properties) the variance and sum of CF is more likely to be greater than the variance and sum of INC and vice versa. Our results shed light on the fact that there are inherent properties of CF and INC that lead to unnecessarily excessive bonuses if the weights placed on CF and INC are not adjusted to allow for these properties. By "unnecessarily excessive", we mean that if the weights are not adjusted upon observation of these properties the bonus paid will be bigger than what should have been paid had the weights been adjusted to reflect these properties. For example assume in time

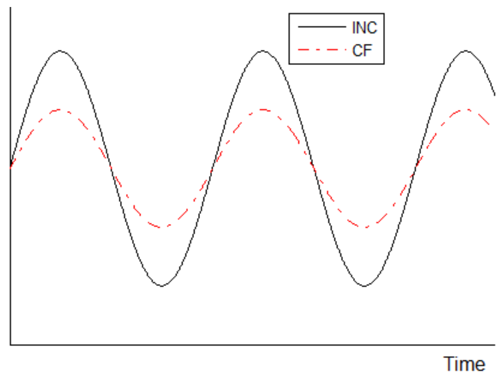

Figure 2: Cash Flows Smooth Earnings

period t a manager has expected bonus range $[a_t, a_t^{'}]$ and the firm is paying them $a_t < a_t^* \leq a_t^{'}$, where $a_t^* = \alpha_t CF_t + \beta_t INC_t$ with $\beta_t > \alpha_t$. Now assume the firm observes certain properties of the earnings process that informs them the probability that $INC_{t+1} > CF_{t+1}$ is high. In period $t+1$ the manager has a new expected bonus range of $[a_{t+1}, a_{t+1}^{'}]$. If the firm does not change the weights to reflect this new expectation from observation of the properties of the earnings process, then the firm will pay the manager the bonus $a_{t+1}^* = \alpha_t CF_{t+1} + \beta_t INC_{t+1}$. Given the new expectation (based on observed properties at time t) the firm should raise the weight on CF and lower the weight on INC such that they pay $a_{t+1}^{**} = \alpha_{t+1} CF_{t+1} + \beta_{t+1} INC_{t+1} < a_{t+1}^*$ with $\beta_{t+1} < \beta_t$ and $\alpha_{t+1} > \alpha_t$. The difference between the bonus paid and the counterfactual bonus is the "excessiveness" we refer to throughout this analysis. The excessiveness is $(\alpha_{t+1} - \alpha_t)CF_{t+1} + (\beta_{t+1} - \beta_t)INC_{t+1} = (\alpha_{t+1}^{**} - \alpha_{t+1}^*)$. This excess obviously depends on the difference in optimal weights chosen for period t and period $t+1$ as well as the realization of period $t+1$ cash flows and earnings.

Note that given a range of bonuses a manager expects to receive, we do not attempt to determine the optimal bonus contract (i.e. the optimal weights to place on INC and CF) which would ensure the firm that they are paying the manager the lower bound of their range. Instead, exploiting the convergence properties between cash flows and accrual earnings, we find properties of the earnings measures where, if they hold, the firm should adjust the weights and pay a bonus lower than they would have had they not observed those properties of the earnings process and not adjusted the weights.

It should be noted that if the manager is fully aware of the bonus formula and thus the weights α_t and β_t then they will know the 'counterfactual' bonus a_{t+1}^* and be able to compare it to the bonus in period $t+1$ or a_{t+1}^{**}. The company cannot really avoid this "post–expectation surprise", however they can ensure that they do not adjust the weights to the point that $a_{t+1}^{**} < a_t^*$. That is, they want to ensure that the manager is paid a bonus in period $t+1$ at least as big as the bonus they are paid in period t ceteris paribus (i.e. effort held constant).

Exploiting the convergence properties of accounting earnings, the compensation paid across alternative earnings (INC, CF or E) measures should converge as the length of the time period increases. Accordingly, we assume that the measure of earnings exhibiting the lower summation and variance over a given length of time is the appropriate baseline ceteris paribus. This is consistent with Holmstrom (1979) and Lambert & Larcker (1987). They suggest that the relative weight given to a particular measure of performance should be increasing in that measure's signal to noise ratio with the respect to the agent's actions. We assume cash flow and accrual income are equally good signals of managerial effort. That is, we assume the mean of each of these signals to be equally sensitive to agent's effort. Therefore the measure which exhibits the least 'noise' should be given greater weight under this assumption. Noise, as defined in Lambert & Larcker, is generally thought of as the variance of the performance measure given the agent's effort. Our analysis holds everything constant (including the agent's effort) except for the 'noise' of the measure. We provide insight regarding the periods and properties which affect this "noise"; properties which, theory predicts, should be taken into consideration when deciding on the relative weights in the agent's bonus contract.

Throughout, we assume the firm has an underlying true earnings process which is a function of the agent's (manager's) actions and the three measures CF, INC and E are approximations to this process; the extent of the approximation being a function of the subjectivity inherent in GAAP. Figure 3 highlights this assumption.

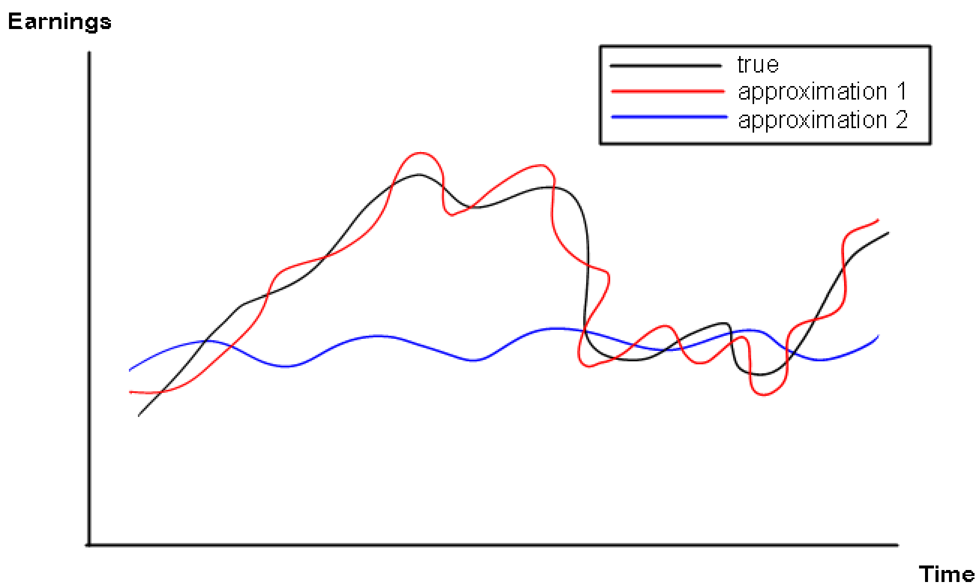

Figure 3: True Earnings and Noisy Measures

The true noise of a particular measure of earnings is, in fact, the deviation from the true process, however we cannot observe the true process and therefore can never hope to capture this deviation with any ex post GAAP–produced accounting measure of earnings. Thus, although the variance of the firm's approximation measure captures the variability of the measure itself, it cannot give us insight into the true noise of the measure. For example approximation 2 above has low variance but is not close to the true process. Also, approximation 1 above has a higher variance but actually is much closer to the true process. In both cases the variance of the measure is not a good proxy for the degree to which the measure diverges from the underlying process. This subtle point has been overlooked in prior literature. Consistent with prior literature we let the variance of the three earnings measures proxy for the "noise" of the measures (the noise that Lambert and Larcker (1987) refer to in the signal–to–noise ratio). Thus approximation 1 above would be considered "noisier" than approximation 2.

A helpful example illustrating how a firm could apply our results to identify the magnitude of the "excessive" bonus paid to a manager over a certain time period is given in Appendix D[4]. The example in Appendix D highlights the contribution we make to the literature. That is, ceteris paribus, a firm would be wise to consider the fundamental properties of their earnings measures when deciding on the bonus formula they will use to compensate their executives. We already know from Lambert and Larcker (1987) that it is in the best interest of the firm to put the greatest weight on the performance measure with the highest signal to noise ratio and accrual income tends to satisfy this property. We show however that there are certain periods and properties of the earnings measures in which cash flows actually have less "noise"[5] and thus, ceteris paribus, satisfy this property and thus it would be in the best interest of the firm to adjust the weights in the bonus formula upon realization of these properties[6]

One final thing to take away from the Appendix D example is that placing weight on economic income in the bonus formula is not desirable. Although economic income would theoretically seem to be the best periodic performance measure of earnings for the firm (since it captures accrual income and cash flows and indirectly measures the future value of the firm), this measure is much more volatile and has a much greater sum than both cash flows and accrual income over variations in the parameters of the earnings process and time periods as demonstrated in our simulations.

II. BACKGROUND LITERATURE

From an agency theory perspective, studying the structure of management's compensation contracts is important as this structure has been shown to affect firm performance and investment decisions. For example, Baxamusa(2012) finds a positive relation between a firm's investments and the dollar value of stock and options owned by the CEO. Thus, the more the CEO is personally invested in the firm the more the firm spends on investments. Given that the CEO is likely more risk–averse than the shareholders on average (since the shareholders can diversify their holdings more) he/she may fail to invest in positive NPV projects that the shareholders would want him/her to take on. This is one commonly mentioned agency conflict in the literature. Thus the results in Baxamusa (2012) directly imply one way the firm can reduce this agency conflict: design a compensation scheme in such a way that the CEO has to be personally invested in the firm. Also, Lee et al. (2008) documents that firm performance increases with the dispersion of management compensation. They use Tobins Q or returns to measure firm performance.

The academic literature can be grouped into three categories of studies investigating the use of accrual accounting income in managerial compensation. The first category documents the explicit use of accrual accounting income in managerial compensation contracts (Lambert and Larcker [1985], Dechow et al. [1994], Ittner et al. [1997], Perry and Zenner's [2001]). These studies typically have small sample sizes of firms which disclose specifics related to the the compensation contracts of their managers.

The second category uses a regression approach and finds evidence of a positive relation between accounting profit and management cash compensation (Lambert and Larcker [1987], Healy et al. [1987], Jensen and Murphy [1990], Natarajan [1999], Banker et al. [2009]). These studies document statistically significant positive associations between accrual accounting income and the management compensation. The reason that those studies do not report the explicit use of accrual accounting income as the performance measure in compensation contracts is because firms do not provide specific enough details regarding how the compensation contracts are formulated.

The third category includes studies which investigate the usage of accrual accounting income as the basis of cash compensation under different circumstances or the usage of adjusted accrual income–based performance measures in the cash compensation contract (Dechow, Huson, and Sloan [1994], Adut et al. [2003], Baber et al. [1996]). These studies show that, in reality, cash compensation plans are set by compensation committees, and it is very likely that these committees could adjust those plans in order to encourage executive non–opportunistic behavior.

Some studies provide evidence that an accrual income-based measure in management compensation has its advantages over a security price-based measure because an accrual income-based measure more fully reflects manager's actions and thus encourages managers to take actions which maximize share-holder wealth. For example, Sloan (1993) presents evidence that earnings are more sensitive to firm-specific changes, and they are less sensitive to market-side movements. Meanwhile, Dechow (1994) empirically tests and finds that accrual income measures are a relatively superior summary of firm performances than realized cash flows. Goel and Thakor (2003) also show that in some circumstances, income smoothing is optimal for shareholders. On the other hand, one of the disadvantages of using accrual income–based measures is that earnings are subject to management's discretionary accounting procedure choice. Healy (1985), Holthausen et al. (1995), Gaver et al. (1995) and Balsam (1998) provide evidence that managers participate in earning management to increase their cash compensation. Another disadvantage of using accrual income–based compensation is the "horizon problem" (Smith and Watts (1982), Dechow et al. [1991]). When managers have a short tenure (i.e. they are close to retirement or about to leave the firm) they have the incentive to maximize their own cash compensation by focusing on short–term performance.

Cash flow has also been recognized as another important accounting performance measure in management cash compensation contracts. According to Holmstrom (1979), a compensation contract should include a signal x as a performance measure if x provides additional information about the action of the manager. Accordingly, cash flow should be used as a performance measure if it reflects manager's input. Evidence that cash flow is used in management's cash compensation exists in the business press. Edwards (1993) explains that cash flows are best connected with a firm's long-term goals and qualify as the best proxy for firm performance and manager performance. Results in Kumar (1993), Clinch et al.(1993), Natarajan (1996), and Nwaeze et al (2006) indicate that cash compensation is associated with cash flows.

In summary, the positive evidence documents that accrual income seems a better/more widely used measure than cash flows of managerial performance on which to base cash bonus compensation and firms tend to employ this measure to the exclusion of cash flow in their contracts. Our study challenges this positive evidence from a normative point of view by demonstrating that, when certain properties and/or periods of a firm's earnings process persist, cash flow tends to satisfy the conditions set forth in Holmstrom (1979) and Lambert and Larcker (1987). Therefore, these properties should be taken into consideration when choosing the relative weights to place on accrual income and cash flows.

Finally, there is a small stream of literature which examines the fundamental properties of earnings and cash flows. For example, Kormendi and Lipe (1994) document the long–horizon mean reverting tendency of annual earnings and test the implication of such mean reversion for security valuation. Specifically, they find that annual earnings are approximately 40 percent less persistence than the traditional random walk model would suggest. Also, Gu et al. (2005) examines the determinants of the variability of accounting accruals. Under the assumption that the variance in accounting accruals provides a measure of the normal level of manager's accounting discretion, it is useful to know the determinants of this variance. Specifically, they show that firm size, leverage, variability of cash flows, operating cycle and growth are all related to the variance of reporting accounting accruals over a large sample period of 1951–2003. They also find significant industry and temporal patterns regarding the relationship between these determinants and the variance of accounting accruals.

The papers in this area look at the empirical properties of earnings and cash flows. Our paper differs in that we simulate the earnings process over variations in the underlying parameters to see how the variance(sum) of earnings and cash flow depends on these parameters. Our paper is more normative in this respect.

III. THEORY

We begin with the framework proposed by Feltham and Ohlson (1996). They consider a firm with stochastic operating cash flows at a sequence of dates $t \in \{0, 1, 2, \ldots\}$. At date t the firm receives cash revenue CR_t and invests cash CI_t, where cash receipts are a function of prior cash investments. They initially assume that current cash receipts and investments constitute the only relevant information for predicting future cash flows. Thus the model is specified below.

$$CR_{t+1} = \gamma CR_t + \kappa CI_t + \epsilon_{CR_{t+1}} \tag{1}$$

$$CI_{t+1} = \omega CI_t + \epsilon_{CI_{t+1}} \tag{2}$$

where $\epsilon_{CR_{t+1}}$ and $\epsilon_{CI_{t+1}}$ are zero–mean stochastic terms (i.e. $E_t[\epsilon] = 0$ for all $t \geq 0$). The model above is fully determined by three parameters γ, κ and ω. $\kappa > 0$ represents the impact of date t cash investments on date $t+1$ cash receipts. $\gamma \in (0, 1)$ is the persistence in cash receipts. $\omega \in [0, R)$ represents the expected growth in cash investments and R represents one plus the risk–free interest rate. Thus $\omega = 1$ implies no expected growth, $\omega > 1$ implies positive expected growth and $\omega \in [0, 1)$ represents an expected decline in cash investment. The rest of the model is as follows.

$$CF_{t+1} = CR_{t+1} - CI_{t+1} \tag{3}$$

$$OA_{t+1} = \delta OA_t + CI_{t+1} \tag{4}$$

$$INC_{t+1} = CR_{t+1} - (1 - \delta) OA_t \tag{5}$$

$$V_{t+1} = \frac{\gamma}{R - \gamma} CR_{t+1} + CI_{t+1} \tag{6}$$

$$E_{t+1} = (V_{t+1} - V_t) + CF_{t+1} \tag{7}$$

CF represents cash flows. OA represents non–cash operating assets with $\delta \in (0, 1)$ the accrual accounting choice parameter which can be thought of as 1 minus a (declining balance) depreciation rate. INC represents accrual accounting income. Note that from Feltham, Ohlson [1996] (p. 214, Corollary 1 and also see proof of Proposition 1) if we have zero net–present value (NPV) investments then $\gamma + \kappa = R$ and risk neutral investors imply (6) above. Then E defines economic income as the periodic difference in value plus current period cash flows.

Prior research tells us that accrual accounting income smoothes the cash flow series and thus has less variance (see Feltham, Ohlson [1996]). Prior research also finds that the variance of accrual accounting income is less than the variance of economic income (Fellingham et al. [1998]) Also, the expectation of accrual accounting income equals the expectation of economic income (Feltham, Ohlson [1994]). However, we are interested in the sums of economic income, cash flows and accrual accounting income over a certain number of periods. As stated before, if one measure has a greater sum, then placing the same weights in period $t+1$ as in period t will result in excess compensation. Deriving the sum of each without the stochastic terms in (3) and (5) gives the following (see Appendices for proofs) ...

$$\sum_{i=1}^{t} E_i \;=\; \frac{R-1}{R-\gamma} CR_1 \sum_{i=2}^{t-1} \gamma^i \;+\; \frac{R-1}{\omega - \gamma} \left(\sum_{i=2}^{t-1} \omega^i - \sum_{i=2}^{t-1} \gamma^i \right) CI_1 + \frac{\gamma R}{R - \gamma} CR_1 + RCI_1 \tag{8}$$

$$\sum_{i=1}^{t} CF_i \;=\; CR_1 \sum_{i=0}^{t-1} \gamma^i \;+\; \frac{1}{\omega - \gamma} CI_1 \left((R - \omega) \sum_{i=1}^{t-1} \omega^i - \kappa \sum_{i=1}^{t-1} \gamma^i - (\omega - \gamma) \right) \tag{9}$$

$$\begin{aligned}\sum_{i=1}^{t} INC_i \;=\; & CR_1\sum_{i=0}^{t-1}\gamma^i \;-(1-\delta)OA_1\left(1+\sum_{i=0}^{t-2}\delta^i\right)\\ & +\frac{\kappa}{\omega-\gamma}CI_1\left(\sum_{i=1}^{t-1}\omega^i-\sum_{i=1}^{t-1}\gamma^i\right)\\ & -\frac{\omega(1-\delta)}{\omega-\delta}CI_1\left(\sum_{i=1}^{t-2}\omega^i-\sum_{i=1}^{t-2}\delta^i\right)\end{aligned} \tag{10}$$

From here calculating which sum is larger for different periods of time is difficult. Looking at the limits of each sum as $t\to\infty$ gives a little more insight (again, see Appendices for proofs)...

$$\lim_{t\to\infty}\sum_{i=1}^{t}E_i=\begin{cases}\frac{\gamma}{1-\gamma}CR_1+\frac{\gamma^2(1-\omega)-\omega^2(1-\gamma)+R(\omega-\gamma)}{(1-\omega)(1-\gamma)(\omega-\gamma)}CI_1 & \omega<1\\ \infty & \omega\geq 1\end{cases} \tag{11}$$

$$\lim_{t\to\infty}\sum_{i=1}^{t}CF_i=\begin{cases}\frac{1}{1-\gamma}CR_1+\frac{1}{\omega-\gamma}\left(\frac{\omega(R-\omega)}{1-\omega}-\frac{\gamma(R-\gamma)}{1-\gamma}-(\omega-\gamma)\right)CI_1 & \omega<1\\ \infty & 1\leq\omega<R\\ \frac{1}{1-\gamma}CF_1 & \omega=R\\ -\infty & \omega>R\end{cases} \tag{12}$$

$$\lim_{t\to\infty}\sum_{i=1}^{t}INC_i=\begin{cases}\frac{1}{1-\gamma}CR_1-(2-\delta)OA_1+\frac{(R-\omega)-\gamma(1-\omega)}{(1-\omega)(1-\gamma)}CI_1 & \omega<1\\ \infty & 1\leq\omega\leq R\\ \infty\ \text{or}\ -\infty\ \text{indeterminate} & \omega>R\end{cases} \tag{13}$$

From above, we see that it is impossible to tell which infinite sum is greater consistently. We can see however that ω seems to be a key parameter since it determines whether the sums are finite, positive or negative infinite. This is because ω is the only parameter in the model which can take on values greater than one (R is greater than one but is never summed over infinity like the other parameters). Even when growth in cash investment is less than one, we cannot rank the infinite sums in order from least to greatest consistently. Recall that this analysis is without the stochastic terms. However the analysis remains the same if we take expectations since we assume that the mean of the stochastic shocks is zero.

Since randomness is inherent, we need some method to see what is happening to these sums (with the random shocks) over variations in the length of the times series (say after 5 or 10 years). Simulation is the natural choice since we can simply generate random numbers for the shocks from a desired distribution, with a specified variance and have the computer loop through equations (1)–(7) for as many periods as we like. With a large enough sample, the series will approach steady state and we can observe the sums over variations in the length of the time series and the parameters determining the model. An empirical study based on this model is difficult because the values for the parameters in equations (1) – (7) are unobservable to us and the process of trying to back out the parameters for each firm would give rise to many construct validity issues. From this initial analysis, we have an idea of which parameter will likely prove key to the time series properties of these sums. Since the sums differ in their limit depending on whether ω is less than or greater than one, it seems the growth in cash investment is the key parameter (at least without stochastic terms). Simulation will also allow us to test what impact the variance of the shocks has on the sums of the different times series.

IV. SIMULATION METHODOLOGY

Matlab was used to simulate the time series equations (1) – (7).[7] We allowed γ and δ to take on values of .2, .5 and .8. Matlab's random number generator was used to assign the shocks which were drawn from a mean–zero normal distribution with either a low, medium or high variance. We ran the simulations without the shocks and found mean cash revenue and cash investment for each parameter set respectively. Then we simply set the variance equal to .5, 1 and 3 standard deviations of mean cash revenue and cash investment for the respective parameter set. Also, ω took on five values (0.9, 1, 1.025, 1.075, 1.1) chosen based on our theoretical analysis earlier.[8] We simulated the equations for 5, 10, 20 and 50 periods. Thus since γ and δ took on three different values, the variances of the shocks took on three values, ω took on five values and we simulated over four different length periods, there were $3 \times 3 \times 3 \times 5 \times 4 = 540$ different parameter sets (i.e. one parameter set would be $\gamma = \delta = .2$, variance = low, $\omega = .9$, 5 periods). Furthermore, we simulated each parameter set 200 times, resulting in $540 \times 200 = 108,000$ simulated firm observations. R was set equal to 1 plus a 5% risk free interest rate throughout. The value of κ was set to satisfy the zero–NPV equilibrium condition in the theoretical development and so $\kappa = R - \gamma$. The initial value for cash investment was arbitrarily set at $CI_0 = 100$ while initial values for all the other variables were set to zero.[9]

V. RESULTS & DISCUSSION

5.1 — Sums of E, INC and CF

Since each parameter set was simulated 200 times, we calculated the mean of the sums of cash flow (CF), accrual income (INC) and economic income (E) over the different time periods.[10] The sums depend greatly on the variance of the shocks in the CI and CR equations. Also, as posited from the analytics, the sums depend on ω —the growth in cash investment. Tables 1 & 2 show how the relationship between the sums changes as the variance of the shocks changes. Note that "CF wins" implies that $mean \sum CF < mean \sum INC$ and "INC wins" means the opposite. In other words, the lower magnitude earnings measure wins.

It should be noted that $mean \sum E$ and the variance of E was largest 95% of the time. This implies that E lost almost always as a sole measure on which to base the bonus. Also, it was never the case where $mean \sum E$ was smallest (for a couple of the parameter sets E came in second in terms of its sum). It is important to note the implications of this evidence. One could contend that some of the recent criticisms regarding bonuses recently awarded by financial institutions may be warranted since financial institution earnings are quite a bit closer to economic earnings than other industries. As a result, these financial institutions are likely basing their manager's bonus on variables that behave much more like E in our analysis than INC or CF. Thus, these results indicate that using mark-to-market accounting (our variable E attempts to capture this) moves the earnings measure closer to economic earnings and may result in bonuses being inappropriately based.

A recent Wall Street Journal article lamented the fact that the big financial institutions (e.g. JP Morgan, Citigroup, Goldman Sachs, Morgan Stanley and Wells Fargo) were on pace to pay their managers a record

$145 billion for 2009 (Grocer, 2009). Grocer finds that executives, traders, investment bankers, money managers and others at 38 top financial companies can expect to earn nearly 18% more than they did in 2008. Their conclusions were based on an examination of securities filings for the first nine months of 2009 and revenue estimates through year–end. We believe our findings shed light on a potential reason why financial industry managers are compensated so much bonus–wise.

One may question why economic income is the least useful performance measure on which to base the bonus. Recall that bonus plans are such that the manager gets the benefit of the upside risk but the manager is usually not subject to the downside risk in other years. In addition, economic income is less conservative regarding realization, and a positive shock in the current year is compounded via its persistence (either expected or actual). Accordingly, upside shocks are magnified and this is manifested in economic income having the largest variance.

Table 1. Prob. CF Wins vs. $Var(\epsilon)$–Sums

$Var(\epsilon)$	$Prob\ CF$ wins	$Prob\ INC$ wins	$Prob\ E$ wins
low	.85	.15	0
med	.60	.40	0
high	.10	.90	0

Table 1 summarizes the differential relationship between the sums across the aggregation of time periods. CF wins across all variances and time periods on average 51.67% of the time $((85\% + 60\% + 10\%)/3)$ while INC wins 48.33% of the time. We see that as the variance of the shocks increases (i.e. the variance of CR and CI increases), CF wins less often. This is consistent with prior knowledge that INC smoothes CF. The INC series has a smaller variance than the CF series and when the variance of the shocks increases, the variance of the CF series increases more than the variance of the INC series. This causes the sum of the CF series to rise faster than the sum of the INC series. Ceteris paribus, this result implies that firms could better link performance to rewards, in terms of their executive bonuses in the current year, by analyzing the variance of their cash revenues and cash investments in prior years. If they both appear to be decreasing and approaching low (as defined in the "Simulation Methodology" section), then the firm should realize that the probability this year that CF will be higher than INC is high and they could shift the weight placed on INC to CF in their bonus formula and pay a lower bonus than they would if they hadn't shifted the weights.[11] Under our assumptions, as long as this bonus is above or equal to the lower bound of the manager's range of expected bonuses, the manager will not decrease his/her effort level the next year. Accordingly, the expended effort level is rewarded by an appropriate bonus.

Table 2 shows the probability that CF wins[12] when the above analysis is broken down by length of time period.

Table 2. Prob. CF Wins vs. $Var(\epsilon)$ by Time Period–Sums

$Var(\epsilon)$	5yr	10yr	20yr	50yr
low	1	1	.8	.6
med	1	.6	.2	.6
high	.1	0	0	.4

From Table 2 we see that when variances are low, the percentage of time CF wins follows a decreasing trend as the length of time period summed over increases. When variances are medium and high, the percentage of time CF wins follows a non-constant trend (first decreasing then increasing) as the length of time summed over increases. The data suggest that it would behoove the firm to place increasingly more weight on INC relative to the weight placed on CF as the time period and variance increase and then to do the opposite when the time period is more than 20 years, although we do not know exactly when the trend reverses after the 20 year time length.

The next two tables show how the relationship between the sums changes as the growth in cash investment (ω) changes. Table 3 shows the probability that CF and INC win respectively over variations in ω across all variations in time period length.

Table 3. Prob. CF Wins vs. ω–Sums

ω	*Prob* CF wins	*Prob* INC wins	*Prob* E wins
$\omega < 1$	.25	.75	0
$\omega = 1$	.42	.58	0
$1 < \omega < R$	.625	.375	0
$\omega > R$	.75	.25	0

From Table 3 it is clear that as ω increases, the percentage of time that CF wins increases from one–fourth to about three–fourths. Taken by itself, Table 3 implies that the weights placed on CF and INC in the bonus formula should depend on ω. The higher ω is, the greater the chance that $mean \sum CF < mean \sum INC$ (i.e. the greater the chance that CF wins). Ceteris paribus, this result implies that firms could better link performance to rewards in terms of their executive bonuses in the current year by analyzing the growth in cash investment in prior years. If the growth in cash investment is increasing then the probability that CF wins over INC this year increases and is high when $\omega > R$. Therefore, if the firm shifts the weights by placing less weight on INC and more on CF, they will pay a bonus less than what they would have paid had they not shifted the weights. This is contrary to what prior literature finds in the sense that executive bonuses (although we know little of the functional form of the bonus formula) tend to correlate much more strongly with accrual income than cash flows across all variations in ω. Frequently, bonus contracts that do include cash flows as a measure, include it only as an incremental measure. For example, the bonus a manager receives is conditioned upon the level of accrual income and the excess cash flows above some target. Therefore, it seems that empirically, firms do not take into account past trends in ω when deciding the appropriate weights.

Table 4 shows the probability that CF wins when the above analysis is broken down by length of time period.

Table 4. Prob. CF Wins vs. ω by Time Period–Sums

ω	5yr	10yr	20yr	50yr
$\omega < 1$	.67	.33	0	0
$\omega = 1$	.67	.67	.33	0
$1 < \omega < R$	.67	.5	.5	.833
$\omega > R$	.67	.67	.33	1

We can see from above that CF wins two–thirds of the time in the short–term (5 year time period) and thus INC only wins one–third of the time across all variations in ω. This implies that in the short run the weight placed on CF vs. INC shouldn't depend on ω. Overall we see that when $\omega \leq 1$ the percentage of time CF wins decreases with the time period length. However, when $\omega \geq 1$ the percentage of time CF wins follows a changing trend (first decreasing then increasing) as the time period length increases.

5.2 — Variances of E, INC and CF

Analyzing the variance of E, INC and CF across all variations in parameters yields similar insights as analyzing the sums. As one would expect, similar results hold since there is a direct relationship between the sum of realizations of a random variable and the variance of that random variable. Table 5 below summarizes the differential relationship between the variances across the aggregation of time periods as the variance of the shocks changes. Note that "CF wins" implies that $mean\ Var(CF) < mean\ Var(INC) < mean\ Var(E)$ and "INC wins" implies that $mean\ Var(INC) < mean\ Var(CF) < mean\ Var(E)$.

Table 5. Prob. CF Wins vs. $Var(\epsilon)$–Variances

$Var(\epsilon)$	$Prob\ CF$ wins	$Prob\ INC$ wins	$Prob\ E$ wins
low	.55	.45	0
med	.10	.90	0
high	.10	.90	0

First, the variance of E was largest 95% of the time.[13] This implies that E lost almost always as a sole measure on which to base the bonus. Also, it was never the case where $mean \sum E$ was smallest (for a couple of the parameter sets E came in second in terms of it's sum). INC wins across all variances and time periods 75% of the time $((45\% + 90\% + 90\%)/3)$ while CF wins 25% of the time $((55\% + 10\% + 10\%)/3)$. We see that as the variance of the shocks increases (i.e. the variance of CR and CI increases), CF wins less often just as when analyzing the differential relationship in the sums.

Table 6 below shows the probability that CF wins when the above analysis is broken down by length of time period.

Table 6. Prob. CF Wins vs. $Var(\epsilon)$
by Time Period–Variances

$Var(\epsilon)$	5yr	10yr	20yr	50yr
low	1	.4	.2	.6
med	.33	0	0	0
high	0	0	0	.4

From above we see that over a short time period, when variances of cash receipts and investments are low, there is a high probability that we will observe $Var(CF) < Var(INC) < Var(E)$. Based on prior research (Lambert & Larcker 1987) it would behoove the firm to consider this when deciding on what weights to apply to INC and CF in the bonus formula since one goal of the firm should be to put greater weight on the proxy with the lowest "noise" ceteris paribus.

Finally, Table 7 shows how the relationship between the variances changes as the growth in cash investment (ω) changes.

Table 7. Prob. CF Wins vs. ω–Variances

ω	$Prob\ CF$ wins	$Prob\ INC$ wins	$Prob\ E$ wins
$\omega < 1$	.17	.83	0
$\omega = 1$	.08	.92	0
$1 < \omega < R$	.25	.75	0
$\omega > R$	.5	.5	0

From Table 7 we can see that CF wins in terms of variance much less often than INC except when growth in cash investment is high (above R). In this case, cash flow and accrual income win with equal probability, implying that both accounting summary performance measures are, more or less, equally volatile. Ceteris paribus the firm would want to shift the weights in the bonus formula such that they were close to equal since the manager's inherent control over the two variables is about equal.

Table 8 shows the probability that CF wins when the Table 7 analysis is broken down by the length of time period.

Table 8. Prob. CF Wins vs. ω by Time Period–Variances

ω	5yr	10yr	20yr	50yr
$\omega < 1$	.33	0	0	.33
$\omega = 1$	.33	0	0	0
$1 < \omega < R$	.33	.33	0	0
$\omega > R$	.33	.17	.17	1

From Table 8 we see that, in the short–term, there is a reasonable chance (33%) that we will observe $Var(CF) < Var(INC) < Var(E)$ across all variations of ω and the firm should also take this into consideration when deciding on the weights to use in the bonus formula.

5.3 — Discussion of Simulation Results

In summary, we first find that both the sum of economic income and the variance are much higher than the sum and variance of accrual accounting income and cash flows over variations in the parameters and time periods of the simulated model. This provides some evidence to support the notion that economic income is an inferior measure on which to base bonuses. Economic income fluctuates much more and is much larger than both cash flows and accrual income. A manager therefore has much less inherent control over economic income than the other two measures and bonuses will inherently be much larger if based on economic income, ceteris paribus.

Next we find that across all variations in the parameters, $mean \sum CF < mean \sum INC$ about as often as $mean \sum INC < mean \sum CF$ (see paragraph below Table 3), but the variance of INC is smaller than the variance of CF 75% of the time. This is likely the reason why prior research finds that accrual income has a stronger correlation with the bonus payout than cash flows. Firms may realize that accrual income has less inherent variance than cash flows and thus view this as a more reliable (i.e. controllable) measure on which to base manager's bonuses. However, over different time period lengths, for certain values of ω and certain shock term variances, we have shown that these overall insights reverse such that the sum of CF and the variance of CF are both less than the sum and variance of INC, respectively. For example if we graph economic income, cash flows and accrual income against time for low variance shock terms and high growth in cash investment (i.e. $\omega > R$) there is a slightly higher probability (see tables) of observing a graph similar to figure 2 than figure 1 with cash flows smoothing accrual income and both smoothing economic income. When variances on the shocks are low and growth in cash investment is high, the probability of the sum and variance of cash flows being less than the sum and variance of accrual income is greater than 0.5. In these potentially observable situations, the firm should shift the weights from accrual income to cash flows and still pay the manager a bonus equal to or bigger than the lower bound of their range while not affecting managerial effort incentives.

The intuition for our results can be understood from equations (2), (3) and (5). Notice that CF and INC both are affected in the same way by revenue, however they are affected differently by investment. It is this differential affect of investment on CF and INC that provides the intuition for our results. The shocks to investment are felt once by CF but are felt more by INC because of the OA term. The OA term is a function of operating assets in prior periods as well as current period investment. Therefore, operating assets are affected by the shocks to cash investment through previous period operating assets as well as shocks to prior cash investment. Since ω is multiplied by the shocks to investment through the time series (see equation (2)), when growth in cash investment is high ($\omega > R$) and variances of the shocks are low, the differential effect of the shocks to investment on CF and INC is magnified such that one would expect, with higher probability, the variance of CF to be smaller than the variance of INC.[14] This implies immediately that the probability the sum of CF is less than the sum of INC should be similar in these situations.

VI. LIMITATIONS

Some important potential limitations follow. First, we use the Feltham & Ohlson model which is a rather simple representation of the firm's cash flow, accrual income and economic income dynamics. Also, only one asset is being depreciated; however, this asset represents all the assets of the firm. To the extent that the model does not capture the firm's true dynamics, inferences obtained from simulation results based on the model are limited. However, simulated data generated from the Feltham & Ohlson model and real firm data over varying length time periods are generally indistinguishable.[15]

Second, our choice of simulation parameter sets is a rather small subset of the simulation space of total possible parameter sets; however, we know of no inherent biases in our choices. We believe our simulation is simple enough to be tractable but complex enough to be a believable representation of reality.

Finally, our analysis assumes that the goal of the firm is to reward the manager's performance at the lowest cost to the firm while ensuring the compensation paid in this period motivates the manager to exert an effort at least as great in the next period. To the extent this assumption is violated in practice, our inferences may not be as useful.

VII. CONCLUSION

In this study, we provide evidence regarding the usefulness of alternative measures of earnings in compensation. Our focus is on the inherent attributes of three different measures of earnings. We attempt to better understand the relationship between cash flows, accrual income and economic income and by doing so provide some insights into the propriety of using these measures for compensation determination. Our results suggest that it is appropriate to adjust the weights placed on these alternative measures of performance based upon known and observable historical patterns. Failure to consider the observable patterns and adjust the weights on the accrual earnings and cash earnings can be detrimental. In addition, our results indicate that economic income may be a poor proxy for performance evaluation since it not only summarizes current period manager performance but also captures expectations which may or may not be ever realized.

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NOTES

1 Economic income, accrual income and cash flows are abbreviated as E, INC and CF respectively throughout the paper.

2 If bonus ranges overlap then the manager cannot expect for certain to receive a higher bonus given he/she puts forth higher effort.

3 The convergence properties are important to our analyses since we can evaluate alternative earnings measures across different numbers of periods via simulation.

4 The interested reader should first read through our results before looking at the example in Appendix D.

5 That is, when certain properties/periods are satisfied, cash flows has a lower variance and sum than accrual income with higher probability.

6 Although we realize that firms have entire compensation committees which likely make adjustments to the relative weights in the bonus contract we are not sure they already make adjustments based on the properties discovered in this study. This is based upon this study offering simulation driven, probabilistic guidance regarding which measure is more volatile and has the lower sum over variations in the properties of the earnings process. That is, it would be almost impossible to predict which properties and over which periods in the earnings process lend cash flows to have lower variance and summation than accrual income with higher probability than the converse without engaging in an exercise such as the one conducted in this study.

7 Appendix E provides a block diagram depicting the simulation we ran in Matlab.

8 Note that the Feltham/Ohlson Model constrains ω between 1 and R but in our analysis we see that the limits of the sums are sensitive to whether ω is bigger or smaller than R so in our simulation we wanted to be sure omega was less than one, between one and R and greater than R. The reason for assigning two values bigger than R to omega was to ensure that we had omega equally bigger than one than it was less than one (.9 and 1.1).

9 We also set the initial values of the variables equal to the steady state they would approach without shocks but with the same results.

10 i.e. for parameter set one ($t = 5$, $\gamma = .2$, $\delta = .2$, $\omega = 0.9$ and medium variance shocks) there were 200 different sums for each of the variables for the five year period and we took the mean of these 200.

11 Of course the firm could lower the weights on both variables as well and accomplish the same goal but at least they have a signal to alert them that the weights may need to change.

12 The probability that INC wins is just $1-$ probability that CF wins.

13 The variance of E was on average 174% higher than the variance of CF and INC across all simulations. Also the sum of E was on average 60% higher than the sum of CF and INC.

14 Note that without specifying the covariance of cash revenue with cash investment and the covariance of cash revenue with operating assets we cannot provide evidence of this intuition analytically.

15 At a conference, one of the authors provided accounting professors with 8 graphs; 4 of which were simulated accrual income and cash flows from the FO model and 4 of which were real firm accrual income and cash flows (with similar parameters as in the simulated FO model) graphed against time. The individuals were asked to identify the real data versus the simulated data. The accounting professors could not systematically distinguish between the simulated versus the real data.

16 When $\omega < 1$ we have a geometric series and we know that $\sum_{i=1}^{t-1}\omega^i = \omega(1+\omega+\cdots+\omega^{t-2}) = \omega\left(\frac{1-\omega^t}{1-\omega} - \omega^{t-1}\right)$ since $1+\omega+\cdots+\omega^{t-1} = \frac{1-\omega^t}{1-\omega}$ by the geometric series formula.

17 That is $Var(\epsilon_{CR}) \leq \mu_{CR} + \frac{1}{2}\sigma_{CR}$ and $Var(\epsilon_{CI}) \leq \mu_{CI} + \frac{1}{2}\sigma_{CI}$.

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APPENDIX A

Here we derive equations (9) and (12). First we find CI_t using equation (2) without the stochastic term as follows ...

$$\begin{aligned}
CI_2 &= \omega CI_1 \\
CI_3 &= \omega CI_2 = \omega(\omega CI_1) = \omega^2 CI_1 \\
&\vdots \\
CI_t &= \omega^{t-1} CI_t
\end{aligned}$$

Then using induction we prove that the above formula holds ...

$$CI_{t+1} = \omega CI_t = \omega(\omega^{t-1} CI_1) = \omega^t CI_1$$

which is of the same form as CI_t above.

Now we find CR_t using equation (1) without the stochastic term and what we found above as follows ...

$$\begin{aligned}
CR_2 &= \gamma CR_1 + \kappa CI_1 \\
CR_3 &= \gamma CR_2 + \kappa CI_2 \\
&= \gamma(\gamma CR_1 + \kappa CI_1) + \kappa\omega CI_1 \\
&= \gamma^2 CR_1 + \kappa CI_1(\gamma + \omega) \\
CR_4 &= \gamma CR_3 + \kappa CI_3 \\
&= \gamma(\gamma^2 CR_1 + \kappa CI_1(\gamma + \omega)) + \kappa\omega^2 CI_1 \\
&= \gamma^3 CR_1 + \kappa CI_1(\gamma^2 + \gamma\omega + \omega^2) \\
CR_5 &= \gamma CR_4 + \kappa CI_4 \\
&= \gamma(\gamma^3 CR_1 + \kappa CI_1(\gamma^2 + \gamma\omega + \omega^2)) + \kappa\omega^3 CI_1 \\
&= \gamma^4 CR_1 + \kappa CI_1(\gamma^3 + \gamma^2\omega + \gamma\omega^2 + \omega^3) \\
&\vdots \\
CR_t &= \gamma^{t-1} CR_1 + \kappa CI_t(\gamma^{t-2} + \gamma^{t-3}\omega + \gamma^{t-4}\omega^2 + \cdots + \gamma\omega^{t-3} + \omega^{t-2}) \qquad \text{(A.1)}
\end{aligned}$$

Another proof by induction similar to the one earlier shows that CR_{t+1} has the same form as CR_t, thus the formula holds. However, we would like to be able to write it in a simpler form. We can in fact simplify the expression that post–multiplies κCI_t in (A.1). Let this expression be represented by A and then calculate $\left(\frac{\omega}{\gamma}A - A\right)$ as follows ...

$$\frac{\omega}{\gamma}A - A = A\left(\frac{\omega}{\gamma} - 1\right)$$

$$= \left(\gamma^{t-3}\omega + \gamma^{t-4}\omega^2 + \cdots + \gamma\omega^{t-3} + \omega^{t-2} + \frac{1}{\gamma}\omega^{t-1}\right) - \left(\gamma^{t-2} + \gamma^{t-3}\omega + \gamma^{t-4}\omega^2 + \cdots + \gamma\omega^{t-3} + \omega^{t-2}\right)$$
$$= \frac{1}{\gamma}\omega^{t-1} - \gamma^{t-2}$$

Now we can solve for A as follows ...

$$A = \frac{\frac{1}{\gamma}\omega^{t-1} - \gamma^{t-2}}{\frac{\omega}{\gamma} - 1} = \frac{\gamma}{\omega - \gamma}\left(\frac{1}{\gamma}\omega^{t-1} - \gamma^{t-2}\right)$$

$$= \frac{\omega^{t-1} - \gamma^{t-1}}{\omega - \gamma}$$

Thus our formula for CR_t becomes the following after substituting A for the expression that post–multiplies κCI_t in (A.1)...

$$CR_t = \gamma^{t-1}CR_1 + \frac{\kappa}{\omega - \gamma}CI_1(\omega^{t-1} - \gamma^{t-1})$$

Now we can find CF_t as follows keeping in mind that $\kappa + \gamma = R$ ...

$$\begin{aligned}
CF_t &= CR_t - CI_t \\
&= \gamma^{t-1}CR_1 + \frac{\kappa}{\omega - \gamma}CI_1(\omega^{t-1} - \gamma^{t-1}) - \omega^{t-1}CI_1 \\
&= \gamma^{t-1}CR_1 + CI_1\left(\frac{\kappa(\omega^{t-1} - \gamma^{t-1})}{\omega - \gamma} - \omega^{t-1}\right) \\
&= \gamma^{t-1}CR_1 + \frac{1}{\omega - \gamma}CI_1(\omega^{t-1}(\kappa - \omega + \gamma) - \kappa\gamma^{t-1}) \\
&= \gamma^{t-1}CR_1 + \frac{1}{\omega - \gamma}CI_1(\omega^{t-1}(R - \omega) - \kappa\gamma^{t-1})
\end{aligned}$$

Now we derive $\sum_{i=1}^{t} CF_i$ using our equation for CF_t and inputting values $t = 1, 2, \ldots, t$ as follows ...

$$\begin{aligned}
\sum_{i=1}^{t} CF_i &= CF_1 + CF_2 + \cdots + CF_t \\
&= (CR_1 - CI_1) + \left(\gamma CR_1 + \frac{1}{\omega - \gamma}CI_1(\omega(R - \omega) - \kappa\gamma)\right) \\
&\quad + \left(\gamma^2 CR_1 + \frac{1}{\omega - \gamma}CI_1(\omega^2(R - \omega) - \kappa\gamma^2)\right) \\
&\quad + \cdots + \left(\gamma^{t-1}CR_1 + \frac{1}{\omega - \gamma}CI_1(\omega^{t-1}(R - \omega) - \kappa\gamma^{t-1})\right) \\
&= \sum_{i=0}^{t-1}\gamma^i \; CR_1 + \frac{1}{\omega - \gamma}CI_1\left((R - \omega)\sum_{i=1}^{t-1}\omega^i - \kappa\sum_{i=1}^{t-1}\gamma^i - (\omega - \gamma)\right)
\end{aligned}$$

which is the same as equation (9) as desired.

Now we can analyze $\lim_{t\to\infty}\sum_{i=1}^{t} CF_i$. First, when $\omega < 1$ we have two Geometric Sums[16]

$$\lim_{t\to\infty}\sum_{i=1}^{t-1}\omega^i = \lim_{t\to\infty}\omega\left(\frac{1-\omega^t}{1-\omega} - \omega^{t-1}\right)^1$$
$$= \lim_{t\to\infty}\omega\left(\frac{1-\omega^{t-1}}{1-\omega}\right) = \frac{\omega}{1-\omega}$$

Similarly $\lim_{t\to\infty}\sum_{i=1}^{t-1}\gamma^i = \frac{\gamma}{1-\gamma}$. Substituting into equation (9) then gives the following ...

$$\lim_{t\to\infty}\sum_{i=1}^{t} CF_i = \frac{1}{1-\gamma}CR_1 + \frac{1}{\omega-\gamma}\left(\frac{\omega(R-\omega)}{1-\omega} - \frac{\gamma(R-\gamma)}{1-\gamma} - (\omega-\gamma)\right)CI_1 \qquad \omega < 1 \tag{A.2}$$

Now when $1 \le \omega \le R$ we know $\lim_{t\to\infty}\sum_{i=1}^{t-1}\omega^i = \infty$ while the other sums remain the same as before since $\gamma \in (0,1)$ thus we have the following ...

$$\lim_{t\to\infty}\sum_{i=1}^{t} CF_i = \infty \qquad 1 \le \omega < R \tag{A.3}$$

Now when $\omega = R$ and using our previous derivations and the fact that $\kappa = R - \gamma$ we have the following ...

$$\begin{aligned}
\lim_{t\to\infty}\sum_{i=1}^{t-1} CF_i &= \frac{1}{1-\gamma}CR_1 + \frac{1}{R-\gamma}CI_1\left(\frac{-\kappa\gamma}{1-\gamma} - (R-\gamma)\right)\\
&= \frac{1}{1-\gamma}CR_1 + \frac{1}{R-\gamma}CI_1\left(\frac{-(R-\gamma)\gamma}{1-\gamma} - (R-\gamma)\right)\\
&= \frac{1}{1-\gamma}CR_1 - CI_1\left(\frac{\gamma}{1-\gamma} + 1\right)\\
&= \frac{1}{1-\gamma}CR_1 - \frac{1-\gamma}{C}I_1\\
&= \frac{1}{1-\gamma}(CR_1 - CI_1)\\
&= \frac{1}{1-\gamma}CF_1 \qquad \omega = R
\end{aligned} \tag{A.4}$$

Finally, when $\omega > R$ the term $(R-\omega)\sum_{i=1}^{t-1}\omega^i$ in (9) approaches $-\infty$ and this term dominates thus we have ...

$$\lim_{t\to\infty}\sum_{i=0}^{t-1} CF_i = -\infty \qquad \omega > R \tag{A.5}$$

Putting (A.2), (A.3), (A.4) and (A.5) together gives (12) as desired.

APPENDIX B

Here we derive equations (10) and (13). First we find OA_t as follows using equations (4) and (2) without the stochastic term ...

$$\begin{aligned}
OA_2 &= \delta OA_1 + CI_2 = \delta OA_1 + \omega CI_1 \\
OA_3 &= \delta OA_2 + CI_3 = \delta^2 OA_1 + \delta\omega CI_1 + \omega^2 CI_1 = \delta^2 OA_1 + \omega CI_1(\delta + \omega) \\
OA_4 &= \delta OA_3 + \omega CI_1(\delta^2 + \delta^2\omega + \delta\omega^2 + \omega^3) \\
&\vdots \\
OA_t &= \delta^{t-1} OA_1 + \omega CI_1(\delta^{t-2} + \delta^{t-3}\omega + \cdots + \delta\omega^{t-3} + \omega^{t-2})
\end{aligned} \tag{B.1}$$

The above formula is correct but we would like to simplify the expression that post multiplies ωCI_1 in (B.1). Let this expression be represented by B and calculate $\left(\frac{\omega}{\delta}B - B\right)$ as follows ...

$$\frac{\omega}{\delta}B - B = B\left(\frac{\omega}{\delta} - 1\right)$$

$$= \left(\delta^{t-3}\omega + \delta^{t-4}\omega^2 + \cdots + \omega^{t-2} + \frac{1}{\delta}\omega^{t-1}\right) - \left(\delta^{t-2} + \delta^{t-3}\omega + \delta^{t-4}\omega^2 + \cdots + \delta\omega^{t-3} + \omega^{t-2}\right)$$
$$= \frac{1}{\delta}\omega^{t-1} - \delta^{t-2}$$

Now we can solve for B as follows ...

$$B = \frac{\frac{1}{\delta}\omega^{t-1} - \delta^{t-2}}{\frac{\omega}{\delta} - 1} = \frac{\delta}{\omega - \delta}\left(\frac{1}{\delta}\omega^{t-1} - \delta^{t-2}\right)$$

$$= \frac{\omega^{t-1} - \delta^{t-1}}{\omega - \delta}$$

Thus our formula for OA_t becomes the following after substituting B for the expression that post–multiplies ωCI_t in (B.1)...

$$OA_t = \delta^{t-1} OA_1 + \frac{\omega}{\omega - \delta} CI_1(\omega^{t-1} - \delta^{t-1})$$

Now we can find INC_t as follows using our formula for OA_t we just derived and our formula for CR_t that we derived in Appendix A ...

$$\begin{aligned}
INC_t &= CR_t - (1-\delta)OA_{t-1} \\
&= \gamma^{t-1} CR_1 - \delta^{t-2}(1-\delta)OA_1 + CI_1\left(\frac{\kappa(\omega^{t-1} - \gamma^{t-1})}{\omega - \gamma} - \frac{\omega(1-\delta)(\omega^{t-2} - \delta^{t-2})}{\omega - \delta}\right)
\end{aligned}$$

Now we derive $\sum_{i=1}^{t} INC_i$ using our equation for INC_t and inputting values $t = 1, 2, \ldots, t$ as follows ...

$$\begin{aligned}
\sum_{i=1}^{t} INC_i &= INC_1 + INC_2 + \cdots + INC_t \\
&= CR_1 - (1-\delta)OA_1 + \gamma CR_1 - (1-\delta)OA_1 + \frac{\kappa}{\omega-\gamma}CI_1(\omega-\gamma) \\
&+ \ \gamma^2 CR_1 - (1-\delta)\delta OA_1 + \frac{\kappa}{\omega-\gamma}CI_1(\omega^2-\gamma^2) - \frac{\omega(1-\delta)}{\omega-\delta}CI_1(\omega-\delta) \\
&+ \vdots \\
&+ \ \gamma^{t-1} CR_1 - (1-\delta)\delta^{t-2} OA_1 + \frac{\kappa}{\omega-\gamma}CI_1(\omega^{t-1}-\gamma^{t-1}) - \frac{\omega(1-\delta)}{\omega-\delta}CI_1(\omega^{t-2}-\delta^{t-2}) \\
&= \sum_{i=0}^{t-1}\gamma^i \ CR_1 - (1-\delta)OA_1\left(1+\sum_{i=0}^{t-2}\delta^i\right) \\
&\qquad + \frac{\kappa}{\omega-\gamma}CI_1\left(\sum_{i=1}^{t-1}\omega^i - \sum_{i=1}^{t-1}\gamma^i\right) \\
&\qquad\qquad - \frac{\omega(1-\delta)}{\omega-\delta}CI_1\left(\sum_{i=1}^{t-2}\omega^i - \sum_{i=1}^{t-2}\delta^i\right)
\end{aligned}$$

which is the same as equation (10) as desired.

Now we can analyze $\lim_{t\to\infty}\sum_{i=1}^{t-1} INC_i$. First, when $\omega < 1$ from equation (10) we have 5 geometric sums which have finite limits that are derived using the geometric sum formula (see footnote 1 in Appendix A). Thus the limit is ...

$$\begin{aligned}
\lim_{t\to\infty}\sum_{i=1}^{t-1} INC_i &= \lim_{t\to\infty} \quad \frac{1-\gamma^t}{1-\gamma}CR_1 - (1-\delta)OA_1\left(1+\left(\frac{1-\delta^t}{1-\delta}-\delta^{t-1}\right)\right) \\
&\quad + \ \frac{\kappa}{\omega-\gamma}CI_1\left(\omega\left(\frac{1-\omega^t}{1-\omega}-\omega^{t-1}\right)-\gamma\left(\frac{1-\gamma^t}{1-\gamma}-\gamma^{t-1}\right)\right) \\
&\quad - \ \frac{\omega(1-\delta)}{\omega-\delta}CI_1\left(\omega\left(\frac{1-\omega^t}{1-\omega}-\omega^{t-1}-\omega^{t-2}\right)-\delta\left(\frac{1-\delta^t}{1-\delta}-\delta^{t-1}-\delta^{t-2}\right)\right) \\
&= \ \frac{1}{1-\gamma} - (2-\delta)OA_1 + \frac{\kappa}{\omega-\gamma}CI_1\left(\frac{\omega-\gamma}{(1-\omega)(1-\gamma)}\right) \\
&\quad - \ \frac{\omega(1-\delta)}{\omega-\delta}CI_1\left(\frac{\omega-\delta}{(1-\omega)(1-\delta)}\right) \\
&= \ \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \frac{\kappa-\omega(1-\gamma)}{(1-\gamma)(1-\omega)}CI_1
\end{aligned}$$

Now substituting in $\kappa = R - \gamma$ and rearranging gives ...

$$= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \frac{(R-\omega)-\gamma(1-\omega)}{(1-\omega)(1-\gamma)}CI_1 \qquad \omega < 1 \tag{B.2}$$

Next, when $\omega = R$ we have only three geometric sums in (10) since γ, $\delta < 1$ but $\omega > 1$. Thus $\sum_{i=1}^{t-1}\omega^i$

approaches ∞ and the other sum involving ω approaches ∞ as well. These terms dominate thus our limit becomes ...

$$
\begin{aligned}
\lim_{t\to\infty}\sum_{i=1}^{t-1} INC_i &= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \frac{R-\gamma}{R-\gamma}CI_1\left(\infty - \frac{\gamma}{1-\gamma}\right) \\
&- \frac{R(1-\delta)}{R-\delta}CI_1\left(\infty - \frac{\delta}{1-\delta}\right) \\
&= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \infty CI_1\left(1 - \frac{R(1-\delta)}{R-\delta}\right) \\
&= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \infty CI_1\left(\frac{\delta(R-1)}{R-\delta}\right) \\
&= \infty \qquad\qquad \omega = R
\end{aligned} \tag{B.3}
$$

Finally, when $\omega \geq 1 \neq R$ we have ...

$$
\begin{aligned}
\lim_{t\to\infty}\sum_{i=1}^{t-1} INC_i &= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \frac{\kappa}{\omega-\gamma}CI_1\left(\infty - \frac{\gamma}{1-\gamma}\right) \\
&- \frac{\omega(1-\delta)}{\omega-\delta}CI_1\left(\infty - \frac{\delta}{1-\delta}\right) \\
&= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \infty CI_1\left(\frac{\kappa}{\omega-\gamma} - \frac{\omega(1-\delta)}{\omega-\delta}\right) \\
&= \frac{1}{1-\gamma}CR_1 - (2-\delta)OA_1 + \infty CI_1\left(\frac{(R-\gamma)(\omega-\delta)-\omega(1-\delta)(\omega-\gamma)}{(\omega-\gamma)(\omega-\delta)}\right) \\
&= \infty \text{ or } -\infty \text{ when } \omega > R
\end{aligned} \tag{B.4}
$$

We see that when $1 \leq \omega < R$ the numerator of the above fraction post–multiplying ∞CI_1 above will be positive with the denominator positive by definition. Thus the limit will be ∞. However if $\omega > R$ the numerator could be positive or negative (i.e. compare the case $\omega = 1.051$, $R = 1.05$, $\gamma = \delta = 0.5$ with the case $\omega = 3$, $R = 1.05$, $\gamma = \delta = 0.5$) while the denominator is positive thus the limit is indeterminate. Putting (B.1), (B.2) and (B.3) together gives (13) as desired.

APPENDIX C

Here we derive equation (8) and (11). First we need an expression for V_t. Using the expressions we found for CI_t and CR_t in Appendix A and equation (6) we have the following ...

$$
\begin{aligned}
V_t &= \frac{\gamma}{R-\gamma}CR_t + CI_t \\
&= \frac{\gamma}{R-\gamma}\left(\gamma^{t-1}CR_1 + \frac{\kappa}{\omega-\gamma}CI_1(\omega^{t-1}-\gamma^{t-1})\right) + \omega^{t-1}CI_1 \\
&= \frac{\gamma^t}{R-\gamma}CR_1 + CI_1\omega^{t-1}\left(\frac{\gamma}{\omega-\gamma}+1\right) - \frac{\gamma^t}{\omega-\gamma}CI_1 \\
&= \frac{\gamma^t}{R-\gamma}CR_1 + CI_1\omega^{t-1}\left(\frac{\omega}{\omega-\gamma}\right) - \frac{\gamma^t}{\omega-\gamma}CI_1 \\
&= \frac{\gamma^t}{R-\gamma}CR_1 + \frac{1}{R-\gamma}CI_1(\omega^t-\gamma^t)
\end{aligned}
$$

Next we simply use equation (7) and substitute in for V and CF which we found above and in Appendix A. After some algebra we have ...

$$E_t = \frac{\gamma^{t-1}(R-1)}{R-\gamma} CR_1 + \frac{(\omega^{t-1} - \gamma^{t-1})(R-1)}{\omega - \gamma} CI_1 \tag{C.1}$$

Note this formula only holds when $t \geq 3$ since our formula for V only holds for $t \geq 2$. We need to find a formula for E_2 (remember E_1 is undefined). We can do this by simply using equation (7), the above derivations of V_t and CF_t, and keeping in mind that $V_1 = 0$. After some algebra this procedure gives E_2 as ...

$$E_2 = V_2 + CF_2 = \frac{\gamma R}{R-\gamma} CR_1 + R * CI_1 \tag{C.2}$$

Now using (C.1) and (C.2) together we calculate the sum of E_t. After algebra we have ...

$$\sum_{i=1}^{t} E_i = E_2 + \sum_{i=3}^{t} E_i = \frac{\gamma R}{R-\gamma} CR_1 + RCI_1 + \frac{R-1}{R-\gamma} CR_1 \sum_{i=2}^{t-1} \gamma^i + \frac{R-1}{\omega-\gamma} \left(\sum_{i=2}^{t-1} \omega^i - \sum_{i=2}^{t-1} \gamma^i \right) CI_1 \tag{C.3}$$

which is the same as equation (8) as desired.

Finally, we calculate the limit of the sum above as $t \to \infty$ similarly as in Appendix A and B. An application of the geometric sum formula when $\omega < 1$ gives $\lim_{t\to\infty} \sum_{i=2}^{t-1} \omega^i = \frac{\omega^2}{1-\omega}$. Applying this fact to (C.3), and remembering that $\gamma < 1$, we have the following after some algebra ...

$$\lim_{t\to\infty} \sum_{i=1}^{t} E_i = \begin{cases} \frac{\gamma}{1-\gamma} CR_1 + \frac{\gamma^2(1-\omega) - \omega^2(1-\gamma) + R(\omega-\gamma)}{(1-\omega)(1-\gamma)(\omega-\gamma)} CI_1 & \omega < 1 \\ \infty & \omega \geq 1 \end{cases}$$

which is the same as equation (11) as desired.

APPENDIX D

An example here is useful in understanding how a firm could utilize these fundamental properties of E, CF and INC in order to minimize compensation ceteris paribus. Suppose a company randomly chooses to look back over the last 5, 10, 20 or 50 years at their cash receipts and investments. Suppose they find, that over the period of time they examine, the average growth in cash investments is $\omega > R$ where R is one plus the risk–free rate of interest (**condition 1**). Then according to the earnings process dynamics that we find in our simulations, the probability that they will have observed $sum(CF) < sum(INC) < sum(E)$ over that time period is 0.75. Likewise, the probability that they will have observed $sum(INC) < sum(CF) < sum(E)$ is 0.25. Thus the probability that $sum(E)$ is less than the sum of either of the other two is zero (see Table 3 of our Results). If we further suppose that, over this period of time, the company finds that both the variance of unexpected cash receipts and investments are less than or equal to one–half standard deviation from mean cash receipts and investments respectively (**condition 2**)[17] then the probability that we observe $sum(CF) < sum(INC) < sum(E)$ jumps to 0.85 while the probability that we observe $sum(INC) < sum(CF) < sum(E)$ falls to 0.15 while E has probability zero of having been less in sum than the other two measures of performance (see Table 1 of our Results). Next, suppose that condition 1 holds. Then the probability that we observe $var(CF) < var(INC) < var(E)$ is 0.5 with $var(E)$ having probability zero of being less than the other two measures of performance (see Table 7 of our Results). Further also suppose that condition 2 holds as well. Then the probability that we observe $var(CF) < var(INC) < var(E)$

jumps to 0.55 while the probability that we observe $var(INC) < var(CF) < var(E)$ falls to 0.45 while again the probability that $var(E)$ is less than either of the other two is zero (see Table 5 of our Results). Now suppose without loss of generality that the time period the company chose to examine was the last 10 years and suppose further that the company has the following CF, INC and E realizations over this time period that are consistent with the probabilities and summarized in Table 9. Thus we observe both $sum(CF) < sum(INC) < sum(E)$ and $var(CF) < var(INC) < var(E)$ over this time period.

Table 9. Example (in $Millions)

	t	CF	INC	E
	1	10	12	20
	2	13	15	28
	3	14	23	31
	4	16	15	38
	5	20	21	30
	6	18	20	43
	7	23	33	21
	8	27	35	33
	9	25	37	62
	10	30	40	58
sum		196	251	364
var		42.93	105.21	202.93

Now further suppose that the company had the following cash bonus formula over the last ten years $B_t = 0.01 * INC_t + 0.005 * CF_t$ which they used in compensating their CEO. That is the company was putting twice as much weight on accrual accounting income than cash flows. The company just assumed that INC was a better measure than CF of managerial performance since the manager inherently has more control over INC and INC tends to be smoother than cash flows and therefore is expected to be less volatile (although this time period happens to be one in which this is not the case). Finally, suppose that the company now knows that their earnings process over the last ten years happened to have the properties discussed before the above table, and they now realize that they could have adjusted the weights to lower their total cash bonus compensation payout over the ten year period. Suppose they feel that the variance and sum of the fundamental performance measure should be taken under equal consideration when deciding the weights to apply to the measures and therefore decide on a new weighting scheme which utilizes the probabilities discussed previously. Specifically the company decides to choose new weights α and β which solve the following system of equations ...

$$\alpha + \beta = 0.015 \tag{a}$$

$$\frac{\alpha}{\alpha + \beta} = \frac{0.15 + 0.45}{(0.15 + 0.45) + (0.85 + 0.55)} = 0.3 \tag{b}$$

where α is the new weight assigned to INC and β is the new weight assigned to CF. Equation (a) requires that the sum of the weights remain the same as the old bonus formula ($0.01+0.005 = 0.015$). This is consistent with a firm first deciding that cash bonus compensation should not exceed a certain percentage of total accrual income and cash flows. Equation (b) utilizes the probabilities discussed earlier. The weight assigned to INC currently is 66% of the total weights $\left(\frac{.01}{.01+.005}\right)$. The firm wants to shift this percentage in favor of the weight assigned to INC based on the probability that they would observe $sum(INC) < sum(CF)$ and $var(INC) < var(CF)$ over the ten–year period assuming the firm's earnings process satisfied condition 1 and condition 2 discussed earlier. That is, they would want the weight assigned to INC to be equal to the ratio of the sum of the probabilities that both $sum(INC) < sum(CF)$ and $var(INC) < var(CF)$ to the sum of all the probabilities. Solving this system of equations gives the solution $\alpha = 0.0045$ and $\beta = 0.0105$. The following table replicates Table 9 and in addition gives the bonus paid under the old weights $(\alpha, \beta) = (0.01, 0.005)$, the bonus paid under the new weights $(\alpha, \beta) = (0.0045, 0.0105)$, the difference in bonus and the percentage difference. The difference in bonus paid between the new weighting scheme and old weighting scheme is our measure of "excessive" compensation.

Table 10. Example Continued (in $Millions)

	t	CF	INC	E	Old Bonus	New Bonus	Difference	% Difference
	1	10	12	20	0.17	0.159	0.011	6.47%
	2	13	15	28	0.215	0.204	0.011	5.12%
	3	14	23	31	0.3	0.2505	0.0495	16.5%
	4	16	15	38	0.23	0.2355	0.0055	-2.39%
	5	20	21	30	0.31	0.3045	0.0055	1.77%
	6	18	20	43	0.29	0.279	0.011	3.79%
	7	23	33	21	0.445	0.39	0.055	12.36%
	8	27	35	33	0.485	0.441	0.044	9.07%
	9	25	37	62	0.495	0.429	0.066	13.33%
	10	30	40	58	0.55	0.495	0.055	10%
sum		196	251	364	3.49	3.1875	0.3135	8.67%
var		42.93	105.21	202.93				

From this example we see that the firm would save around 9% on total cash bonus compensation over the ten–year period had they employed the "new" weights. Applying this savings to the $18.4 billion bonus payout to bank executives that President Obama labeled as "shameful" in 2008 and assuming that 25% of this was cash bonuses we see that a $414 million dollar cash bonus savings would have been realized ($18.4 billion$*0.25 * 0.09$). This however is all under the assumption that each of those companies had earnings processes adhering to conditions 1 and 2 discussed earlier and that their accrual income and cash flow realizations over the prior ten years were similar to those of the example.

The above example highlights the contribution we make to the literature. That is, ceteris paribus, a firm would be wise to consider the underlying fundamental dynamics of their earnings process when deciding on the bonus formula they will use to compensate their executives. We already know from Lambert and Larcker (1987) that it is in the best interest of the firm to put the greatest weight on the performance measure with the highest signal to noise ratio and accrual accounting income tends to satisfy this property. We show however that there are certain periods and properties of the earnings process in which cash flows actually have less noise and thus, ceteris paribus, satisfy this property. According to previous research (see Holmstrom (1979) and Lambert & Larcker (1987)), it would be in the best interest of the firm to adjust the weights in the bonus formula upon realization of these properties.

One final insight from the above example is that placing weight on economic income in the bonus formula is not desirable. Although economic income would theoretically seem to be the best periodic performance measure of earnings for the firm, this measure is much more volatile and has a much greater sum than both cash flows and accrual accounting income over variations in the parameters of the earnings process and time periods as demonstrated in our simulations.

APPENDIX E

Below is a visual depiction of our simulation run in Matlab.

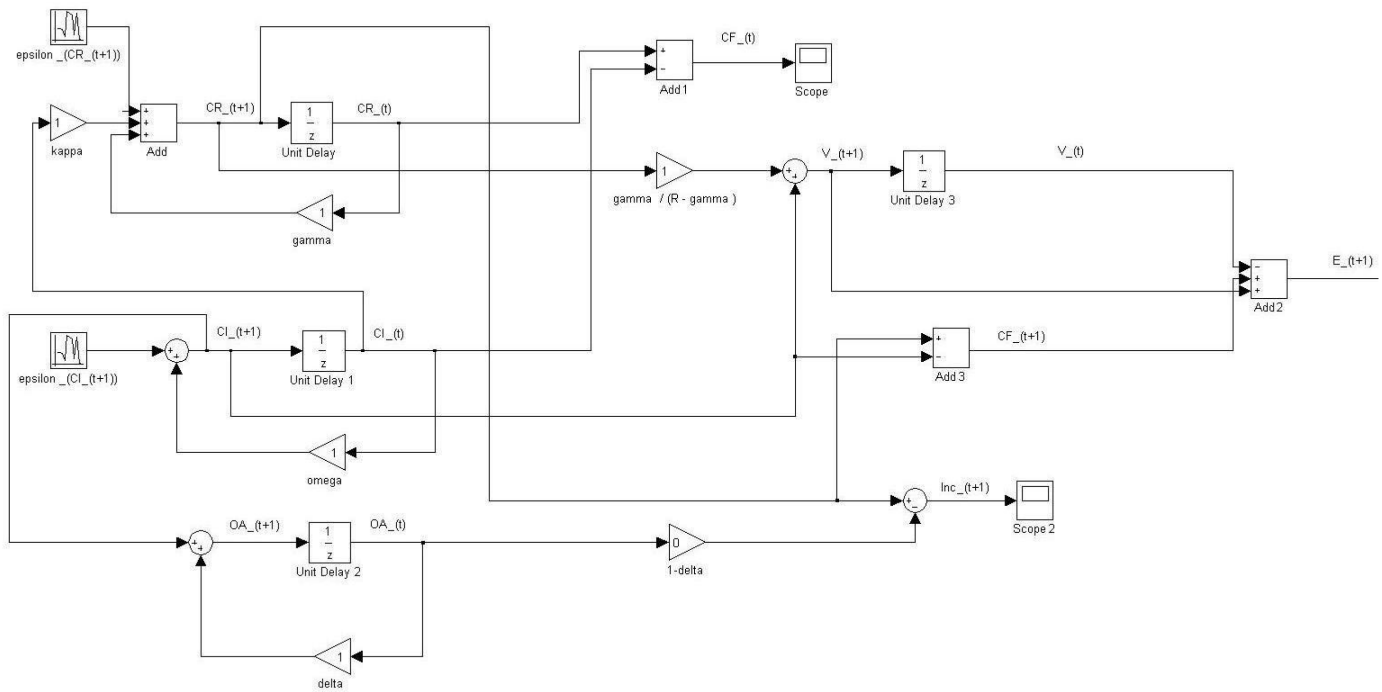

Figure 4: Simulation in Matlab