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SONIA DI GIANNATALE

On the Long-Run Component of the Executive Pay- Firm Performance

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Abstract

In this paper we study some dynamic aspects of the relationship between exective compensation and firm performance. We propose a dynamic agency model with capital accumulation. A numerical exercise is presented to analyze the structure of the optimal contract and capital accumulation pattern under asymmetric information. We find that the principal uses both present and future compensation to provide incentives to the agent at all values of the state variables. However, as capital increases, the agent's future compensation is more used by the principal for incentive provision. We also generate some data in order to produce some pay-performancesensitivties that can be compared to those obtained in the empirical literature on CEO compensation. Our results are consistent with findings of this literature. Our contribution in this article is the finding that past perfomances affect more the future compensation part of executive pay, while contemporaneous performance influence more the salary component of executive pay.

Keywords: Asymmetric Information, Capital Accumulation, Dynamic Contract, Managerial Compensation.

Journal of Economic Literature Classification Numbers: C63, D82, G30, E22

Resumen

En este artículo nos proponemos estudiar algunos aspectos dinámicos de la relación que existe entre la compensación gerencial y el desempeño de las firmas. Con este fin, estudiamos un modelo dinámico de agente-principal con acumulación de capital. Se presentan y discuten los resultados de un ejercicio numérico derivado del mencionado modelo con el objetivo de analizar la estructura del contrato óptimo y del patrón de acumulación de capital. Se encuentra que el principal usa las herramientas de compensación presente y compensación futura para todos los valores de las variables de estado de este modelo. Más aún, cuando el valor del capital aumenta, el principal utiliza mayoritariamente la compensación futura para proveer incentivos al agente. Se generan unos datos inducidos del ejercicio numérico ya mencionado para calcular las sensibilidades de la compensación gerencial con respecto al desempeño de las firmas. Luego, se comparan las mismas con las que se pueden observar en la literatura empírica de compensación gerencial. Nuestros resultados son consistentes con los que se encuentran en dicha literatura. La contribución de nuestro artículo es la observación que los desempeños pasados de la firma afectan más el componente de compensación futura, mientras que los desempeños contemporáneos afectan más el componente de compensación presente del gerente.

Palabras Claves: Información asimétrica, acumulación de capital, contrato dinámico, compensación gerencial.

Clasificación de números consultados : C63, D82, G30, E22

1 Introduction

Our objective is to theoretically study some dynamic aspects of the relationship between the compensation of executives and firm performance. As Boschen *et al.* (1995) point out, the long run component of the aforementioned relationship is relevant because firms and managers generally engage in multiyear relationships and, most importantly, because one crucial component of the compensation packages of executives is future pay, which is tied to past performances of the firm.

With this purpose in mind, we propose a model in which a dynamic agency model is embedded in a neoclassical growth model. Its analysis will allow us to examine the behavior of future and current compensation of the agent under different realizations of a productivity shock, and the principal's investment decisions under asymmetric information within a firm. The intuition of our model is the following: In the starting period, the principal begins with a given level of capital, and makes a promise to the agent regarding a level of expected discounted utility. Then, the agent decides on an effort level, and this is only known to her. By the end of this period, a productivity shock is observes by both the principal and the agent, and this shock is conditional on the agent's effort decision. The principal now pays a salary and promises a level of discounted expected utility from the second period on to the agent, which depend on the observed productivity shock. Afterwards, the principal decides how much capital to accumulate in the next period. In the following period, the initial capital level and the agent's promised discounted expected utility are determined by the principal's decisions in the previous period, and the story is repeated *ad infinitum*.

In our model, the principal employs both future and current compensation to provide incentives to the agent, for all values of the state variables. As capital increases, the principal relies more on the agent's future compensation for incentive provision, while current compensation increases and becomes more stable with respect to the different realizations of the productivity shock. That is, the principal increases the use of long term incentive tools as the firm becomes larger. This result is sensible because long term incentive tools tend to be more costly for the principal to implement.

A branch of the literature that is related to this article includes papers that analyze the effect of asymmetric information in macroeconomic models. Marcet and Marimon (1992) consider contractual elements while studying the dynamics of capital accumulation, and find that asymmetric information does not significantly affect growth. Khan and Ravikumar (2001) study how private information affects growth by analyzing a model with capital accumulation where productivity shocks are privately known by the agents, who engage in long-term relationships with insurance providers. They find that, under private information, growth tends to be lower. In a similar model, Khan and Ravikumar (2002) consider linear technologies that are subject to privately observed productivity shocks. This model has a monotonicity property that permits the reduction of the state space, which makes easier both the analytical and the computational work. Acemoglu and Zilibotti (1999) study the abilities of economies in different stages of development to produce information and to face the consequences of agency costs. They conclusde that as an economy has a higher stock capital, it will be able of generating more information and of achieving better risk sharing. We have a common interest with these authors in analyzing capital accumulation in the presence of asymmetric information, however our analysis is focused at the firm level.

The empirical research on CEO compensation has also motivated some of the questions examined here. Jensen and Murphy (1990) estimated the magnitude of the incentives provided by several compensation mechanisms. Using a sample of US corporations, they concluded that CEO wealth changes \$3.25 for every \$1,000 change in shareholder wealth, and that even though this relationship is positive and significant, it is small given the importance of designing incentive schemes for CEOs in large corporations. On the other hand, Hall and Liebman (1998) measured the responsiveness of CEO pay to firm performance by using a newer data set that included information on CEO stock options and stock ownership. They reported that there is a positive and strong relation between CEO pay and firm performance, and that the major part of this responsiveness is generated by stock options and stock ownership. From their evidence, they concluded that CEOs are not paid like bureaucrats. Furthermore, Aggarwal and Samwick (1999) provided an empirical confirmation of one of the predictions of the principal-agent model: that the responsiveness of CEO pay to firm performance is decreasing with respect to the firm performance's variance. They also reported that estimates of responsiveness that do not take directly into account the firm performance's variance are biased toward zero.

There have been also theoretical responses to the puzzle proposed by Jensen and Murphy (1990). Wang (1997) numerically solved a dynamic agency model and, using model-generated data was able to obtain magnitudes of the responsiveness measures that are consistent with the findings of Jensen and Murphy (1990). His model predicts that the relationship between the shareholder wealth and the CEO future compensation is inverse, which is in contradiction with respect to what is found in the empirical studies mentioned above. Also, his environment does not provide the tools to evaluate heterogeneity of firms in terms of firm size. Clementi and Cooley (2001) numerically solved a dynamic agency model in which the agent's present and past effort choices affect the productivity of the firm. They let the principal borrow physical capital from an outside lender by paying a constant interest rate per period, thus allowing them to include firm size into their analysis without studying the dynamics of capital accumulation. They are able to produce model-generated data that are consistent with some empirical features of CEO compensation, which validates their hypothesis that the history of effort choices of the agent plays a role in the firm's productivity and consequently, in the agent's compensation scheme. We consider that including capital accumulation in the dynamic agency problem allows us to study the effect that the history of the realizations of a productivity shock, that is stochastically related with the agent's effort choice, has on the dynamics of the firm's growth.

Murphy (1999) reported a series of stylized facts regarding CEO compensation using a sample of US corporations. He found that the level of pay depends on the industry, and that it has increased substantially between 1992 and 1996, mainly because of the increase in the grant of stock options in the 1980s and 1990s. According to Murphy (1999), the "best-documented stylized fact regarding CEO pay" is that CEOs receive higher levels of compensation in larger firms. However, the data shows that the relationship between CEO pay and company size has become weaker and that firm sales has lost significance as measure of firm size. The most commonly used measure of the responsiveness of CEO pay to firm performance is the pay-performance sensitivity, which is "the dollar change in the CEO's wealth associated with a dollar change in the wealth of shareholders," as defined by Jensen and Murphy (1990). There are some stylized facts about pay-performance sensitivities that Murphy (1999) reported. First, that the compensation component that primarily drives pay-performance sensitivities is future compensation, measured by stock options and stock ownership. Second, there is heterogeneity in the pay-performance sensitivities across industries. Third, there is an inverse relationship between pay-performance sensitivities and firm size. Boschen *et al.* (1995) explore the long-run response of CEO compensation on the firm performance by analyzing a long time series of executive pay data. They find that the pay-performance relationship has a significant long-run component. However, they do not differentiate which component of CEO pay is more affected by past performances.

This paper is organized in the following way: In the second section, we present our dynamic model. In the third section, we solve a numerical example to study the structure of the optimal contract, and discuss some of our results. In the fourth section, we evaluate two of the stylized facts of CEO compensation reported by Murphy (1999) that are related to dynamic issues of the pay-performance relationship, and, also, try to establish whether our model produces the comparative static prediction that pay-performance sensitivities are decreasing with respect to the firm performance's variance. Lastly, we present some concluding remarks.

2 The Environment

We propose a dynamic agency model with capital accumulation, as in the neoclassical growth model, in order to study the dynamic aspects of the pay-performance relationship. That is, there is a principal and an agent that both maximize their respective discounted expected utilities. Also, there is a single good, which has the role of the consumption good, and can be stored in the capital accumulation process.

Time is discrete and is indexed as $t = 1, 2, ...$ The principal owns the production technology, and the agent is hired to operate it. We assume that the output of the production process is public information, while the agent's effort to use the production technology is his private information. Therefore, there is a trade-off for the principal as a consequence of his the inability of the principal to observe the manager's effort choice in terms of resource allocation to both provide incentives to the manager and to ensure the firm's growth. Let us denote the capital stock at the beginning of period t by k_t, and the manager's choice of effort per unit of capital available at period t by a_t. We assume that $k_t \in [\underline{k}, \overline{k}] \in \Re_+$. We also make the assumption that the manager's effort is bounded and continuous, that is, $a_t \in A$, where $A = [\underline{a}, \overline{a}] \in \Re_+$.

The production function is given by the following expression:

$$y_t = \theta_t f(k_t),$$

where θ_t represents a productivity shock that behaves according to the time invariant distribution function $G(\theta_t | a_t)$. Let us assume that G has a density denoted by g, and that g is twice continuously differentiable with respect to a. We also assume that for a fixed a, the distribution is *i.i.d.* from one period to the next, and that the support of the productivity shock distribution is compact.

At time t, the principal pays the agent a compensation of c_t, that should be non-negative. Let us assume that the principal does not have access to the credit markets. Therefore, there will be a resource constraint that needs to be satisfied:

$$c_t + i_t \leq \theta_t f(k_t),$$

where, i_t denotes the amount of investment resources in period t, and $i_t \geq 0$. Also, the stock of capital of the next period is generated according to the following expression:

$$k_{t+1} = (1-\delta)k_t + i_t,$$

where, $\delta \in (0,1)$ denotes the depreciation rate.

Thus, we can write the resource constraint in this reduced form:

$$c_t \leq \theta_t f(k_t) + (1-\delta)k_t - k_{t+1}.$$

Let us assume that the principal is risk-neutral, and that the agent is risk-averse. The agent's preferences are given by the utility function $u(c_t, m(a_t)l(k_t))$, which we assume to be bounded, strictly increasing and strictly concave in c_t, and strictly decreasing in $m(a_t)l(k_t)$. The argument $m(a_t)l(k_t)$ is included in the agent's utility function to model the idea that as the amount of capital stock increases, the agent's managerial effort will become more complex. We assume that $m(a_t)$ is an increasing and convex mapping with respect to a_t, as is commonly assumed in standard agency models. The only restriction we impose on the function $l(k_t)$ is that it should be increasing with respect to k_t. We also assume that $u(c_t, m(a_t)l(k_t))$ is additively separable in the arguments c_t and $m(a_t)l(k_t)$.

To introduce dynamic elements in this environment, the principal and the agent employ history-dependent pure strategies, as in Wang (1997). The principal's problem is to construct a sequence of effort recommendations $\left\{a_t(h^{t-1})\right\}_{t=1}^{\infty}$, and a sequence of compensation schemes for the agent $\left\{c_t(h^t)\right\}_{t=1}^{\infty}$, where $h^t = \{y_1, y_2, ..., y_t\}$, in order to maximize the principal's lifetime discounted expected utility subject to the incentive compatibility constraint and the participation constraint, which promises an expected discounted utility of w_0 to the agent. Let σ denote a contract, where $\sigma = \{a_t(h^{t-1}), c_t(h^t)\}_{t=1}^{\infty}$. Also, the principal has to make a decision on the sequence of future capital levels $\left\{k_{t+1}(h^t)\right\}_{t=1}^{\infty}$. Notice that the lifetime discounted expected wealth of the principal is affected by the process of capital accumulation, that depends on the level of activity given by the realization of the random variable θ_t, which, in turn, is conditional on the sequence of effort decisions made by the agent. Thus, the principal's strategy consists of the sequence $\{c_t(h^t), k_{t+1}(h^t)\}_{t=1}^{\infty}$, and the agent's strategy consists of the sequence $\{a_t(h^{t-1})\}_{t=1}^{\infty}$.

The continuation profile of a contract σ from date $t+1$ on, given h_t, is denoted as $\sigma|h_t$. Conditional on the agent following the action recommendation given by $\sigma|h_t$, then the continuation value for the expected discounted utility of the agent is denoted by $w(\sigma|h_t)$, and that of the principal is denoted by $v(\sigma|h_t)$.

A contract $\sigma = \{a_t(h^{t-1}), c_t(h^t)\}_{t=1}^{\infty}$is *feasible* if the effort choice of the agent belongs to A and the reduced resource constraint is satisfied in every period, given the history of outputs:

$$a_t(h^{t-1}) \in A, \forall t \geq 1, \forall h^{t-1}, \tag{1}$$

$$0 \leq c_t(h^t) \leq \theta_t f(k_t) + (1-\delta)k_t - k_{t+1}, \forall t \geq 1, \forall h^t. \tag{2}$$

A contract $\sigma = \{a_t(h^{t-1}), c_t(h^t)\}_{t=1}^{\infty}$is *incentive compatible* if:

$$a_t(h^{t-1}) \in \arg\max_{a} \int_{\theta} \left\{ u(c_t(h^t), m(a)l(k_t)) + \beta w(\sigma|h^t) \right\} g(\theta_t|a)d\theta, \forall t \geq 1, \forall h^t, \tag{3}$$

where, $\beta \in (0,1)$ denotes the discount factor of both the principal and the agent. Since in this environment, $a_t(h^{t-1})$ is a continuous variable, we use the first-order approach to incentive compatibility, which is not universally valid. To ensure the validity of this approach, we assume that the Monotone Likelihood Ratio Property and the Convexity of the Conditional Distribution Condition hold, following Rogerson (1985) and Spear and Srivastava (1987). This constraint ensures that the agent will not deviate from the principal's effort recommendation plan in any future date, from period $t+1$ on.

Let Ω be the set of capital levels and expected discounted utilities of the agent that can be generated by a feasible, and incentive compatible contract:

$$\Omega \equiv \left\{ (k,w) \in \Delta \mid \exists \sigma \ s.t. 1,\ 2,\ 3, \text{ and, } w(\sigma|h^0) = w \right\},$$

where $\Delta \in \Re^2$ is the space in which (k,w) is allowed to take values. Assume Δ is nonempty and compact, and that it is endowed with a structure such that Ω is nonempty as well. Note that the agent is promised a level of expected discounted utility of w. The promise-keeping constraint is expressed as an equality, which is a valid representation, given the assumption of the separability of the agent's utility function in c and $h(a)l(k)$ (see Grossman and Hart (1983).)

For every (k,w), the principal's problem is:

$$\max_{\sigma} v(\sigma|h^0) \ s.t. 1,\ 2,\ 3, \text{ and, } w(\sigma|h^0) = w.$$

The solution of the above problem would be the optimal contract that ensures a lifetime discounted expected utility of w. We assume that both parties are committed to the contract. For every $(k,w) \in \Omega$, we define the following set:

$$\Phi(k,w) = \left\{ v(\sigma|h^0) \mid 1,\ 2,\ 3, \text{ and, } w(\sigma|h^0) = w \right\},$$

where, Φ is the set of feasible and incentive compatible expected discounted utilities of the principal given (k,w). We prove the existence of such a contract σ in Di Giannatale (2003). In that paper, we also prove that this problem admits a valid Bellman equation representation, given by the following optimization problem:

$$T(v)(k,w) = \max \int_{\theta} \left\{ \theta f(k) - c - k' + (1-\delta)k + \beta v(k',w') \right\} g(\theta|a)d\theta$$

$$s.t. \int_{\theta} \left\{ u(c, m(a)l(k)) + \beta w' \right\} g(\theta|a)d\theta = w \tag{4}$$

$$a \in \arg\max_{a} \int_{\theta} \left\{ u(c, m(a)l(k)) + \beta w' \right\} g(\theta|a) d\theta \tag{5}$$

$$0 \leqslant c \leqslant \theta f(k) - k' + (1-\delta)k \tag{6}$$

$$a \in A \tag{7}$$

$$(k', w') \in \Omega \tag{8}$$

where the decision variables in the optimization process are the following: $a = a(k,w)$, $c = c(\theta,k,w)$, $k' = k(\theta,k,w)$, and $w' = w(\theta,k,w)$. Also, the operator T that maps from the space of bounded and continuous functions $v : \Omega \rightarrow \Re$ into itself, with the sup norm. The solution of this problem is Markovian stationary, and perfect in the sense that no deviation from the agent is expected in any period. Given that the just mentioned decision variables are expressed in stationary terms, then the history of the realizations of the output distribution is being summarized by the state variables (k,w). In Di Giannatale (2003), we demonstrate that $v^*(k,w)$ is a fixed point of T.

Given that Ω is a convex subset of $\Re^2$, that Φ is non-empty, compact-valued and continuous, that the return function is bounded and continuous, and that $\beta \in (0,1)$, then we have that the operator T has a fixed point with the standard properties. This means that the principal's problem has a solution, that can be obtained by a value function iteration process.

To perform the value function iteration process, we need first to find the set Ω. with this purpose we use the approach proposed by Abreu, Pierce and Stacchetti (1990). In Di Giannatale (2003) we demonstrate that Ω is self-generating, and this will allow us to device an algorithm to compute Ω. This algorithm is also provided in the aforementioned article.

In this section, we have proposed a dynamic agency model with capital accumulation, demonstrated that a solution exists to this model and that it has a valid Bellman equation representation.

3 A Numerical Exercise

To study the characteristics of a solution of the previous model and to perform a comparative static analysis, we solve a numerical example. First, we specialize the model. The preferences of the agent are assumed to be represented by the utility function $u(c, h(a)l(k)) = \sqrt{c} - ak$. Given our assumption of a continuum of effort levels, and that $A = [0, \overline{a}]$, where $\overline{a} \in \Re_+$; we need to set a numerical value for a high enough such that it will not perturb the numerical solution We set $\overline{a} = 20.0$, after performing some initial numerical exercises. We assume that the technology shock can take two values, $\{\theta_1, \theta_2\} = \{0.5\ ,\ 2.0\}$, with probabilities $\exp(-a)$ and $1-\exp(-a)$ respectively. The production function is $f(k) = k^{\varepsilon}$, where $\varepsilon \in (0,1)$. For this particular example, we assume that $\varepsilon = 0.36$ and that $\beta = 0.9633$. We also assume that $\delta = 0.1$. We must clarify that this is just a numerical experiment and that we do not intend to calibrate this model.

We construct a grid with $N1$ equidistant points over the continuous and compact interval $[k_{\min}, k_{\max}]$, in which the state variable k can take values. We also build a grid with $N2$ equidistant points over the continuous and compact interval $[w_{\min}, w_{\max}(k = k_{\max})]$, in which the state variable w is allowed to take values. We set $N1 = 10$, and $N2 = 100$.

Our set of constraints becomes:

$$a \in A \tag{9}$$

$$0 \leq c_i \leq \theta_i k^{\varepsilon} \ - k_i' + (1-\delta)k, \ i = 1, 2 \tag{10}$$

$$\arg\max_a \ [\sqrt{c_1} - ak + \beta w_1'] \exp(-a) + [\sqrt{c_2} - ak + \beta w_2'](1 - \exp(-a)) \tag{11}$$

$$[\sqrt{c_1} - ak + \beta w_1'] \exp(-a) + [\sqrt{c_2} - ak + \beta w_2'](1 - \exp(-a)) = w. \tag{12}$$

3.1 Some Results

We used the parametric approach to value function iteration to obtain the solution of the above specialization of our model. Our computational strategy is described in Di Giannatale (2003). We will now show some of our results and discuss our findings.

The value function that we obtained is a smooth surface which depends on both the current level of capital and the lifetime expected utility of the agent. In Figure 1, we present two-dimensional version of the value function, in wich it depends only on the lifetime expected utility of the agent and keeping capital constant at several levels, specified in the graph, using a continuous line. In the same figure, we also show the value function that resulted from the solution of the standard dynamic agency model without capital accumulation (benchmark model), using a dashed line. We have selected this model as the benchmark model since we aim to emphasize the novel aspects that capital accumulation introduces in this context. To compute the benchmark model we used a fixed level of capital and the realizations of the productivity shock marked the difference between the high and low production level. We repeated the procedure with several capital levels in order to make comparisons with the results of the model with capital accumulation.

The value function is decreasing and concave with respect to the lifetime expected utility of the agent in both cases (except for the very low values of the lifetime expected utility of the agent where it is increasing), which is consistent with the predictions of the standard dynamic principal-agent model. In part (a) of this figure, where the fixed capital level is $K = 0.09$, we observe that the value function of our model dominates the value function of the benchmark model. In parts (b), (c), and (d), where the capital is fixed at higher values, we have that the value function of the benchmark model dominates the value function of our model up to a certain level of the lifetime expected utility of the agent, which decreases with the level of capital, after which there is a flip in the dominance pattern.

In Figure 2, we show the value function of our model depending only on the current level of capital, keeping constant the lifetime expected utility of the agent. We consider several levels of the lifetime expected utility of the agent, specified in the graph. We observe that the value function is increasing and concave with respect to the today's level of capital, a result which is typical in the neoclassical growth model with a decreasing returns to scale technology. We confirm that the value function decreases with respect to the level of the agent's lifetime expected utility.

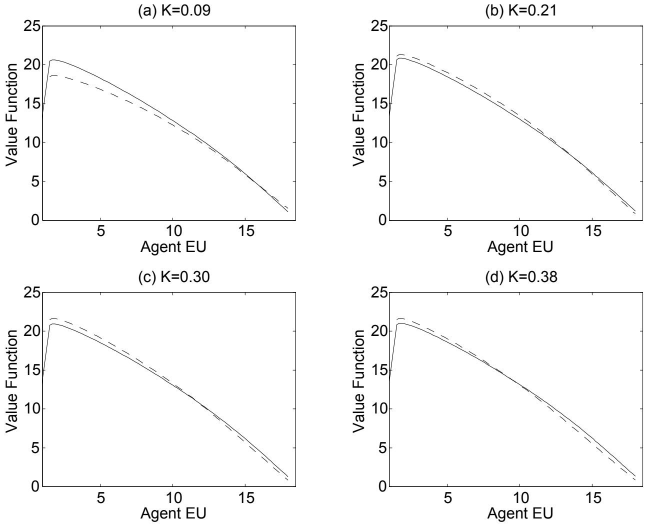

Figure 1: 2-D Value Function: With Capital [-] and Without Capital [- -]

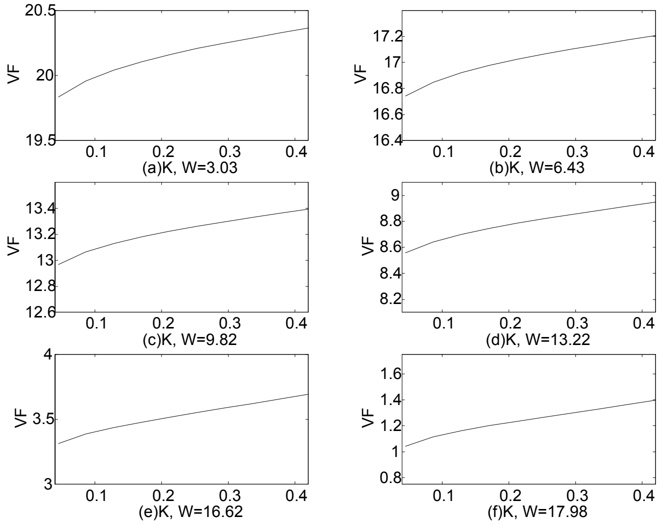

Figure 2: Another 2-D Value Function

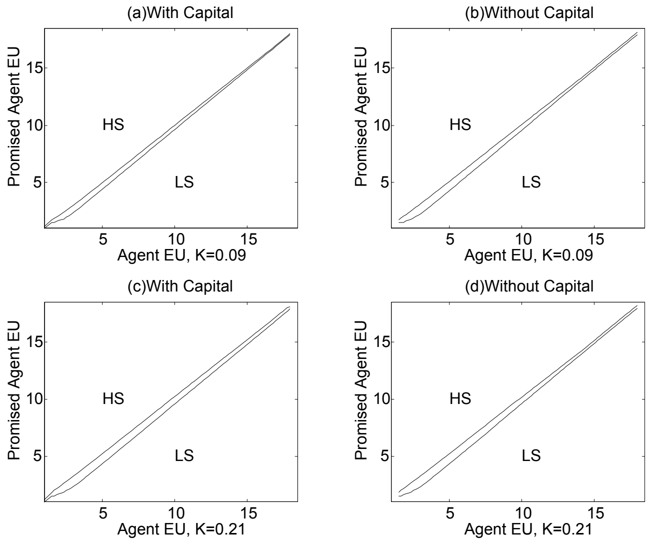

Figure 3: 2-D View of the Laws of Motion of the Agent's Discounted Expected Utility

We will now discuss how the incentive tools work in this model. In Figure 3(a) we show the policy rules of the agent's promised discounted expected utility, keeping the level of current capital constant ($k = 0.09$). As expected, the agent will achieve a higher level of promised discounted expected utility in the event of the high productivity shock. Abstracting from the lowest values of the agent's current lifetime utility, observe that as the current lifetime expected utility of the agent increases, the separation of those policies rules decreases. This means that as the current lifetime expected utility of the agent increases, this incentive tool loses effectiveness. This is in line with the concavity of the value function with respect to the lifetime expected utility of the agent; which implies that as the latter increases, it becomes more costly to the principal, in terms of expected utility, to compensate the agent using future discounted expected utility. In Figure 3(b), we depict the same laws of motion corresponding to the benchmark model. Note that for this level of capital, ($k = 0.09$), the spread is higher in the benchmark model. In parts (c) and (d) of the same figure, we plot again the mentioned law of motions for each model but for a different capital level ($k = 0.21$). Furthermore, we present the last observation in a summarized way in Figure 4, which depicts the behavior of the spread of high and low shock policy rules of the agent's promised discounted expected utility for several capital levels ($k = 0.09$, $k = .21$, $k = 0.30$, and $k = 0.38$). The higher the curve, the higher the associated capital level is. Thus, from the graphs, we could say that the principal relies more on this incentive tool for incentive provision as the firm's physical capital grows.

To continue with the description of the incentive tools of this model, in Figures 5(a) and 6(a) we show the current compensation of our model's agent for the high and low productivity shock respectively, keeping constant the capital level ($k = 0.09$ and $k = 0.21$, respectively). Current compensation is non-decreasing with respect to the current level of the agent's lifetime expected

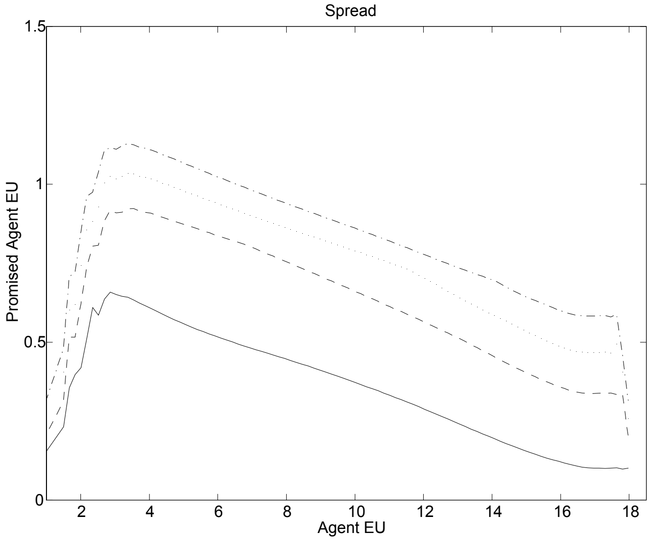

Figure 4: Spread of the Agent's Expected Utility

utility. Note that, as expected, the current compensation of the agent is higher when, relative to when the low shock is observed, the high productivity shock is realized. Also, the separation between those two schedules becomes larger as the level of the lifetime expected utility of the agent increases. This is compatible with the result observed for the laws of motion of the promised discounted future utility of the agent. That is, as the current level of the lifetime expected utility of the agent becomes larger, the incentive tool that becomes more effective (and less costly to the principal) is the current compensation. However, it must be said that both incentive tools are operating at all levels of the current lifetime expected utility of the agent. In Figures 5(b) and 6(b), we show the optimal current compensation schedules of the agent that result from numerically solving the benchmark model. We observe that the pattern of behavior is similar to what we can see in our model, however the separation between the high and low shock optimal current compensation schedules is lower in the standard dynamic agency model for the lower capital level. This can be confirmed by looking at Figure 5(c) and Figure 5(d), which show the agent's optimal current compensation paths of our model (in continuous line) and the benchmark model (in dashed line) for the high and low shocks respectively. On the other hand, we can note that as the capital level increases, the difference between current compensation for the low and high shocks diminishes for the case of our model. That is, our model passes from having a bigger difference between the current compensation schedules for the low and high shocks for the lowest capital level considered, to having the lower difference between those schedules for the highest capital level considered. Therefore, we can say that as capital increases, the principal tends to rely more on the promised discounted expected utility of the agent as an incentive tool.

It is noticeable that for very high values of the state variable w as the capital level increases, the pattern of the compensation of the agent in the case of the realization of the high productivity

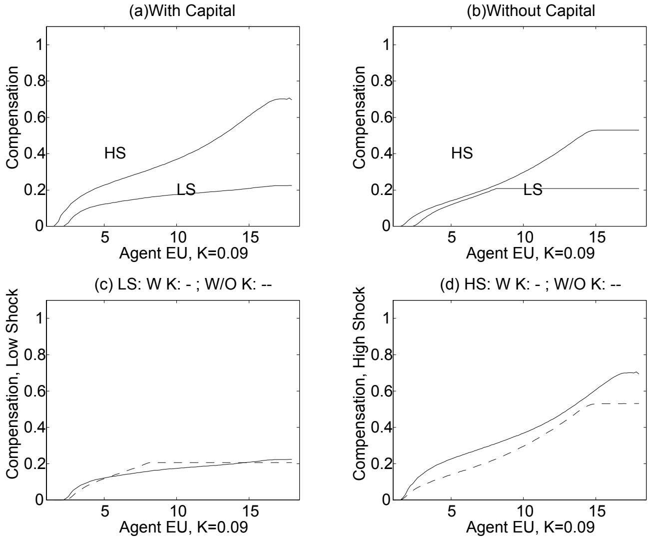

Figure 5: 2-D View of the Optimal Compensation of the Agent

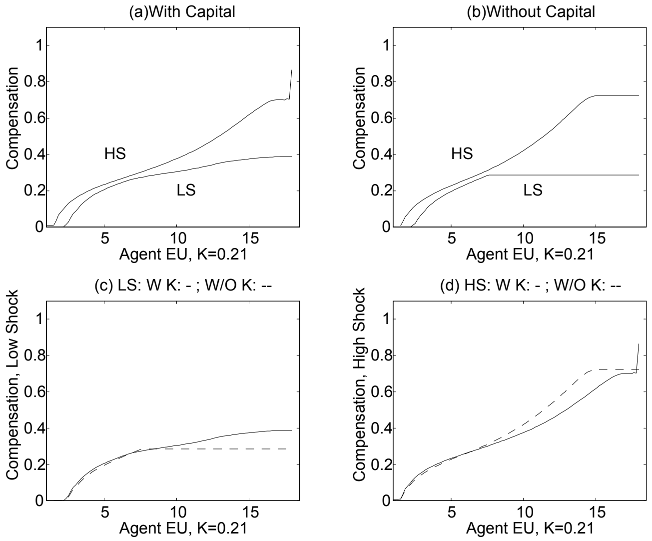

Figure 6: 2-D View of Optimal Compensation of the Agent (Continuation)

shock, shows non-monotonicities for the higher capital values plotted. These results might be due to problems of the computational program in dealing with the upper boundaries of the agent's expected utility policy rules. We performed additional numerical exercises to see whether we could improve these results. First, we used a denser grid for the higher values of the state variable w, and we obtained similar results to those showed above. We also performed another experiment in which we doubled the number of grid points for the state variable w with respect to the original number of grid points we considered for this variable. That is, originally we considered 100 grid points for w, and for this experiment we considered 200 of evenly spaced grid points for w, with the result that the non-monotonicities in the schedule of agent's compensation for the high shock realization for the highest values of w could still be observed[1].

More results of this numerical exercise can be seen in Di Giannatale (2003).

Summarizing our analysis, we say, first, that when the level of capital increases, the principal uses the promised discounted expected utility of the agent as the dominant incentive tool. Also, the principal pays higher and closer salaries to the agent when both the high and low shocks are observed. That is, as capital increases, future compensation becomes the dominant tool for achieving risk sharing. However, future compensation becomes more costly to the principal as the lifetime expected utility of the agent increases.

4 Application of the Model to Executive Compensation Issues

In this section we intend to evaluate, in the context of our model, some issues related to CEO compensation that have been discussed in the literature. In the first place, we evaluate two stylized facts regarding CEO compensation reported by Murphy (1999): First, the responsiveness of CEO pay to firm performance, measured by pay-performance sensitivities, is mainly determined by stock options and stock ownership. While evaluating this empirical fact, we also discuss the dynamic aspects of the pay-performance relationship. Secondly, pay-performance sensitivities are lower in larger firms. Finally, we would like to establish whether our model produces the same comparative static prediction as the static principal-agent model, that is, that pay-performance sensitivities are decreasing with respect to the firm performance's variance.

4.1 Are pay-performance sensitivities determined mainly by future pay?

The revision of our model's ability to produce predictions that are consistent with this stylized fact arises the need of generating data from the numerical solution of our model, described in the previous section. In the simulation we performed to generate the data, we considered an environment that comprised 400 agents or CEOs and 15 periods. Also, we selected combinations of ten (10) equidistant levels of initial capital (selected from the range of possible values of capital), and ten (10) equidistant levels of initial lifetime expected utility of the agent (also, selected from the range of possible values of the lifetime expected utility of the agent). That is, for each of those

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[1] For more details of these exercises, see Di Giannatale (2001).

100 pairs of current capital and current lifetime expected utility of the agent, we produced pertinent time series of 15 periods of length for 400 CEOs.

We will estimate the sensitivity of future compensation of the agent to the performance of the firm using the following regression equation:

$$\Delta w_t = \alpha^w + \beta_1^w \Delta V_t + \beta_2^w \Delta V_{t-1}$$

where, Δw_t is the change in the agent's promised discounted expected utility during the current period, ΔV_t is the change in the expected wealth of the agent during the current period, and ΔV_{t-1} is the change in the expected wealth of the agent during the immediate previous period. It should be pointed out that our measure of future compensation is given in utility terms since it is not possible to convert these expected utility in monetary terms.

Notice that the above equation implies that we are assuming that time trends and pay-performance relationships are constant across agents. This means that the estimation was done by pooling all the model-generated data. The reason for doing this is just to produce estimates of similar nature to those reported in related articles. We have also selected two lags in the variation of the performance of the firm (measured as changes in the value function) in order to capture important features of our model, as we will see in the following paragraphs.

The estimated regression equation is the following:

$$\Delta w_t = 0.05448 + 0.0021 \Delta V_t + 0.03349 \Delta V_{t-1}$$

The t-statistic of α^w is 109.09, that of β_1^w is 1.44, and that of β_2^w is 22.86. The F-statistic is 262.74, and the adjusted R-square is 0.0011. We can conclude that the effects of performance of the firm on the future compensation of the agent are relevant after two lags, while the immediately previous lag is not significant explaining changes in the agent's future compensation. The adjusted R-square is very low, however it should be noted that we are using first-differences in our estimation.

Now, we will estimate the sensitivity of present compensation of the agent to the performance of the firm using a similar regression equation:

$$\Delta c_t = \alpha^c + \beta_1^c \Delta V_t + \beta_2^c \Delta V_{t-1}$$

where, Δc_t is the change in the agent's present compensation during the current period, and ΔV_t and ΔV_{t-1} are defined as before. Note that here the present compensation of the agent is also given in utility terms in order to be able to make comparisons with the sensitivities of future compensation.

The estimated regression equation is the following:

$$\Delta c_t = 0.00362 + 0.02858 \Delta V_t + 0.00487 \Delta V_{t-1}$$

The t-statistic of the estimated α^c is 68.39, that of the estimated β_1^c is 184.96, and that of the estimated β_2^c is 31.39. The F-statistic is 17,669.31, and the adjusted R-square is 0.0686. We can conclude that the effects of performance of the firm on the present compensation of the agent are relevant in the immediately previous lag, while the second lag is still relevant, but in a much lower extent, explaining changes in the agent's future compensation.

The above results are reasonable in the sense that future compensation is affected by more distant lags and present compensation by nearer lags. That is, history explains better the movements in the agent's future compensation while current events explain better the happenings of current compensation of the agent. Comparing the magnitudes of the sensitivities of future and present compensation as a whole, we could say that the sensitivity of future compensation is higher than the one of present compensation however, they are rather close. Therefore, it might be said that our model reproduces the fact that pay-performance sensitivities are driven by future compensation, but it must be pointed out that in our model present compensation still plays an important role driving the pay-performance sensitivities.

4.2 Are pay-performance sensitivities lower in larger firms?

The evaluation of this stylized fact in the context of our model is based on our definition of firm size, which is determined by the current level of physical capital that the firm has in stock. The procedure we followed to examine this issue is similar to the procedure in the previous section. That is, we computed the pay-performance sensitivities using the same regression equations. The difference in this section is that we computed the estimates by grouping firms with the same initial capital level. Given that we have performed our simulation by considering ten initial levels of capital, we have estimated the regression equations for the same ten initial capital levels.

The sensitivities of future compensation of the agent with respect to the performance of the firm are computed using again the following regression equation:

$$\Delta w_t = \alpha^w + \beta_1^w \Delta V_t + \beta_2^w \Delta V_{t-1}$$

The results are summarized in Table 1. In looking the results, we can say that the immediately previous lag is not significant and of much lower impact explaining the sensitivity of future compensation with respect to the firm performance. As the level of initial capital increases, the significance and impact of this sensitivity decreases, except for $k_5 = 0.215$. The significance and impact of the second lag is higher. We can also state that from $k_5 = 0.215$ on, the magnitude and significance of this sensitivity is weakly decreasing. We might say that the results are moderately consistent with the stylized fact we are evaluating in our environment. Notice that as the level of initial capital increases, the variance of the value function increases too, which also explains this result. However, the fact that the mean of the value function decreases with the level of initial capital might mean that probably the evaluation of this stylized fact should be done using another measure of firm size, which would imply another simulation strategy.

The sensitivities of current compensation of the agent with respect to the performance of the firm are estimated using again the following regression equation:

$$\Delta c_t = \alpha^c + \beta_1^c \Delta V_t + \beta_2^c \Delta V_{t-1}$$

The results are summarized in Table 2. Those results allow us to conclude that the significance and magnitude of the sensitivity associated with the first lag increase as the level of initial capital

Table 1: Pay-Performance Sensitivities for Future Pay

Capital	α^w	t	β_1^w	t	β_2^w	t	F	$\overline{R^2}$	Mean VF	Var VF
$k_1 = 0.079$	0.0560	35.12	0.0032	0.69	0.0336	7.21	26.30	0.0011	16.57	6.84
$k_2 = 0.113$	0.0555	34.94	0.0029	0.62	0.0340	7.31	26.94	0.0011	16.54	6.89
$k_3 = 0.147$	0.0552	34.81	0.0026	0.55	0.0341	7.34	27.14	0.0011	16.51	6.93
$k_4 = 0.181$	0.0548	34.62	0.0025	0.53	0.0337	7.25	26.45	0.0011	16.50	6.96
$k_5 = 0.215$	0.0546	34.55	0.0028	0.59	0.0341	7.35	27.24	0.0011	16.48	6.99
$k_6 = 0.250$	0.0543	34.95	0.0020	0.43	0.0336	7.26	26.52	0.0011	16.46	7.04
$k_7 = 0.284$	0.0540	34.32	0.0019	0.40	0.0335	7.26	26.49	0.0011	16.44	7.05
$k_8 = 0.318$	0.0538	34.21	0.0015	0.33	0.0333	7.20	26.02	0.0011	16.43	7.07
$k_9 = 0.352$	0.0535	34.03	0.0010	0.23	0.0325	7.05	24.90	0.0010	16.42	7.07
$k_{10} = 0.386$	0.0532	33.91	0.0008	0.18	0.0325	7.06	24.94	0.0010	16.40	7.07

Table 2: Pay-Performance Sensitivities for Current Pay

Capital	α^w	t	β_1^w	t	β_2^w	t	F	$\overline{R^2}$	Mean VF	Var VF
$k_1 = 0.079$	0.0037	22.02	0.0273	55.92	0.0050	10.17	1621.74	0.063	16.57	6.84
$k_2 = 0.113$	0.0037	21.80	0.0276	56.34	0.0051	10.27	1647.16	0.064	16.54	6.89
$k_3 = 0.147$	0.0037	21.83	0.0281	57.35	0.0050	10.26	1704.75	0.066	16.51	6.93
$k_4 = 0.181$	0.0036	21.60	0.0283	57.78	0.0049	10.00	1726.25	0.067	16.50	6.96
$k_5 = 0.215$	0.0036	21.55	0.0286	58.30	0.0050	9.92	1755.13	0.068	16.48	6.99
$k_6 = 0.250$	0.0036	21.57	0.0289	58.78	0.0049	9.68	1781.56	0.069	16.46	7.04
$k_7 = 0.284$	0.0036	21.58	0.0291	59.76	0.0047	9.69	1840.05	0.071	16.44	7.05
$k_8 = 0.318$	0.0036	21.53	0.0293	60.05	0.0048	9.76	1858.14	0.072	16.43	7.07
$k_9 = 0.352$	0.0036	21.48	0.0293	60.30	0.0048	9.76	1873.76	0.072	16.42	7.07
$k_{10} = 0.386$	0.0035	21.27	0.0294	60.36	0.0048	9.74	1876.83	0.073	16.40	7.07

increases. However, the magnitude of the sensitivity associated with the second lag is weakly decreasing with respect to the initial level of capital, except for $k_5 = 0.215$.

Summarizing the results of Table 1 and Table 2 we can say that as firms are larger, the sensitivity of future compensation with respect to firm performance decreases while the sensitivity of current compensation with respect to firm performance is weakly increasing. As the initial capital of firms becomes larger, the variance of the value function or performance of the firm increases and hence, it seems reasonable that current compensation becomes the dominating incentive tool.

4.3 Do pay-performance sensitivities decrease with firm performance's variance?

Following the argument of Aggarwal and Samwick (1999) we would like to test whether in our framework the comparative static prediction of the principal-agent model that pay-performance sensitivities are decreasing with respect to the variance of firm performance still holds.

In estimating pay-performance sensitivities, Aggarwal and Samwick (1999) use the following

Table 3: Pay-Performance Sensitivities for Future Pay

Capital	α^w	t	β_1^w	t	β_2^w	t	β_3^w	t	F	$\overline{R^2}$
$k_1 = 0.079$	0.0424	17.00	0.0042	0.90	0.0371	7.91	-0.0036	-7.05	34.11	0.0021
$k_2 = 0.113$	0.0427	17.21	0.0038	0.81	0.0372	7.96	-0.0034	-6.75	33.16	0.0020
$k_3 = 0.147$	0.0427	17.33	0.0034	0.73	0.0372	7.97	-0.0032	-6.58	32.52	0.0020
$k_4 = 0.181$	0.0428	17.44	0.0032	0.70	0.0366	7.86	-0.0031	-6.36	31.14	0.0019
$k_5 = 0.215$	0.0428	17.50	0.0035	0.76	0.0370	7.95	-0.0031	-6.28	31.33	0.0019
$k_6 = 0.250$	0.0427	17.52	0.0028	0.60	0.0365	7.86	-0.0030	-6.24	30.66	0.0019
$k_7 = 0.284$	0.0428	17.62	0.0026	0.56	0.0364	7.83	-0.0029	-6.05	29.87	0.0018
$k_8 = 0.318$	0.0430	17.72	0.0022	0.48	0.0359	7.75	-0.0028	-5.88	28.87	0.0017
$k_9 = 0.352$	0.0429	17.74	0.0017	0.37	0.0351	7.58	-0.0027	-5.74	27.59	0.0017
$k_{10} = 0.386$	0.0430	17.83	0.0015	0.32	0.0350	7.56	-0.0026	-5.56	26.95	0.0016

regression equation for a given executive i working at firm j in period t:

$$w_{ijt} = \gamma_0 + \gamma_1 \pi_{jt} + \gamma_2 F(\sigma_{jt}^2)\pi_{jt} + \gamma_2 F(\sigma_{jt}^2) + \lambda_i + \mu_t + \epsilon_{it}$$

where, w_{ijt} denotes the compensation of the CEO, π_{jt} denotes the shareholders' return, $F(\sigma_{jt}^2)$ denotes the cumulative distribution function of the variance of the shareholders' return, λ_i denotes a CEO's fixed effect, μ_t denotes a time effect and, ϵ_{it} denotes the error term. They justify the use of the cumulative distribution of the variance of the return of shareholders to be able to transform the estimates of γ_1 and γ_2 into pay-performance sensitivities at any percentile of the distribution.

In order to test this prediction we should run the above regression equation using our model-generated data. However, it should be noted that we would need to estimate the distribution of the variance of the shareholder's return. Also, this specification is essentially different from the one we have been using in this work. Therefore, we propose to estimate the following simplified regression equation instead for the case of future compensation:

$$\Delta w_t = \alpha^w + \beta_1^w \Delta V_t + \beta_2^w \Delta V_{t-1} + \beta_3^w (Var(V_t) - Var(V_{t-1}))$$

We are aware of the limitations of the above specification, but it should serve us to establish whether the sensitivity of the change in future compensation is related directly or inversely to the change in the variance of the shareholder's wealth.

Given that in the previous section we observed that the variance of the shareholder's wealth increases with the initial capital level, we decided to run the above regression equation for each of the initial capital levels listed in the following table, which also shows the estimates:

The results of Table 3 allow us to conclude that the magnitude and significance sensitivity of the change in future compensation are decreasing in absolute value with respect to the change in the variance of the shareholder's wealth, for all the considered initial capital levels. Also, we need to say that those sensitivities have negative sign, which allows us to say that there is an inverse relationship between the change in the level of future compensation and the change in the variance of

Table 4: Pay-Performance Sensitivities for Current Pay

Capital	α^c	t	β_1^c	t	β_2^c	t	β_3^c	t	F	$\overline{R^2}$
$k_1 = 0.079$	0.0022	8.37	0.0274	56.15	0.0054	10.89	-0.00039	-7.40	1100.61	0.064
$k_2 = 0.113$	0.0022	8.38	0.0277	56.55	0.0054	10.96	-0.00038	-7.28	1116.94	0.065
$k_3 = 0.147$	0.0022	8.36	0.0282	57.57	0.0054	10.96	-0.00038	-7.39	1155.00	0.067
$k_4 = 0.181$	0.0022	8.36	0.0284	57.98	0.0053	10.68	-0.00038	-7.27	1169.68	0.068
$k_5 = 0.215$	0.0022	8.42	0.0287	58.50	0.0053	10.61	-0.00037	-7.20	1188.59	0.069
$k_6 = 0.250$	0.0022	8.50	0.0290	58.98	0.0051	10.35	-0.00037	-7.14	1205.96	0.070
$k_7 = 0.284$	0.0022	8.71	0.0292	59.95	0.0051	10.34	-0.00035	-6.92	1243.85	0.072
$k_8 = 0.318$	0.0023	8.90	0.0294	60.23	0.0051	10.37	-0.00034	-6.67	1254.71	0.073
$k_9 = 0.352$	0.0023	8.87	0.0294	60.48	0.0051	10.37	-0.00034	-6.69	1265.23	0.073
$k_{10} = 0.386$	0.0023	9.01	0.0295	60.52	0.0051	10.32	-0.00032	-6.35	1265.70	0.073

shareholder's wealth. It must be pointed out that all the estimates of β_3^w are significant. Also, that as capital increases this sensitivity decreases. It is interesting to notice that the pay-performance sensitivities estimated using this specification are higher in magnitude than the ones estimated in the previous section. However, the pattern of behavior is similar, so the same conclusions are still valid.

For the current compensation sensitivities we propose a similar regression equation:

$$\Delta c_t = \alpha^c + \beta_1^c \Delta V_t + \beta_2^c \Delta V_{t-1} + \beta_3^c (Var(V_t) - Var(V_{t-1}))$$

The results obtained using our model generated data for each of the listed initial capital levels are showed in the following table:

The results of Table 4 allow us to conclude that the sensitivity of the change in current compensation is negative and decreasing in absolute value with respect to the change in the variance of the shareholder's wealth. Also, that as capital increases this sensitivity decreases. All of them are significant. We may also notice that the magnitudes of the sensitivities of the change in current compensation with respect to the change in the variance of shareholder's wealth are much lower with respect to the magnitudes of the sensitivities of the variation in future compensation with respect to the change in the variance of shareholder's wealth. That is, the change in the variance of shareholder's wealth has a higher impact in the change of future compensation. It is interesting to observe that the pay-performance sensitivities estimated using this specification are similar in magnitude than the ones estimated previously, as well as their pattern of behavior. Therefore, the same conclusions are still valid. We might then conclude that the comparative static prediction that the pay-performance sensitivities are decreasing with respect to the variance of firm performance, still holds in our framework in the sense that the sensitivities of current and future compensation with respect to the variation in the variance of shareholder's wealth are negative and decreasing in absolute value.

From our results we see that future compensation is affected by more distant lags and present compensation by nearer lags. That is, history explains better the movements in the agent's future compensation while current events explain better the happenings of current compensation of the agent. Secondly, we observe that as firms grow, the sensitivity of future compensation with respect to firm performance decreases while the sensitivity of current compensation with respect to firm performance is weakly increasing. Thus, we can conclude that as the firm grows and its performance becomes more variable, the principal relies more on future compensation to provide incentives, but the link between the agent's wealth and firm's performance becomes weaker given the risk-averse nature of the agent.

5 Concluding Remarks

We will now present a discussion of our results comparing them with several facts reported in the cited empirical studies of executive compensation. We obtained some model-generated pay-performance sensitivities which reflect the existence of an inverse relationship between those sensitivities and firm size. This is one of the stylized facts regarding CEO pay that Murphy (1999) reports, as well as the observations that larger firms pay more to their CEOs and that the compensation component that establishes a stronger link between CEO pay and firm's performance is future compensation. Moreover, Clementi and Cooley (2000) inferred from the empirical literature on CEO compensation that the contemporaneous effect of firm performance on CEO compensation is lower than the cumulative effect, that includes lagged information. With our model-generated data, we obtained the result that the history of the firm's performance has a stronger effect on future compensation and the current firm's performance has a stronger effect on the present compensation of the CEO.

Boschen *et al.* (1995) underline the importance of the long-run components on the pay-performance relationship. We agree with their conclusion, and add that future compensation (translated into payments to executives in the form of stock options and stock ownership) reflects more heavily the effect of past performances than current compensation or salary.

Firm size is important in our model because with have allowed for capital accumulation. We obtained as a result that the principal tends to rely more on future compensation for incentive provision as the firm's capital is higher. Then, we conclude that, in fact, as firms grow and the variance of their performance increases, their moral hazard problem becomes more severe in that the shareholders need to implement a compensation scheme that ensures a stronger relationship between the performance of the firm (or the interests of the shareholders) and the CEO's compensation.

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