CEO Incentives and Firm Productivity*

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Abstract

This paper investigates the relationship between firm productivity and CEO performance incentives in a sample of 917 U.S. manufacturing firms during the period 1992-2003. We first find that CEO equity ownership enhances firm productivity and that firm productivity enhances corporate financial performance. We then find that the relationship between CEO performance incentives and productivity is quite complex. There is an inverse U-shaped relationship between productivity and the sensitivity of CEO wealth to share value (*delta*), which suggests that the high CEO portfolio risk associated with high *delta* discourages CEOs from undertaking risky positive-NPV, productivity-enhancing projects. We also find that greater sensitivity of CEO option wealth to stock return volatility (*vega*) generally increases firm productivity, consistent with stock option grants making CEOs less concerned with risk due to the down-side protection it offers. However, for a range of *delta* values, higher *vega* may actually reduce productivity, a result that has not been previously documented empirically. This suggests that stock options may not always achieve their intended effect of making CEOs less risk-averse. These results highlight the importance of careful structuring of CEO compensation contracts. Encouragingly, we find that CEO performance incentives positively impact productivity for the vast majority of the firms in our sample.

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Introduction

This paper investigates the relationship between firm productivity and CEO performance incentives. The existing theoretical literature suggests that CEO ownership, or specifically the share of a corporation owned by the CEO, has multiple influences on firm performance.[1] On the positive side, when CEOs own more shares of their firm, they benefit more from value-maximizing decisions since these result in share-price increases. However, when CEOs own a large fraction of corporate shares they can become "entrenched," i.e. independently powerful and difficult to dislodge. In this case, he may attempt to benefit himself at the expense of less powerful shareholders. This could create an inverse U-shaped relationship between CEO ownership and corporate performance. In addition, when CEOs own a large absolute amount of corporate shares they become more exposed to share-price volatility directly and indirectly, insofar as their portfolios become less diversified. This will concern risk-averse CEOs who may forgo risky yet value-enhancing projects.

Given these ambiguities, it is not surprising that the empirical literature has not reached a consensus regarding the relationship between managerial ownership and corporate performance, which is typically measured as Tobin's q. The earliest papers that have linked managerial ownership to Tobin's q found that the relationship is non-linear and essentially has an inverse U-shape (Morck, Shleifer and Vishny (1988), McConnell and Servaes (1990)). These studies suffer, however, from the potential endogeneity of ownership (Himmelberg, Hubbard and Palia (1999), Palia (2001)). More recent studies attempt to address the endogeneity problem by using instruments for ownership or by using simultaneous equation estimation. The results from these studies

[1] Berle and Means (1935), Jensen and Meckling (1976), Demsetz (1983), Fama and Jensen (1983), Smith and Stulz (1985) and Morck, Shleifer and Vishny (1988).

are mixed: some find that managerial ownership affects Tobin's q and that this relationship is non-monotonic, while others find no relation at all.[2]

In this paper, we focus on the real side of firm performance, namely productivity. It is well known that productivity growth accelerated during the 1990s and this growth has been attributed to technology improvements (Basu, Fernald, and Shapiro (2001)). It is also well known that CEO incentive contracts shifted towards stock and stock option grants beginning in the 1980s (Murphy (1999), Perry and Zenner (2000)). In particular, Hall and Liebman (1998) show that stock option grants have dramatically increased both the level of CEO compensation and the sensitivity of CEO compensation to firm performance in the 1990s compared to the 1980s. Our results suggest that the shift in compensation strategies may have contributed to the relatively rapid productivity growth of the 1990s, as seen in Figure 1. Moreover, not only did the growth in productivity and CEO compensation coincide, but also in 2001-2002, both productivity and CEO compensation declined, suggestive of a systematic relationship between firm productivity and CEO compensation incentives.

Furthermore, our focus on productivity is driven by three important observations. First, it is critical to come to understand not just whether managerial incentives influence firm financial performance but also how they exert this influence. If the theories are correct such that managerial incentives do indeed influence financial performance by affecting firm fundamentals, then there ought to be a corresponding relationship between managerial incentives and the real side of firm performance, i.e. productivity should be a channel through which incentives work to influence financial performance. Second, in a

[2] Hermalin and Weisbach (1991), Loderer and Martin (1997), Cho (1998), Himmelberg, Hubbard and Palia (1999), Holderness, Kroszner, and Sheehan (1999), Demsetz and Villalonga (2001), Palia (2001), Claessens, Djankov, Fan and Lang (2002), Cui and Mak (2002), Coles, Lemmon and Meschke (2007), and Brick, Palia and Wang (2005).

perfect world, financial performance would be a good indicator of underlying firm productivity. However in the presence of information asymmetries, the relationship between productivity and financial performance may be weak. For example, the relationship between managerial incentives and financial performance can reflect management's ability to manipulate accounting statements. In such a situation, a fraudulently inflated stock price may not reflect improvements in firm fundamentals. A third and related point, is that of crowding out. With a short tenure clock and multiple demands on a CEO's time, efforts at improving stock prices per se (especially since compensation contracts are tied to it) may crowd out efforts at productivity improvement as such improvements are largely unobservable to shareholders in the short-run.[3] Focusing on the real side of firm performance allows us to avoid these potential complications.

Thus, our analysis of the relationship between managerial incentives and firm productivity permits us simultaneously to sort out the ambiguity in the empirical evidence and to examine in greater depth the mechanism through which managerial incentives influence firm financial performance. After all, we expect improvements in productivity to have more permanent and lasting effects on firm financial performance.

We measure the real side of firm performance as total factor productivity (TFP). We follow Olley and Pakes (1996) to obtain consistent estimates of TFP, with labor and capital as inputs to production. This widely-accepted methodology corrects for endogeneity of the capital stock, unobserved heterogeneity and sample selection bias in

[3] This is not to argue that the two strategies of improving share performance and increasing firm productivity are incompatible. In our sample, a one percent increase in the firm's stock price increases mean CEO wealth by half a million dollars. Increases in productivity are largely unobservable and unless they translate into one-for-one stock price increases, the returns to managers from exerting effort to increase the stock price independently of increasing productivity may be greater than those directed at productivity improvement.

the estimation of the production function. Our data covers 917 U.S. manufacturing firms from Compustat and ExecuComp during the period 1992-2003.

To determine the relationship between productivity and CEO performance incentives, we face two estimation issues. First, is the endogeneity of CEO incentives, and second, is the persistence of productivity shocks. The endogeneity problem has been widely recognized and is generally attributed to unobservable firm heterogeneity or differences in the firm's contracting environment (Himmelberg, Hubbard and Palia (1999), Palia (2001)). For example, firms with a superior technology, *ceteris paribus*, are more productive. At the same time, however, having the superior technology also means that a lower level of incentives is required to ensure that this firm's CEO will pursue productivity-enhancing endeavors. Hence, optimal compensation contracts are determined endogenously and are affected by (unobservable) firm characteristics that also affect firm performance.[4]

If we appropriately address this endogeneity problem, it can be argued that if value-maximizing contracts are awarded to CEOs then we should not observe a systematic relationship between productivity and CEO incentives since both productivity and CEO contracts are determined by firm-specific factors in the firm's environment. On the other hand, if transaction costs inhibit optimal contracting[5] then we would observe a systematic relationship between CEO incentives and productivity.[6] Our findings support the latter view. Moreover, contracting on productivity is practically impossible in the sense that a specific firm's TFP is not readily observable by the shareholders. Setting financial performance targets (such as the share price) are more easily implemented than

[4] Earlier studies such as Demsetz (1983) and Jensen and Warner (1988) have also recognized that managerial ownership is endogenous to the value-maximization problem of firms.
[5] Tirole (1999) reviews the incomplete contracting literature and categorizes transaction costs into 1) unforeseen contingencies, 2) the cost of writing contracts and 3) the cost of enforcing contracts.
[6] See Agrawal and Knoeber (1996) and Palia (2001).

setting productivity targets. At best, we observe TFP measures at the aggregate level.[7] Thus, we can infer from the relationship between CEO incentives and firm productivity whether CEO contracts are able to provide adequate incentives for improving firm fundamentals that consequently increase shareholder value. Moreover, our findings also show that certain types of contracts are clearly sub-optimal since they are related to lower productivity.

To address the two estimation issues mentioned above, we use the difference-GMM (generalized method of moments) methodology of Arellano and Bond (1991). With the appropriate instruments, GMM corrects for endogeneity. Furthermore, difference-GMM exploits the dynamic nature of panel data sets by utilizing the moment conditions with lagged values of covariates. These moment conditions imply that instruments for endogenous variables need only be predetermined (weakly exogenous) and not strictly exogenous to the empirical model. Additionally, this procedure allows us to account for the persistence of productivity over time by including lagged productivity as a regressor. In contrast, traditional instrumental variable-fixed effects estimation requires strict exogeneity of instruments and would yield inconsistent coefficient estimates with a lagged dependent variable.

We first find a significant positive relationship between CEO ownership and total factor productivity, and an even stronger positive relationship between TFP and Tobin's q. This corroborates the literature's broad theoretical conclusion that stock ownership can help align the incentives of CEOs with those of shareholders (i.e. shareholder wealth maximization). We find that this relationship between CEO ownership and TFP is

[7] Reported quarterly by the Bureau of Labor and Statistics, for example.

monotonic, rather than inverse U-shaped, which suggests that the "entrenchment" effect is not strong.

Equity ownership, however, is an incomplete measure of the CEO's equity-based incentives. It does not reflect option contracts and does not capture the sensitivity of CEO wealth, *per se*, to stock price performance. In this paper, we focus on two measures of equity-based incentives. The first measure is "*delta*," the sensitivity of CEO wealth to percent changes in his firm's stock price. This depends on the amount of shares he owns, the number of options he owns, and various properties of the options such as maturity and strike prices. The second measure is "*vega*," the sensitivity of CEO wealth to percent changes in stock return volatility. This depends primarily on the option component of CEO wealth, and reflects the positive influence of volatility on option value. A CEO's expected return will depend on both *delta* and *vega*; his expected risk will depend primarily on *delta*. The way in which corporate directors divide compensation between stocks and options will clearly influence *delta* and *vega*.[8]

We enhance our analysis of the relationship between incentives and productivity by replacing ownership with these two more nuanced measures, an approach that has not previously been undertaken to our knowledge. We find that productivity has an inverted U-shape relationship with the sensitivity of CEO wealth to changes in share value (*delta*). This suggests that the high CEO portfolio risk associated with high *delta* discourages CEOs from undertaking risky positive-NPV, productivity-enhancing projects. This result underscores the importance of CEO risk aversion, which could be particularly relevant to us in the case of risky R&D (research and development) investments, for example, since prior work has shown that R&D positively impacts productivity.

[8] Palia (2001), Coles, Lemmon and Meschke (2007) and Brick, Palia and Wang (2005) use similar measures for CEO pay-performance sensitivity.

Next, we find that greater sensitivity of CEO option wealth to stock return volatility (*vega*) generally increases firm productivity, as expected. This is because stock options offer down-side protection that makes CEOs less concerned with risk. However, for a range of *delta* values higher *vega* may actually reduce productivity, a result that has not been previously documented empirically. This finding implies that a more convex compensation contract (e.g. one with more stock option grants) can make CEOs more risk-averse, contrary to what is normally expected. Ross (2004) illustrates the conditions under which this can actually occur.

Our findings highlight the complexity of the relationship between CEO performance incentives and corporate performance, underlining the importance of careful structuring of CEO compensation contracts. Encouragingly, we find that CEO incentives positively impact productivity for the vast majority of the firms in our sample.

Very few studies have looked at the relationship between productivity and managerial incentives. The paper closest in spirit to ours is Palia and Lichtenberg (1999). They estimate the production function with managerial ownership as a third factor input, in addition to labor and capital. To address endogeneity concerns, they employ a fixed effects methodology and use lagged values of all factor inputs. From a randomly selected sample of 255 US manufacturing firms over the period 1982-1993, they find that changes in the equity holdings of managers are positively correlated with changes in productivity, consistent with our findings for CEO ownership.[9] While Palia and Lichtenberg look solely at managerial ownership, in this paper, we focus on the CEO's *delta* and *vega*.

[9] Barth, Gulbrandsen and Schøne (2005) examine a sample of Norwegian firms and find that family ownership and family management have a negative impact on productivity. Perez-Gonzales (2004) investigates the impact of multinational ownership on the productivity of Mexican manufacturing plants and finds that ownership by a multinational corporation is positively related to productivity. Additionally, Nickell, Nicolitsas and Dryden (1997) and Köke and Renneboog (2003) find that the existence of a dominant outside shareholder has a positive impact on productivity growth.

Another closely related paper is Coles, Daniel and Naveen (2006). This paper examines the relationship between managerial incentives and specific firm policies on capital expenditures, research and development (R&D) and leverage. Their main finding is that higher CEO *vega* results in riskier firm policies (lower capital expenditures, higher R&D and higher leverage). While they show that CEO compensation in the form of stock options induces risk-taking behavior, our results show that when we look at over-all firm performance in terms of productivity, awarding stock options may not always achieve their intended effect of making CEOs less risk-averse.

The remainder of the paper is organized as follows: Section I describes our data and our empirical methodologies. Section II shows that CEO ownership enhances productivity and productivity enhances Tobin's q. Section III shows that two dimensions of managerial incentives are important for the influence of compensation on productivity, and that the influence is complex and nonlinear. Section IV concludes.

I. Data and Methodology

A. Sample Selection and Variable Construction

We gather data from two main sources. We obtain annual CEO compensation data from ExecuComp for the period 1992-2003. Our sample begins in 1992, when ExecuComp came into existence, and extends to 2003. We obtain firm characteristics from Compustat. We focus exclusively on manufacturing firms, for which our productivity estimation is likely to be most reliable. Our sample thus comprises all 917 of the manufacturing firms represented in both ExecuComp and Compustat with no missing observations for certain key variables.[10] Because ExecuComp focuses on major firms,

[10] These variables are productivity, lagged productivity, total assets, firm age and CEO share holdings.

such as the S&P 500, our sample is dominated by large firms.[11] Our primary sample consists of 6,636 firm-year observations.

1. Measuring CEO Incentives

We measure CEO incentives in three ways. As a benchmark for comparison to previous work, we first construct CEO *holdings* using the standard definition of the fraction of equity shares held by the CEO to total shares outstanding. We measure *delta*, the CEO's wealth sensitivity to changes in the firm's stock price, as the dollar change in the CEO's equity and option holdings in response to a one-percent change in the firm's stock price. We measure *vega*, the CEO's wealth sensitivity to changes in the volatility of the firm's stock return, as the dollar change in the CEO's option holdings for a one-percent change in the firm's stock return volatility. Our measures are exactly those used in Core and Guay (2002), which are further described in the appendix. The *vega* of option holdings has been shown by Guay (1999) to be of an order of magnitude larger than the *vega* of stock holdings. Thus, we approximate the CEO's *vega* to be the *vega* from option holdings.[12]

2. Measuring Total Factor Productivity

Total factor productivity or TFP is the conventional measure of firm-level productivity. TFP is defined as the change in output that cannot be explained by a corresponding change in factor inputs. The two most commonly identified sources of

[11] In a recent paper, Cadman, Klasa and Matsunaga (2006) document some systematic differences between ExecuComp and non-ExecuComp firms. They find that increasing the heterogeneity of the sample by including non-ExecuComp firms "uncover(s) previously hidden conditional or nonlinear relations." We acknowledge that our use of ExecuComp firms may weaken the generality of our findings. On the other hand, our results already indicate a non-linear relation between firm productivity and CEO performance incentives, so that the "biases" that these authors document may not be as severe for this study.

[12] Coles, Daniel and Naveen (2006), also make the same approximation.

productivity gains are changes in technology and unobserved efficiency increases. Early work has used ordinary least squares to estimate firm-level production functions. However, this method suffers from some serious flaws. The main problems are that of endogeneity of inputs, unobserved heterogeneity across firms and selection bias. Olley and Pakes (1996) developed a methodology that addresses these problems. We follow this procedure and obtain consistent estimates of TFP for each firm.[13] Since the underlying production function parameters may be different across industries, we estimate the production function separately for each industry group following the Fama-French 49 industry classification. TFP is then calculated as the residual between the predicted and actual output. The appendix describes this estimation procedure in greater detail.

To make the TFP estimates comparable across industries, we compute a productivity index (Pavcnik (2002), Aw, et. al (2001)) as follows: We consider 1992 to be the base year for which we calculate the mean TFP estimate by industry group. We then subtract this 1992 industry mean from firm-level TFP to obtain the productivity index: $pindx_{it}=prodv\_est_{it} - prodv\_est_{j,1992}$, where j is the industry group of firm i and t denotes the current year. In the regression analysis that follows, we use this productivity index as the dependent variable. Table A2 provides descriptive statistics for this index.

3. Measuring Firm Characteristics

To evaluate the contribution of CEO incentives to productivity, it is important to control for other important factors. Following previous work, we require the following

[13] Another advantage of this methodology is that it yields productivity estimates that are robust to a variety of estimation issues. Its shortcoming is that these estimates can be quite sensitive to measurement error in investment (Biesebroeck (2004)). In this paper, investment is measured as capital expenditures (in property, plant and equipment). Since this is a flow variable that is reported by firms each year, we believe measurement problems are not that severe.

additional factors in our analysis: firm size (total assets), firm age, industry concentration (Herfindahl index), Tobin's q, sales, tangible assets, capital expenditures, book leverage, stock return volatility, research and development, advertising, and CEO tenure. Further details on the measurement and construction of these variables are outlined in the appendix.

Table 1A reports descriptive statistics for our estimation sample. For a majority of the observations, CEOs own less than 0.5 percent of their firm's stock. However, this distribution is heavily skewed since the mean equity stake is 2.81 percent. The patterns for *delta* are similar to that of equity holdings. A one percent increase in the firm's stock price results in a median increase in CEO wealth of $180,000, while the mean increase is $540,000. With regards to *vega*, a one percent increase in the volatility of a firm's stock return corresponds to a median (mean) increase in CEO wealth of $30,000 ($80,000). In Table 1B, we report the correlation matrix for our variable set.

B. Estimating the Productivity-Incentives Relationship

Next, we estimate the following empirical model relating CEO performance incentives to total factor productivity:

$$\text{Prod}_{\text{it}} = \beta_0 + \beta\, \textit{CEO Incentives}_{\text{it}} + \gamma_0 \text{Prod}_{it-1} + \gamma\, \textit{Controls}_{it} + \alpha_i + \delta_t + \mu_{it}\,, \qquad (1)$$

The dependent variable is the productivity index previously described. *CEO Incentives* consists of the CEO ownership and sensitivity variables explained above, *Controls* are basic determinants of productivity, α_i is a firm fixed effect for firm i, δ_t is a year fixed effect for year t, and μ_{it} is the error term. We include the lagged productivity index to account for the persistence of productivity shocks over time. To obtain consistent coefficient estimates in the presence of this lagged dependent variable, we use a dynamic panel data estimator called difference-GMM, according to Arellano and Bond (1991).

Since total factor productivity is the residual from estimating a production function, it is commonly interpreted as a measure of increased efficiency. There is a large literature that has identified important factors that influence firm-level productivity. Some basic factors are firm size (Soderbom and Teal (2001)), firm age (Huergo and Jaumandreu(2004), Haltiwanger et. al. (1999)) and industry structure and competition (Tang and Wang (2005), Rogers (2004)). Other significant factors include R&D (Griliches (1986), (1980), Griliches and Lichtenberg (1984)), FDI and technology spillovers (Haskell et. al. (2004), Keller (1999), Basant and Fikkert (1996)), trade liberalization and exports (Keller and Yeaple (2003), Ozler and Yilmaz (2001), Keller (1997)), use of better technology, specifically computers (Lehr and Lichtenberg (1997)), changing workplace organization (Black and Lynch (2003)) and managerial efficiency (Bartelsman and Doms (2000)).

Based on this literature, the basic control variables for productivity that we use are firm age, firm size, industry concentration and R&D.[14] Among the additional factors that these studies have shown to affect productivity, managerial effort (or efficiency) is the main focus in this paper. Furthermore, for our analysis, the firm's level of technology is an unobservable factor and is a likely source of endogeneity. Consider, for example, two identical firms except one has the superior technology. Given the same factor inputs, the superior technology firm would be more productive. At the same time, however, having the superior technology also means that a lower level of incentives (i.e. less incentive

[14] To preserve sample size, we follow Himmelberg, Hubbard and Palia (1999) and include a dummy variable to account for missing values of R&D. This dummy variable equals 1 if R&D is non-missing. Missing values of R&D are replaced with zeros.

alignment with shareholder goals or a compensation contract with a flatter slope) is required for this firm's CEO to pursue productivity-enhancing endeavors.[15]

With the appropriate instruments, the Arellano and Bond (1991) methodology addresses this endogeneity issue. Moreover, this efficient-GMM estimator does not require the strict exogeneity of instruments, only that they are predetermined (weakly exogenous). The firm fixed effect is eliminated by first-differencing equation (1). The set of valid instruments follows from the moment conditions with lagged variables. Thus, all lagged values of the covariates, which include twice-lagged lagged productivity, can be used as instruments for the first-differenced covariates. Hence, an added advantage of this methodology is that it allows past productivity levels to affect CEO incentives. Over-all, the Arellano-Bond methodology corrects for the two estimation issues we face, i.e. the endogeneity of CEO compensation and the persistence of productivity shocks. These issues cannot both be addressed by the standard instrumental variables – fixed effects techniques used in prior work.

Previous studies have shown that the following factors affect CEO incentives: firm size, firm age, CEO tenure, stock return volatility, advertising, and book leverage. The first two factors are also control variables and hence, their lagged values are part of the instrument set. We use the lagged values of the latter four factors as additional instruments for CEO incentives. The justifications for these instruments are well-articulated by Core and Guay (1999), Himmelberg, Hubbard and Palia (1999) and Palia (2001). We summarize these arguments as follows: 1) Firm size is related to agency costs since larger firms are more difficult to monitor. Moreover, larger firms require

[15] Prior studies have acknowledged that managerial ownership and firm value are endogenously determined by exogenous factors in the firm's contracting environment (Jensen and Warner (1988), Himmelberg, Hubbard and Palia (1999), Palia (2001)). Moreover, these factors are to a large extent unobservable.

highly skilled managers who demand greater compensation and are thus wealthier. Thus larger firms would need higher levels of CEO incentives (greater incentive-alignment or a steeper slope of the compensation contract). On the other hand, rating agencies and top management may benefit from monitoring economies of scale in larger firms. This would predict that larger firms require lower incentive levels. 2) Firm age would affect CEO incentives for similar reasons as firm size, but would also affect the composition of compensation packages. Younger firms are more likely to use options and restricted stock grants for CEO pay. 3) CEO tenure is the number of years the executive has been the CEO of the company, constructed from ExecuComp. CEO experience is a proxy for CEO wealth. To a certain extent, it also captures the CEOs proximity to retirement. To avoid short horizon concerns, higher incentives levels would be necessary. Thus, higher tenures would be related to higher incentive levels. 4) Stock return volatility is a proxy for CEO risk aversion. High stock return volatility may distort the performance incentives of equity ownership in a firm due to the CEO's inability to diversify his portfolio. To mitigate this effect, CEOs of firms with high stock return volatility are normally given more convex compensation contracts (e.g. stock option grants) to induce more risk-taking behavior. 5) Advertising is a measure of discretionary spending. Discretionary expenses are more difficult to monitor and would thus require a higher level of incentives. Similar to R&D, we include a dummy variable that equals 1 if advertising is non-missing. Missing values of advertising are replaced with zeros in order to preserve sample size. 6) Finally, we include book leverage to control for agency costs according to Jensen's (1986) free cash flow theory. Higher leverage mitigates these agency costs and reduces the need for high CEO incentive levels.[16]

[16] Additionally, Guay (1999) shows that stock return volatility is positively related to CEO *vega* while

We calculate robust standard errors with a finite-sample correction to the two-step covariance matrix according to Windmeijer (2005). We report two specification tests to ensure the validity of our instruments: 1) the Hansen J test for over-identifying restrictions; and 2) the Arellano-Bond *m2* test for lack of serial correlation in the error term μ_{it}.[17] For both tests, p-values of less than 10 % would mean a rejection of the validity of the instruments at conventional levels of significance.

II. CEO Ownership and Corporate Performance

Prior work has not reached a consensus on the effect of managerial ownership on firm financial performance, measured by Tobin's q. This is an important empirical question since the stated objective of a CEO is to maximize shareholder value. However, Tobin's q is a fairly short-run performance indicator as opposed to productivity which is a more long-term performance measure for a firm. Increase in advertising, obtaining patents, new investment announcements may all raise stock market prices and thus Tobin's q without necessarily changing the underlying productivity of a firm. However, without fundamental changes to underlying productivity, sustained improvements in financial performance will not be possible. In order to connect these short-term and long-term performance measures, we begin our analysis by documenting how productivity and a firm's financial performance are related and then relate CEO ownership to productivity. We first show that higher productivity is associated with a higher Tobin's q and that greater CEO ownership is also associated with higher productivity. Thus, by looking at

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Coles, Daniel and Naveen (2006) show that riskier firm policies (high R&D and high leverage) result in lower CEO *delta* and higher CEO *vega*.

[17] The latter test is implemented by testing for the absence of second-order serial correlation in the first-differenced errors. The absence of second-order serial correlation in first-differences implies the absence of serial correlation in levels.

the real-side of firm performance, we illustrate that CEO ownership does indeed enhance firm financial performance. Equivalently, we show that greater CEO ownership enhances firm value by way of enhancing total factor productivity.

A. Long-Run and Short-Run Measures of Firm Performance

We first estimate the determinants of productivity excluding CEO incentives and then investigate how changes in productivity change the short-term financial performance of a firm, as captured by Tobin's q. Results are presented in Table 2 and are consistent with those found in earlier studies. For the productivity regression (column 1), the coefficient on lagged productivity is positive, highly significant and stable, justifying our use of the dynamic panel estimator[18]. We also find that older and larger firms have higher productivity. Unlike earlier studies, we do not find any significant relationship between industry concentration and productivity or between R&D and productivity. We believe this is because there is not a lot of time variation in the concentration measure and our estimation in first differences removes industry fixed effects. The lack of the R&D effect may reflect the relative unimportance of R&D for many of the traditional manufacturing firms in our sample, which is not surprising since our sample consists mostly of firms whose R&D costs are minor.[19] Moreover, for these traditional manufacturing firms, R&D is likely to be more related to product development than basic research.

Next, we investigate how these productivity changes are reflected in a firm's financial performance. Figure 1 shows that the productivity surge of the 1990s coincided with the large increase in CEO pay. Moreover, it is also the case that the stock market

[18] The Arellano-Bond *m2* test for autocorrelation in the first-differenced errors are consistent with the model assumptions, i.e. there is no serial correlation in the error term. However, the Hansen J test of over-identifying restrictions clearly rejects the validity of the instruments. This suggests that we may have omitted a critical variable, which could well be managerial effort. In these base specifications, the instruments used are lagged values and differences of the explanatory variables.
[19] Median R&D is 16 % of net property, plant and equipment and is 3.8 % of total assets.

reached unprecedented heights over this same time period. This begs the question of whether these productivity gains translate into enhanced corporate value. Arguably, many factors such as advertising, leverage and volatility can affect firm valuation. CEO actions can alter these factors and hence impact a firm's financial performance. However, we argue that productivity is another important, and often overlooked, channel through which a firm's financial performance is affected. Ultimately, a CEO's motivation for increasing firm productivity is to increase shareholder value. This in an important link to establish, since one may argue that with a relatively short average tenure, CEOs may not be interested in investing resources to increase productivity, which is typically difficult to measure and may not be immediately reflected in stock prices. However, if productivity is valued correctly and reflected in the market valuation of the firm, then irrespective of their expected tenure horizons, CEOs would have an incentive to invest in long-term productivity enhancements and not just short-term fixes to increase Tobin's Q since such changes alter their net worth. Thus if we observe a direct link between productivity and financial performance, we should also expect to see a link between CEO incentives and productivity.

Following previous work, we use Tobin's q as a market-based measure of the firm's financial performance. We measure productivity here as the estimated productivity residual from the production function (equation (2) in the Appendix), rather than the productivity index that we have used as a dependent variable. This is because we want to relate the firm's actual measure of TFP, which is the residual, to its market valuation. Our results are unchanged if we use the productivity index instead of the residual. We control for the influence of various additional determinants of Tobin's q that have been identified by prior studies (Himmelberg, Hubbard and Palia (1999)) such as firm size, tangible assets, investment, industry concentration, R&D, advertising, leverage and stock return volatility. We use a firm fixed effects methodology to estimate this empirical specification. The results in Table 2 (column 2) show that productivity has a highly significant, positive impact on Tobin's q even after controlling for these other influences.[20] These results suggest that our findings on the relationship between productivity and CEO ownership should carry over to Tobin's q. Thus, a CEO's incentives for maximizing shareholder wealth are manifested in the relationship between firm productivity and CEO ownership. Productivity is an important mechanism through which CEO incentives affect firm financial performance.

B. CEO Ownership and Productivity

Next, we study the link between productivity and CEO incentives in detail. In Table 3, we add CEO ownership (*holdings*) to our empirical model[21] and investigate the nature of the productivity-ownership linkage. Theory suggests that ownership may have a non-linear relationship with firm performance, thus we add not only CEO ownership itself but also its square and its cube. The results, shown in Table 3, show that higher CEO ownership results in higher total factor productivity, consistent with Palia and Lichtenberg's (1999) findings for managerial ownership. In addition, it appears that the linear specification is sufficient in our sample. That is, it appears that productivity is not undermined when CEOs own larger and larger shares of a corporation, suggesting that the "entrenchment effect" is not economically large. Importantly, the Arellano-Bond test

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[20] Palia and Lichtenberg (1999) also find that Tobin's q is positively related to productivity.

[21] Since industry concentration and R&D were found to have no additional effect on productivity in Table 2, we exclude these variables from the main regressions that follow. Although we no longer use R&D as a control variable, we retain lagged values of R&D as instruments in all the remaining analyses. Similar to advertising, R&D is a measure of discretionary spending that is difficult to monitor. Thus R&D-intensive firms will require higher CEO incentive levels.

remains consistent with the model assumptions and the Hansen J tests no longer suggest specification problems such as the exclusion of important productivity determinants. This supports our decision to analyze the influence of CEO incentives on productivity.[22]

III. A Closer Look at CEO Incentives

Having established that greater CEO ownership enhances firm value by enhancing productivity, we now take a closer look at the incentive structure of CEO pay and its impact on productivity. Stock ownership is just one component of CEO compensation. Ownership does not reflect option contracts and does not capture the sensitivity of CEO wealth, *per se*, to share performance. The CEO's wealth sensitivity to changes in the stock price and stock return volatility are more indicative of CEO incentives than just equity ownership since the former are more closely tied to firm performance. Thus, we use two measures of CEO incentives that are widely used in the literature, but have not previously been linked to productivity. These are the *delta*, the sensitivity of CEO wealth to percent changes in the firm's share price, and the *vega*, the sensitivity of CEO wealth to percent changes in stock return volatility. A CEO's expected return will depend on both *delta* and *vega*; his expected risk will depend primarily on *delta*. This section shows that *delta* and *vega* are positively related to productivity for the vast majority of our firms, but that the relationship is nonlinear and can be different at certain levels of *delta*. Thus, appropriate combinations of *delta* and *vega* must be chosen in order to enhance productivity, which will consequently enhance firm value.

[22]Note that in Tables 2-7, the number of observations used in the estimation vary from the primary sample reported in Table 1A. This is because the estimation is in first-differences and missing years for some variables reduces the sample size. All our results continue to hold if we use the restricted sample with non-missing observations for all first-differenced explanatory variables.

A. CEO *Delta*

We first extend the regressions used to evaluate the influence of CEO ownership on productivity in Table 3 by including CEO *delta*. The results, shown in Table 4, column 1, indicate that both holdings and *delta* are insignificant. This is expected because *delta* is partly a function of equity holdings, and the two are strongly correlated. When we allow the relationship between *delta* and productivity to be nonlinear, as suggested by theory, we find that *delta* becomes significant while ownership – which is included without nonlinear terms based on the results in Table 3 – remains insignificant (columns 2 and 3). This is not surprising since *delta* is a more comprehensive measure of the sensitivity of CEO wealth to share price than ownership. Henceforth, we focus on *delta* rather than ownership.

Overall, we find that there is a significant relationship between productivity and *delta* that is non-monotonic. The linear term has a positive coefficient, the squared term has a negative coefficient, and the cubic term has a positive coefficient. The overall relationship is portrayed in Figures 2 and 3. These show that productivity initially increases with *delta*, consistent with the incentive-alignment effect, i.e. CEO incentives are aligned with those of shareholders. Then, for larger values of *delta*, productivity decreases, but the rate of decrease slows to almost zero at the highest levels of *delta*. The negative effect on productivity for higher values for *delta* is more consistent with the risk-aversion hypothesis. Managers, whose personal wealth is closely tied to the financial performance of the firm, become averse to investing in risky, but productivity-enhancing projects. This conclusion is also consistent with evidence presented in Coles, Daniel and Naveen (2006) that looks at the empirical relationship between CEO *delta* and specific firm policies. They find that high *delta* induces CEOs to take less risky decisions, such as more capital expenditures and less R&D.

Recall from table 1A that the distribution of CEO *delta* is heavily skewed with a median of $180,000 and a mean of $540,000. Five percent of the observations have *delta*s greater than $2.26 million. Three percent of the observations have *delta*s greater than $3.34 million. Thus, it is not surprising that in Figure 3 where we have the cubic specification, the 95 % confidence interval widens considerably beyond the $3 million mark. Although the cubic model yields a statistically significant third order coefficient for *delta*, this appears to be driven by the upper tail of the distribution where the 95 percent confidence interval is rather large.

An alternative to these higher-ordered polynomial functions is to estimate piece-wise linear functions of *delta*, similar to Morck, Shleifer and Vishny's (1988) piece-wise linear specification for managerial ownership. For this specification, we allow the slope to change at various threshold points that coincide with the top percentiles of the *delta* distribution. Our choice of threshold points are motivated by our findings from the previous table.[23] The results, shown in Table 5, confirm our findings from the quadratic and cubic models: there is a statistically significant inverted-U relationship between productivity and CEO *delta*. This initially positive relationship becomes negative at high levels of *delta*. Although Tables 4 and 5 show that this relationship becomes positive once more at *delta* levels greater than $8 M, this evidence is weak. Hence, for the remainder of the paper, we focus on the quadratic specification for *delta*.

Our findings on productivity and CEO *delta* are not only statistically significant, but economically significant as well. The average annual increase in the level of the

[23] The local maximum and minimum from figures 2 and 3 occur at the top 5th percentile of the *delta* distribution.

productivity index is 0.04 (see Table A2). For values of *delta* less than $4.34 million (Table 5, column 2), a one standard deviation ($1.17 M) increase in *delta* is more than sufficient to achieve this average annual increase in productivity. If CEO *delta* merely doubles from its median value of $180,000, the result is an *increase* in the productivity index of 0.0068 -- which is 17 % of the average annual productivity gain. On the other hand, for values of *delta* greater than $4.34 million, a one standard deviation increase in *delta* will *reduce* the productivity index by 0.3, which is 75 % of the average annual productivity gain.

B. CEO *Vega*

It appears that when *delta* is high the alignment of shareholder interests with CEO interests becomes less well aligned. This has been one motivation for providing CEOs with option contracts. If higher risk can increase expected option values even while creating uncertainty, CEOs might be less hesitant to undertake risky projects. Equivalently, CEOs might be less concerned with risk when they have option wealth, which of course has downside protection.

In Table 6, we add CEO *vega* to our empirical specification. Recall that we measure *vega* as the sensitivity of CEO option wealth to stock return volatility. The coefficient on *vega* is not statistically significant, while the results for *delta* remain unchanged (column 1). This result is surprising because Coles, Daniel and Naveen (2006) find that high *vega* implements riskier firm policy choices.

We conjecture that the influence of *vega* might be most apparent at high levels of *delta*, when CEO risk aversion effects would be most severe. To test this hypothesis, we interact *delta* with *vega*. For simplicity of interpretation, we adopt the piece-wise linear specification for *delta* instead of the quadratic model. We use various percentile threshold points for the piece-wise linear function and obtain similar results. In columns 2 and 3, we provide the estimates when the slope changes at the 98^{th} percentile of *delta*. We use the 98^{th} percentile for *delta* because it is the closest to the predicted maximum point from the quadratic model in column 1.

When interacted with *delta*, we find that *vega* does indeed tend to increase productivity. The coefficient on the linear *vega* term of 0.174 implies economically significant effects. As we anticipated, this effect is particularly intense at high levels of *delta*, since the interaction term between *vega* and high *delta*s has a positive coefficient. What is puzzling, however, is the interaction term between *vega* and lower *delta*s has a negative coefficient.

The effect on productivity of different combinations of *delta* and *vega* is best portrayed in Figure 4. The graph clearly shows that the relationship between productivity and these two incentive measures is quite complex. Not only does *delta* have opposing effects on productivity, but so does *vega* for a given *delta*. When we calculate the net effect of *vega* on productivity for a given *delta*, we find that a rise in *vega* enhances productivity for the vast majority – over 95 percent -- of the firms in our sample. However, for a small fraction of firms in our sample, where *delta* values are in the mid-range ($2.15 M -$4.34M), increasing *vega* decreases productivity.

On the one hand, we find that higher *vega* enhances productivity, which is consistent with the view that stock options makes managers more willing to take risk. On the other hand, we also find that for certain *delta* values, a higher *vega* lowers productivity, which is more consistent with CEO risk aversion. One possible explanation for these puzzling results is given in Ross (2004), who shows that adding call options to a manager's compensation package also increases the *delta* and can actually make a manager more risk-averse, contrary to conventional wisdom.[24] Although we do not explicitly model any feedback between the CEO's *delta* and *vega*, it precisely in the region where *delta* is close to its negative slope threshold that increased *vega* can make the CEO more risk-averse since *delta* is already high. Our findings thus show that awarding managers with stock option grants may not always achieve the intended effect of encouraging more risk-taking behavior.

In sum, we find that CEO incentives have significant real effects on firm performance, which consequently impact firm value. These effects however, are not monotonic. Our findings imply that appropriate combinations of stock and stock option grants should be chosen in order to increase productivity, which consequently increase firm value. Encouragingly, for most of the firms in our sample, we find that CEO compensation structures create incentives that positively impact productivity.[25]

C. Robustness Tests

We perform two categories of robustness tests for our specifications. First, we deal with issues of mis-specifications due to omitted variables or choice of instruments. To mitigate this concern we modify our empirical specifications in Tables 4-6 as follows: 1) exclude R&D and the R&D dummy from the instrument set; 2) include R&D and the R&D dummy in the control group; 3) include leverage in the control group; and 4) include volatility in the control group. The rationale for the first two tests is that although

[24] A similar counter-intuitive observation is made in Carpenter (2000).
[25] It is also possible that the *delta-vega* combination we observe is not the optimal compensation structure chosen by the shareholders, but is a result of two factors: one, the CEO's tenure with the company; and two, the CEO's portfolio rebalancing (to the extent possible). Core and Guay (2002), however, present evidence contrary to this hypothesis. They find that firms award new stock and stock option grants to optimize CEO incentive levels. Their sample is taken from ExecuComp over the period 1992-1997.

R&D is insignificant in our base regression in Table 2, prior work has still found R&D to be a significant determinant of productivity. We perform the third test because previous studies have argued that leverage may also affect productivity indirectly through investment. For example, Lang, Ofek and Stulz (1996) document that leverage is negatively related to investment; this finding is attributed to the Myers (1977) under-investment hypothesis or debt overhang. Finally, the occurrence of productivity shocks over time may induce a correlation between productivity levels and firm volatility. Thus, we also include volatility as a control variable. With these modifications to our empirical model, we obtain results that are very similar to our main findings. In addition, R&D, leverage and volatility have no additional effect on productivity in these alternative specifications.

Second, we estimate some of our main regressions using an alternative econometric specification. Although we believe that the dynamic panel estimator is the most appropriate specification to use since productivity is persistent, we also acknowledge the fact that the test for identifying the correct instrument set are weak when there is a large number of instruments. Therefore, in Table 7 we provide some benchmark models -- static fixed effects instrumental variable regressions (FEIV). Since we cannot correct for productivity persistence in this model we include covariates (such as R&D and the concentration index) that we believe may proxy well for the lagged dependent variable. We use all the instruments from the earlier dynamic panel models and treat the CEO compensation variables as endogenous. Thus this specification corrects for the endogeneity of compensation in the productivity regression but does not address the productivity persistence issue.

We find that the main results are quite similar to those found in the dynamic panel model, with a few differences. For most specifications the sign of all the control variables are similar to earlier results. Firm size and age have a positive impact on productivity similar to earlier results. The R&D variable has no impact and the market concentration index is strongly negative in all specifications suggesting that less competition hinders productivity growth. The CEO compensation variables show some minor differences in sign when compared to the dynamic panel results. However, they are all at least an order of magnitude larger than the earlier results.

Comparing column 1 in Table 7 to column 2 in Table 3 we find that for the static results the productivity index increases by .008 percent in the latter and .08 percent in the former when CEO holdings increase by 1 percent. The coefficients on delta show similar differences in magnitude. Vega is positive and economically very significant in columns 3 and 4 (compared to Table 6 columns 1 and 2). We believe that the difference in results is explained by the fact that we have omitted the lagged productivity variable from our robustness regressions. The last column in Table 7, where a piece-wise function is estimated, does not perform as well as the dynamic panel estimator. However, the direction of effect is the same for all the significant coefficients. Thus, we find that even a simple fixed effects IV model, that may be subject to omitted variable bias, gives us similar results as the dynamic panel model.

IV. Conclusions and Extensions

There has been much interest in the effect of managerial ownership on a firm's financial performance. However, the empirical evidence is mixed and it is still unclear whether managerial ownership has any effect on firm value. In this paper, we trace the effects of CEO incentives on firm value to total factor productivity. In doing so, we examine whether the stock and stock option ownership of CEOs have any real effects on firm performance.

We have two main results: First, we find an inverse U-shaped relationship between productivity and CEO *delta*, which suggests that the high CEO portfolio risk associated with high *delta* discourages CEOs from undertaking risky positive-NPV, productivity-enhancing projects. Second, we also find that CEO *vega* generally increases productivity, consistent with stock option grants making CEOs less concerned with risk due to the down-side protection it offers. However, for a range of *delta* values it may actually reduce productivity, suggesting that stock option grants may not always achieve their intended effect of making CEOs less risk-averse. These results highlight the importance of careful structuring of CEO compensation contracts. Encouragingly, we find that CEO incentives positively impact productivity for the vast majority of the firms in our sample.

We also examine the relationship between productivity and firm value and find that more productive firms have significantly higher Tobin's q. Hence, a CEO's incentives for maximizing shareholder wealth are manifested in the relationship between total factor productivity and CEO incentives. Productivity is thus an important mechanism through which CEO incentives affect firm financial performance.

The focus of this paper has been on the relationship between firm productivity and CEO incentives due to stock and stock option holdings. However, there is much scope for future work. Equity-linked compensation, although a large component of CEO pay, is not the only element. Sundaram and Yermack (2005) find that debt-based compensation, such as pension plans, play an important role in determining the CEO's overall incentives. In particular, they find that high debt-based compensation results in more conservative policy choices for the firm. Beyond executive compensation, we expect that governance structures should also have a significant impact on firm productivity. Numerous studies have examined the effect of board ownership, board structure, shareholder rights and institutional ownership on firm financial performance. A natural extension of this study would be to examine the effect of these various factors on firm productivity.

Appendix A: Estimating Total Factor Productivity

Consider that firms have idiosyncratic efficiencies but face the same market structure and factor prices. Firms produce output (y) using a fixed factor, capital (k), and a variable input such as labor (l), as given by the equation below.

$$y_{it} = \alpha_0 + \beta_1 l_{it} + \beta_2 k_{it} + \omega_{it} + \varepsilon_{it} \quad (2)$$

In this equation, ω_{it} is the efficiency parameter that is unobserved by the econometrician but known by the firm when making investment and staffing decisions. ε_{it} is the idiosyncratic error term. Endogeneity arises from the fact that, 1) the capital stock is correlated with productivity through past productivity and selection bias, and 2) firms with a larger capital stock may continue to produce even at low productivity levels. Thus the coefficient on capital may be biased downward. The selection bias exists because OLS does not control for firm exit, which may occur due to a negative productivity shock.

Olley and Pakes (1996) have developed a methodology for the consistent estimation of a firm-level production function. They assume that efficiency is a function of investment and capital and that there exists a monotonic relationship between investment and unobserved firm-level productivity. They then use this to correct for the simultaneity issue. They correct for the selection bias by calculating the survival probability of a firm. The primary condition that is needed to implement this methodology is that firms have positive investment. For our sample of firms, this condition is easily satisfied.

The estimation sample consists of US manufacturing firms from 1992 to 2003 that are included in Compustat and ExecuComp. We classify these manufacturing firms into industry groups following the Fama-French 49 industry classification.[26] The largest industry group in our sample is 'Chips' and the smallest group is 'Toys'. We calculate the productivity estimates separately for each industry group since the underlying production function parameters may be different across these groups.

The Olley-Pakes methodology yields consistent estimates of the production function for each industry type.[27] Table A1 provides these estimates. Over-all, the input shares of labor and capital are consistent with the estimates of Palia and Lichtenberg (1999) with the exception of electrical equipment, autos & trucks and computer hardware, whose estimated share of capital is not significant. Electrical equipment and computer hardware consist of small precision instruments so it is quite plausible that only the share of labor is significant. The result for autos and trucks, on the other hand, is surprising since we expect this to be a capital-intensive industry. Hence, we drop the auto industry from our sample. As a robustness check, we performed our analyses excluding the electrical equipment and hardware industries; our findings are unchanged. Productivity is then calculated as the residual between the predicted and actual output.

As an alternative to this two-factor production function, we also estimate a production function with labor, capital and materials as inputs; our main findings are unchanged. Moreover, the closest proxy available for material inputs is cost of goods sold (Compustat data item 41). This is a noisy measure of materials since it includes other items such as wages and rent. Thus, our preferred specification is that with only labor and capital as inputs to production.

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[26] We only include those industries that have at least 100 observations during our sample period to obtain reliable productivity estimates. The industries that do not meet this criterion are Beer and Liquor, Boxes (Shipping Containers), Business Services (Commercial Printing), Candy and Soda, Fabricated Products, Guns (Defense), Shipbuilding and Railroad Equipment, and Tobacco – totaling 455 observations. The industry grouping is from Ken French's website.

[27] Both output and inputs to the production function are measured in logs.

Appendix B: Variable Construction

All variables used as covariates are winsorized at the 1 % tails. (Compustat data item in parenthesis)

A. Variables used in the Productivity Estimation

Output = Sales (data12) deflated by the producer price index (PPI) at the four-digit SIC level[28]

Capital Stock = We use the perpetual inventory method to calculate the replacement value of the capital stock. The inputs are gross property plant and equipment (data7), depreciation (data14), capital expenditures (data128) and the price index for non-residential private fixed investment.[29] See Salinger and Summers (1983) for more details.

Labor = Employees (data29)

Investment = Capital expenditures (data128) deflated by the price index for non-residential private fixed investment

B. CEO Incentive Measures

CEO *Holdings* = number of shares of the firm held by the CEO/total shares outstanding

CEO *delta* = Equity *delta* + Option *delta* (or Equity *delta* if Option *delta* is missing)[30]

$$\text{Equity } delta = \left[\partial(\text{equity value}) / \partial(\text{stock price})\right] * (\text{stock price}/100)$$

$$\text{Option } delta = \sum_{j=1}^{N} \left[\partial(\text{option value}_j) / \partial(\text{stock price})\right] * (\text{stock price}/100)$$

$$\text{CEO } vega = \sum_{j=1}^{N} \left[\partial(\text{option value}_j) / \partial(\text{stock return volatility})\right] * (\text{stock return volatility}/100)$$

Equity value is the number of shares outstanding multiplied by the stock price. Option value is calculated using the Black-Scholes (1973) formula for European call options for every option grant *j* awarded to the CEO, accounting for dividends according to Merton (1973). We measure stock return volatility as the standard deviation of monthly returns for the previous 60 months, reported by ExecuComp. If this is missing, it is calculated using CRSP data.[31] See Core and Guay (2002) for more details. CEO *delta* and *vega* are calculated in 2003 dollars.

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[28] The PPI is obtained from the Bureau of Labor and Statistics website.

[29] This price index is obtained from the Bureau of Economic Analysis website.

[30] There are 279 firm-year observations for which there is insufficient information to calculate the CEO's option *delta* and *vega*.

[31] Our findings are unchanged if we use the standard deviation of daily returns for the previous 252 trading days.

C. Variables used as Determinants of Productivity

Firm Size = Log(Total Assets) (data6) [32]

Firm age = current year – incorporation year[33] where available; if the incorporation year is unavailable, we use the earliest year on CRSP that a firm has a positive stock price or the earliest year in Compustat that a firm has non-missing data for total assets

Industry Concentration Index = Herfindahl Index based on Compustat data. This is given by: $\Sigma\alpha_i^2$ where α_i is the output (sales) share of each firm in the industry in that particular year and is summed over all firms in the industry. This is an industry concentration measure and the closer to zero this measure is, the more competitive the industry.

R&D/K = R&D expenditures / net property, plant and equipment (data46/data8)

R&D dummy = equals one if R&D is non-missing, equals zero otherwise; missing values of R&D are set to zero

D. Additional Variables used in the Tobin's q Regressions

Tobin's q = (data199*data25+ 10*data19 + data181)/data6, following Himmelberg, Hubbard and Palia (1999)

Tangible Assets, K/S = net property, plant and equipment / sales (data8/data12)

Investment, I/K = capital expenditures / net property, plant and equipment (data128/data8)

E. Additional Variables Used as Instruments for CEO Incentive Measures

CEO Tenure = current year – year the executive became CEO, as reported in ExecuComp

Advertising/K = Advertising expenditures / net property, plant and equipment (data45/data8)

Advertising dummy = equals one if Advertising is non-missing, equals zero otherwise; missing values of Advertising are set to zero

Volatility = the standard deviation of the previous 60 months stock returns, reported by ExecuComp, and if missing, is calculated from CRSP

Book leverage = (data6-book equity)/data6 where book equity = (data6 – data181 + data35 – data10)

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[32] The use of total sales as a measure of firm size leaves our results mostly unchanged and qualitatively similar. We remain cautious however, with this alternative specification because total sales is the measure of output in the productivity estimation.

[33] We are grateful to John Ritter for the use of his data on incorporation dates.

References

Agrawal, Anup and Charles R. Knoeber, 1996, "Firm Performance and Mechanisms to Control Agency Problems between Managers and Shareholders," *Journal of Financial and Quantitative Analysis, Vol. 31(3), pp. 377-397.*

Arellano, Manuel and Stephen Bond, 1991, "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *Review of Economic Studies, Vol.* 58, pp. 277-297.

Aw, Bee Yan, Xiaomin Chen and Mark J. Roberts, 2001, "Firm-level Evidence on Productivity Differentials and Turnover in Taiwanese Manufacturing," *Journal of Development Economics, Vol. 66(1), pp. 51-86.*

Bartelsman, Eric J. and Mark Doms, 2000, "Understanding Productivity: Lessons from Longitudinal Microdata", *Journal of Economic Literature*, vol. 38(3), pages 569-594, September..

Barth, Erling, Trygve Gulbrandsen, and Pål Schøne, 2005, "Family Ownership and Productivity: The Role of Owner-Management," *Journal of Corporate Finance, Vol. 11, pp. 107-127.*

Basant, Rakesh and Brian Fikkert, 1996, "The Effects of R&D, Foreign Technology Purchase, and Domestic and International Spillovers on Productivity in Indian Manufacturing Firms," *Review of Economics and Statistics, Vol. 782, pp. 187 – 199.*

Basu, Susanto, John G. Fernald, and Matthew D. Shapiro, 2001, "Productivity Growth in the 1990s: Technology, Utilization or Adjustment?" *Carnegie-Rochester Conference Series on Public Policy*, *Vol. 55, pp. 117-165*.

Berle, Adolph and Gardiner Means, 1932, The Modern Corporation and Private Property, Macmillan, New York.

Biesebroeck, Johannes V., 2004. "Robustness of Productivity Estimates," *NBER Working Paper No.* 10303

Black, Fischer and Myron Scholes, 1973, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy, Vol. 81, pp. 637-659.*

Black, Sandra. E. and Lisa M. Lynch, 2003, "What's driving the New Economy: The Benefits of Workplace Innovation," *California Centre for Population Research Working Paper, CCPR-017-03.*

Brick, Ivan E., Darius Palia, and Chia-Jane Wang, 2005, "Simultaneous Estimation of CEO Compensation, Leverage, and Board Characteristics on Firm Value", *Working paper*.

Cadman, Brian, Sandy Klasa and Steve Matsunaga, 2006, "Evidence on How Systematic Differences Between ExecuComp and non-ExecuComp Firms Can Affect Empirical Research Results," *Northwestern University Working Paper*

Carpenter, Jennifer N., 2000, "Does Option Compensation Increase Managerial Risk Appetite?" *Journal of Finance, Vol. 55, pp. 2311-2331.*

Claessens, Stijn, Simeon Djankov, Joseph P. H. Fan and Larry H. P. Lang, 2002, "Disentangling the Incentive and Entrenchment Effect of Large Shareholdings," *University of Amsterdam, Working Paper.*

Cho, Myeong-Hyeon, (1998), "Ownership Structure, Investment, and the Corporate Value: An Empirical Analysis," *Journal of Financial Economics, Vol. 47, pp. 103-121.*

Coles, Jeffrey L., Naveen D. Daniel, and Lalitha Naveen, 2006, "Managerial Incentives and Risk-Taking," *Journal of Financial Economics, Vol. 79, pp. 431-468.*

Coles, Jeffrey L., Michael L. Lemmon, and Felix Meschke, 2007, "Structural Models and Endogeneity in Corporate Finance: The Link Between Managerial Ownership and Corporate Performance," *Working Paper, Arizona State University.*

Core, John and Wayne Guay, 1999, "The Use of Equity Grants to Manage Optimal Equity Incentive Levels," *Journal of Accounting and Economics, Vol. 28, pp. 151-184.*

Core, John and Wayne Guay, 2002, "Estimating the Value of Employee Stock Option Portfolios and Their Sensitivities to Price and Volatility," *Journal of Accounting Research, Vol. 40(3), pp. 613-630.*

Cui, Huimin and Y.T. Mak, 2002, "The Relationship Between Managerial Ownership and Firm Performance in High R&D Firms," *Journal of Corporate Finance, Vol. 8, pp. 313-336.*

Demsetz, Harold, 1983, "The Structure of Ownership and the Theory of the Firm," *Journal of Law and Economics, Vol. 26, pp. 375-390.*

Demsetz, Harold and Belen Villalonga, 2001, "Ownership Structure and Corporate Performance," *Journal of Corporate Finance, Vol. 7, pp. 209-233.*

Fama, Eugene F. and Michael C. Jensen, 1983, "Separation of Ownership and Control," *Journal of Law and Economics, Vol. 26, pp. 301-325.*

Griliches, Zvi, 1980, "R&D and Productivity Slowdown," *American Economic Review, Papers and Proceedings of the Ninety-Second Annual Meeting of the American Economic Association, Vol. 70(2), pp. 343-348.*

Griliches, Zvi, 1986, "Productivity, R&D, and Basic Research at the Firm Level in the 1970's," *American Economic Review, Vol. 76(1), pp. 141-154.*

Griliches, Zvi and Frank R. Lichtenberg, 1984, "Interindustry Technology Flows and Productivity Growth: A Reexamination**",** *Review of Economics and Statistics, Vol. 66(2), pp. 324-329.*

Guay, Wayne, 1999, "The Sensitivity of CEO Wealth to Equity Risk: An Analysis of the Magnitude and Determinants," *Journal of Financial Economics, Vol. 53, pp. 43-71.*

Hall, Brian J. and Jeffrey B. Liebman, 1998, "Are CEOs Really Paid Like Bureaucrats?" *Quarterly Journal of Economics, Vol. 113, pp. 653-691.*

Haltiwanger, John C., Lulia I. Lane, and James R. Speltzer, 1999, "Firm Size and Wages - Productivity Differences Across Employers: The Roles of Employer Size, Age, and Human Capital", *American Economic Review, Vol. 89(2), pp. 94 – 99.*

Haskell, Jonathan E., Sonia C. Pereira, and Matthew J. Slaughter, 2004, "Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms", *Working Paper.*

Hermalin, Benjamin E., and Michael S. Weisbach, 1991, "The Effects of Board Composition and Direct Incentives on Firm Performance," *Financial Management, Vol. 20, pp. 101-112.*

Himmelberg, Charles P., Glenn R. Hubbard, and Darius Palia, 1999, "Understanding the Determinants of Managerial Ownership and The Link Between Ownership and Performance," *Journal of Financial Economics, Vol. 53, pp. 353-384.*

Holderness, Clifford G., Randall S. Kroszner, and Dennis P. Sheehan, 1999, "Were the Good Old Days That Good? Evolution of Managerial Stock Ownership and Corporate Governance Since the Great Depression," *Journal of Finance, Vol. 54, pp. 435-469.*

Huergo, Elena and Jordi Jaumandreu, 2004, "Firms' Age, Process Innovation and Productivity Growth", *International Journal of Industrial Organization, Vol. 22(4), pp. 541 – 561.*

Jensen, Michael C., 1986, "Agency Costs of Free Cash Flow, Corporate Finance and Takeovers," *American Economic Review, Vol. 76(2), pp. 323-329.*

Jensen, Michael C. and William Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure," *Journal of Financial Economics, Vol. 3, pp. 305-360.*

Jensen, Michael C., Kevin J. Murphy and Eric G. Wruck, 2004, "Remuneration: Where we've been, how we got to here, what are the problems and how to fix them," *ECGI Finance Working Paper # 44.*

Jensen, Michael C. and Jerold B. Warner, 1988, "The Distribution of Power Among Corporate Managers, Shareholders and Directors," *Journal of Financial Economics, Vol. 3, pp. 3-24.*

Keller, Wolfgang, 1997, "Are International R&D Spillovers Trade-Related? Analyzing Spillovers Among Randomly Matched Trade Partners", *European Economic Review, Vol. 42(8), pp. 1469 – 1483.*

Keller, Wolfgang, 1999, "How Trade Patterns and Technology Flows Affect Productivity Growth", *NBER Working Paper Series, No. 6990.*

Keller, Wolfgang and Stephen R.Yeaple, 2003, "Multinational Enterprises, International Trade and Productivity Growth: Firm Level Evidence From the United States", *NBER Working Paper Series, No. 9504.*

Köke, Jens F. and Luc Renneboog, 2005, "Do Corporate Control and Product Market Competition Lead to Stronger Productivity Growth? Evidence from Market-Oriented Blockholder-Based Governance Regimes," *Journal of Law and Economics, Vol. 48, pp. 475-516.*

Lang, Larry, Eli Ofek and Rene M. Stulz, 1996, "Leverage, Investment, and Firm Growth," *Journal of Financial Economics, Vol. 40, pp. 3-29.*

Lehr, Bill and Frank Lichtenberg, 1997, "Information Technology and Its Impact on Firm-Level Productivity: Evidence from Government and Private Data Sources", *Centre for Study of Living Standards Conference on Service Sector Productivity and the Productivity Paradox, Working Paper.*

Loderer, Claudio and Kenneth Martin, 1997, "Executive Stock Ownership and Performance: Tracking Faint Traces," *Journal of Financial Economics, Vol. 45, pp. 223-255.*

McConnell, John J. and Henri Servaes, 1990, "Additional Evidence on Equity Ownership and Corporate Value," *Journal of Financial Economics, Vol. 27, pp. 595-612.*

Merton, Robert, 1973, "Theory of Rational Option Pricing," *Bell Journal of Economics and Management Science, Vol. 4, pp. 141-183.*

Morck, Randall, Andrei Shleifer, and Robert W. Vishny, 1988, "Management Ownership and Market Valuation: An Empirical Analysis," *Journal of Financial Economics, Vol. 20, pp. 293-315.*

Murphy, Kevin J., 1999, "Executive Compensation," Handbook of Labor Economics, Ashenfelter, O., Card, D. (editors), Elsevier Science, North Holland, *Vol. 3b, pp.2485-2563.*

Myers, Stewart C., 1977, "Determinants of Corporate Borrowing," *Journal of Financial Economics, Vol. 5, pp. 147-175.*

Nickell, Stephen, Daphne Nicolitsas, and Neil Dryden, 1997, "What Makes Firms Perform Well?" *European Economic Review*, *Vol. 41, pp.783-796.*

Olley, Steven G. and Ariel Pakes, 1996, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica, Vol. 64(6), pp. 1263 – 1298.*

Ozler, Sule and Kamil Yilmaz, 2001, "Does Trade Liberalization Improve Productivity: Plant-Level Evidence from Turkish Manufacturing Firms," *Working Paper*.

Palia, Darius, 2001, "The Endogeneity of Managerial Compensation in Firm Valuation: A Solution," *Review of Financial Studies, Vol. 14(3), pp. 735-764.*

Palia, Darius and Frank Lichtenberg, 1999, "Managerial Ownership and Firm Performance: A Re-Examination Using Productivity Measurement," *Journal of Corporate Finance, Vol. 5, pp. 323-339.*

Pavcnik, Nina, 2002,"Trade Liberalization, Exit and Productivity Improvements: Evidence from Chilean Plants", *Review of Economic Studies, Vol. 69(238), pp.245-276* .

Perez-Gonzales, Francisco, 2004, "The Impact of Acquiring Control on Productivity," W*orking paper, Columbia University.*

Perry, Todd and Marc Zenner, 2000, "CEO Compensation in the 1990s: Shareholder Alignment or Shareholder Expropriation?" *Wake Forest Law Review, Vol. 35, pp. 123-152*.

Rogers, Mark, 2004,"Competition, Agency and Productivity," *International Journal of the Economics of Business, Vol. 11(3), pp. 349-367.*

Ross, Stephen A., 2004, "Compensation, Incentives, and the Duality of Risk Aversion and Riskiness," *Journal of Finance, Vol. 59(1), pp. 207-225.*

Salinger, Michael A. and Lawrence Summers, 1983, "Tax reform and corporate investment: A microeconomic simulation study," Behavioral Simulation Methods in Tax Policy Analysis, edited by M. Feldstein, Chicago: University of Chicago Press, pp. 247-286

Smith, Clifford W. and Rene M. Stulz, 1985, "The Determinants of Firm's Hedging Policies," *Journal of Financial and Quantitative Analysis*, *Vol. 20(4), pp. 391-405.*

Soderbom, Mans M. and Francis Teal, 2001, "Firm Size and Human Capital as Determinants of Produtivity and Earnings," *Working Paper, University of Oxford*.

Sundaram, Rangarajan K. and David L. Yermack, 2005, "Pay Me Later: Inside Debt and Its Role in Managerial Compensation," *Journal of Finance, forthcoming.*

Tang, Jianmin and Weiming Wang, 2005, "Product Market Competition, Skill Shortages and Productivity: Evidence from Canadian Manufacturing Firms", *Journal of Productivity Analysis, Vol. 23(3), pp. 317-33.*

Tirole, Jean, 1999, "Incomplete Contracts: Where do we stand?" *Econometrica, Vol. 67(4), pp. 741-781.*

Windmeijer, Frank, 2005, "A finite sample correction for the variance of linear efficient two-step GMM estimators," *Journal of Econometrics, Vol. 126, pp. 25-51.*

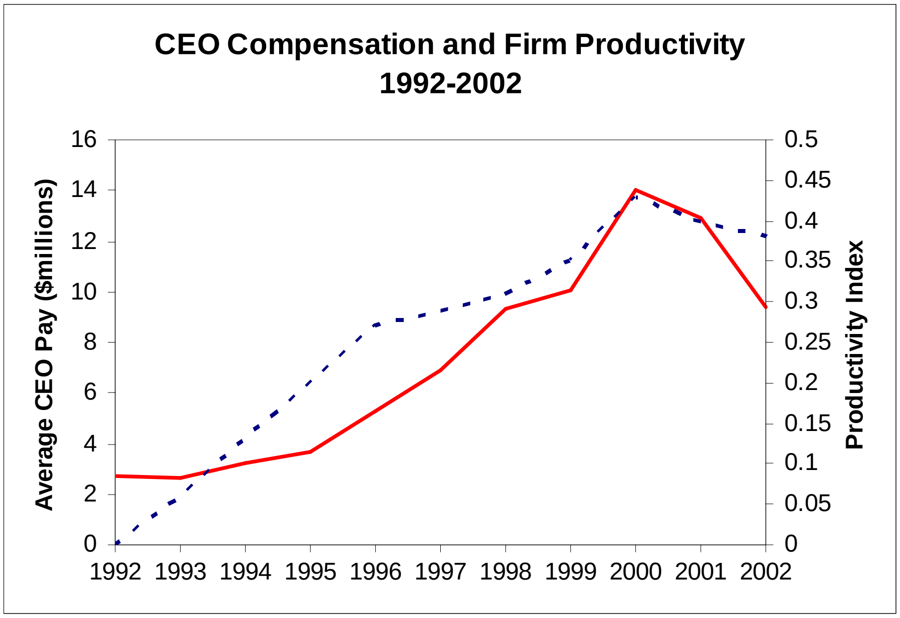

Figure 1. The solid line represents the average CEO compensation package (2002 dollars) that includes salary, bonus, stock and options, for S&P 500 firms. This data is taken from Jensen, Murphy and Wruck (2004). The dashed line represents total factor productivity, whose estimation is described in Section I. This data covers 20 manufacturing industries from Compustat and Execucomp.

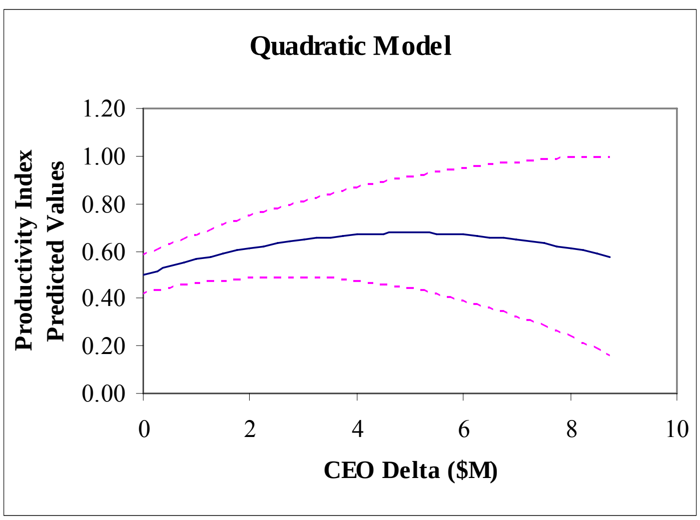

Figure 2: The solid line represents predicted values of the productivity index as a quadratic function of CEO *delta*, estimated from Table 4, column 5. The region between the dashed lines represents the 95 % confidence interval. The maximum productivity level is achieved at CEO *delta* = $5 million.

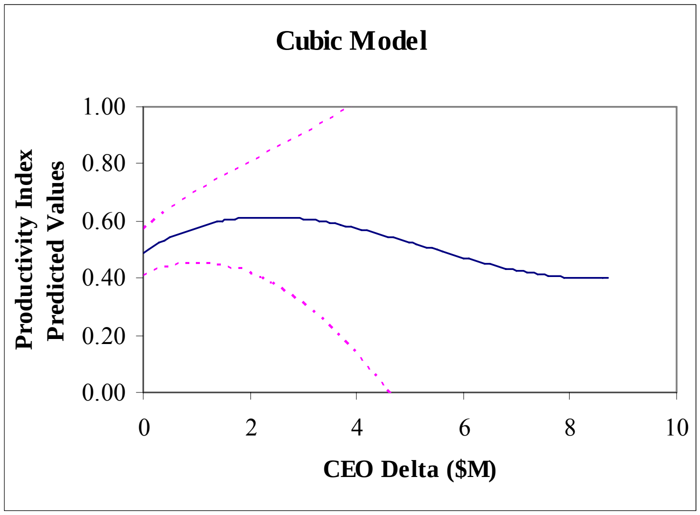

Figure 3: The solid line represents predicted values of the productivity index as a cubic function of CEO *delta*, estimated from Table 4, column 6. The region between the dashed lines represents the 95 % confidence interval. The local maximum and minimum levels of productivity are achieved at $2.3 million and $8.3 million respectively.

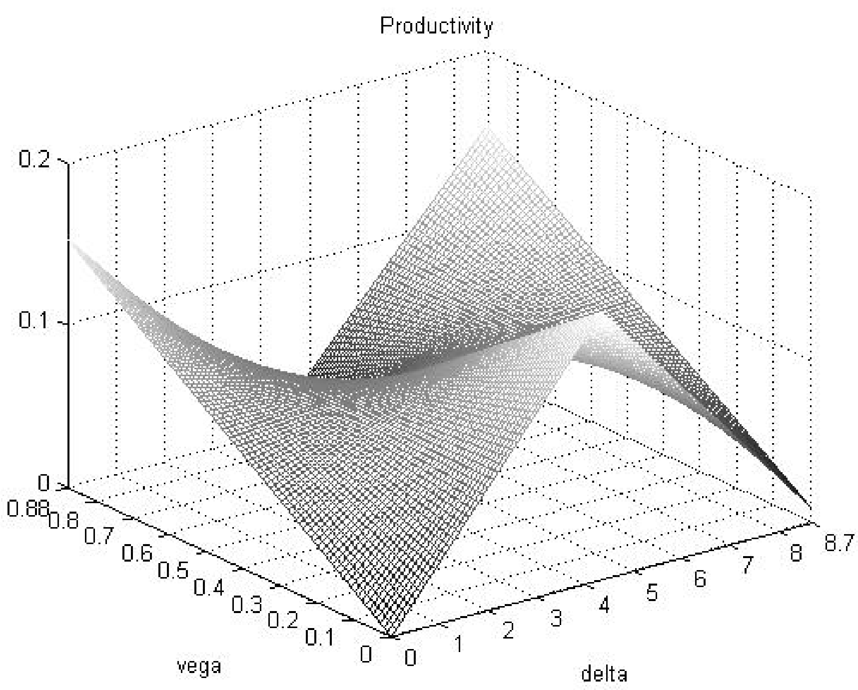

Figure 4: Relationship between CEO d*elta*, v*ega* and productivity. *Delta* and *vega* are measured in millions of dollars. Productivity is the productivity index described in Section I.

TABLE 1A
DESCRIPTIVE STATISTICS
Estimation Sample (1992-2003)

	Mean	Median	Std. Dev.	Min.	Max.	Obs.
Firm Characteristics						
Productivity Index	0.30	0.26	0.49	-1.77	1.99	6636
Total Assets ($M)	3359.24	930.87	6689.52	19.18	40657.21	6636
Total Sales ($M)	3199.11	945.63	6318.46	5.25	42245.13	6636
Firm Age	38.91	43.00	21.29	1.00	147.00	6636
Industry Concentration Index	580.38	465.19	495.07	275.14	3618.07	6636
Tobin's Q	2.28	1.69	2.00	0.50	34.69	6621
Tangible Assets, K/S (Net Property, Plant and Equipment/Total Sales)	0.29	0.22	0.26	0.03	1.75	6635
Investment, I/K (Capital Expenditures/Total Sales)	0.24	0.20	0.15	0.03	0.85	6570
Book Leverage	0.47	0.49	0.20	0.01	1.00	6461
Volatility	43.28	37.30	20.51	16.50	110.42	6607
RD/K (R&D/Net Property, Plant and Equipment)	0.45	0.16	0.78	0	4.80	5225
AD/K (Advertising/Net Property, Plant and Equipment)	0.24	0.09	0.34	0	1.45	2101
CEO Characteristics						
Holdings (%)	2.81	0.39	6.13	0	33.38	6636
Delta ($M)	0.54	0.18	1.17	0.000116	8.70	6636
Vega ($M)	0.08	0.03	0.14	0	0.88	6386
Tenure (years)	7.17	4.90	7.29	0	48.36	6636

Notes: The primary sample of 6,636 observations is based on non-missing observations for the productivity index, lagged productivity index, total assets, firm age and CEO holdings. Total assets, total sales, *delta* and *vega* are reported in 2003 dollars.

TABLE 1B
SAMPLE CORRELATIONS
Estimation Sample (1992-2003)

	Prod. Index	Assets	Sales	Firm Age	Industry Conc.	Tobin's q	K/S	I/K	Leverage	Volatility
Productivity Index	1									
Assets	0.1004	1								
Sales	0.1276	0.9394	1							
Firm Age	-0.149	0.3549	0.3557	1						
Industry Concentration	-0.0201	0.0316	0.0435	0.0409	1					
Tobin's q	0.1605	-0.0232	-0.0256	-0.2193	-0.0155	1				
K/S	-0.3083	0.1274	0.0432	-0.0109	-0.1284	-0.0171	1			
I/K	0.262	-0.1507	-0.1403	-0.3427	0.023	0.3466	-0.1824	1		
Leverage	-0.0789	0.2344	0.2549	0.3554	0.0345	-0.296	-0.0035	-0.3367	1	
Volatility	0.2229	-0.2733	-0.2961	-0.4096	-0.0225	0.1623	0.0452	0.3216	-0.2766	1
R&D/K	0.2048	-0.1523	-0.1646	-0.354	0.0039	0.287	-0.0476	0.4172	-0.3049	0.4925
AD/K	0.1996	-0.0628	-0.0259	0.0716	0.327	0.0952	-0.3336	0.1799	0.0429	0.023
CEO Holdings	-0.0674	-0.1553	-0.1477	-0.148	0.0428	0.0077	-0.0724	0.066	-0.1848	0.0593
CEO *Delta*	0.1533	0.1433	0.1434	-0.0069	0.0425	0.2772	-0.0436	0.0768	-0.0965	-0.0497
CEO *Vega*	0.1449	0.4798	0.4253	0.2149	0.0242	0.1251	0.0355	-0.0602	0.1318	-0.124
CEO Tenure	-0.0076	-0.0712	-0.0636	-0.0592	0.0281	0.0357	-0.027	0.04	-0.1055	0.0097

	R&D/K	AD/K	CEO Holdings	CEO *Delta*	CEO *Vega*	CEO Tenure
R&D/K	1					
AD/K	0.1519	1				
CEO Holdings	-0.0147	0.1194	1			
CEO *Delta*	-0.0301	0.1616	0.4592	1		
CEO *Vega*	-0.0546	0.0104	-0.154	0.2783	1	
CEO Tenure	0.0142	0.0008	0.3056	0.2479	0.0085	1

TABLE 2
EXPLAINING LONG-RUN AND SHORT-RUN FIRM PERFORMANCE

	(1)	(2)
Dependent Variable	Productivity Index	Tobin's Q
Lagged Productivity Index	0.468***	
	(0.047)	
Productivity Estimate		0.464***
		(0.121)
Firm Age	0.075***	
	(0.009)	
Log(Assets)	0.049*	-0.396***
	(0.029)	(0.063)
Lagged Industry Concentration	-0.027	-0.014
Index	(0.064)	(0.128)
R&D/K	-0.019	0.153
	(0.044)	(0.126)
Tangible Assets, K/S		-0.424*
		(0.250)
Investment, I/K		1.294***
		(0.239)
Advertising/K		0.033
		(0.203)
Book Leverage		-0.974***
		(0.211)
Volatility		-0.006**
		(0.002)
Relevant Statistics		
Observations	6596	6341
Number of Firms	902	908
Wald Statistic	942.628	
Hansen J Statistic p-value	0.000	
Arellano-Bond *m2* Statistic p-value	0.984	
Adjusted R-Square		0.142
F Statistic		21.345

Notes: Col 1: Arellano-Bond dynamic panel data estimation (difference-GMM). Unbalanced Panel. Range 1992- 2003. All specifications contain year fixed effects. Windmeijer (2005) robust standard errors are reported in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. The Hansen J test is a test of over-identifying restrictions. The Arellano-Bond *m2* test is a test of lack of serial correlation in the error term. For both tests, p-values less than 0.10 reject the validity of the instruments.
Col 2: Firm fixed effects estimation. Unbalanced Panel. Range 1992- 2003. Q is restricted to be less than 10. All specifications contain year fixed effects. The smaller sample size in column (3) is due to missing data in the construction of book leverage. Standard errors (in parentheses) are robust and clustered by firm. * significant at 10%; ** significant at 5%; *** significant at 1%. Robustness checks include: 1) the addition of log(assets) squared and tangible assets squared as explanatory variables, and 2) substituting the productivity index for the productivity estimate.

TABLE 3
INFLUENCE OF CEO HOLDINGS
Dependent Variable: Productivity Index

	(1)	(2)	(3)
CEO Incentives			
Holdings (%)	0.004* (0.002)	0.009* (0.005)	0.008 (0.010)
Holdings Squared		-0.0002 (0.0001)	-0.0002 (0.001)
Holdings Cubed			-0.000001 (0.00001)
Control Variables			
Lagged Productivity Index	0.318*** (0.045)	0.318*** (0.043)	0.319*** (0.042)
Firm Age	0.073*** (0.008)	0.073*** (0.008)	0.073*** (0.008)
Log(Assets)	0.061** (0.024)	0.062*** (0.023)	0.060*** (0.022)
Relevant Statistics			
Observations	5601	5601	5601
Number of Firms	886	886	886
Wald Statistic	580.415	583.039	602.432
Hansen J Statistic p-value	0.200	0.339	0.487
Arellano-Bond *m2* Statistic p-value	0.819	0.813	0.809

Notes: Arellano-Bond dynamic panel data estimation (difference-GMM).Unbalanced Panel. Range 1992 – 2003. All specifications contain year fixed effects. Additional pre-determined variables used as instruments in the estimation: CEO tenure, volatility, R&D/K, Advertising/K, book leverage, and R&D and Advertising dummies. Windmeijer (2005) robust standard errors are reported in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%. The Hansen J test is a test of over-identifying restrictions. The Arellano-Bond *m2* test is a test of lack of serial correlation in the error term. For both tests, p-values less than 0.10 reject the validity of the instruments.

TABLE 4
INFLUENCE OF CEO DELTA
Dependent Variable: Productivity Index

	(1)	(2)	(3)	(4)	(5)	(6)
CEO Incentives						
Holdings (%)	0.003	0.001	0.001			
	(0.002)	(0.002)	(0.002)			
Delta ($M)	0.004	0.065***	0.111***	0.011*	0.070***	0.117***
	(0.007)	(0.021)	(0.035)	(0.006)	(0.021)	(0.034)
Delta Squared		-0.007***	-0.029***		-0.007***	-0.032***
		(0.002)	(0.010)		(0.002)	(0.010)
Delta Cubed			0.002***			0.002***
			(0.001)			(0.001)
Control Variables						
Lagged Productivity Index	0.311***	0.310***	0.304***	0.309***	0.302***	0.302***
	(0.044)	(0.043)	(0.044)	(0.044)	(0.044)	(0.043)
Firm Age	0.071***	0.068***	0.066***	0.070***	0.067***	0.066***
	(0.008)	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)
Log(Assets)	0.067***	0.081***	0.077***	0.057***	0.067***	0.061***
	(0.022)	(0.021)	(0.021)	(0.022)	(0.021)	(0.021)
Relevant Statistics						
Observations	5601	5601	5601	5601	5601	5601
Number of Firms	886	886	886	886	886	886
Wald Statistic	566.977	592.875	579.576	534.230	562.321	568.542
Hansen J Statistic p-value	0.257	0.157	0.155	0.150	0.256	0.448
Arellano-Bond *m2* Statistic p-value	0.821	0.958	0.945	0.805	0.926	0.919

Notes: Arellano-Bond dynamic panel data estimation (difference-GMM).Unbalanced Panel. Range 1992 – 2003. All specifications contain year fixed effects. Additional pre-determined variables used as instruments in the estimation: CEO tenure, volatility, R&D/K, Advertising/K, book leverage, and R&D and Advertising dummies. Windmeijer (2005) robust standard errors are reported in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%. The Hansen J test is a test of over-identifying restrictions. The Arellano-Bond *m2* test is a test of lack of serial correlation in the error term. For both tests, p-values less than 0.10 reject the validity of the instruments.

TABLE 5

INFLUENCE OF CEO DELTA: PIECE-WISE LINEAR SPECIFICATION

Dependent Variable: Productivity Index

	(1)	(2)	(3)	(4)
Percentile Threshold	P1=P2=97th	P1=P2=98th	P1=95th, P2=99th	P1=96th, P2=99th
CEO Incentives				
*Delta*1 [0< *Delta* ($M) ≤ P1]	0.049***	0.038***	0.062***	0.055***
	(0.015)	(0.012)	(0.021)	(0.018)
*Delta*2 [P1< *Delta* ($M) ≤ P2]			-0.022*	-0.028**
			(0.012)	(0.014)
*Delta*3 [P2 ≤ *Delta* ($M)]	-0.019**	-0.026**	0.158	0.186*
	(0.009)	(0.013)	(0.102)	(0.112)
Control Variables				
Lagged Productivity Index	0.300***	0.305***	0.304***	0.302***
	(0.044)	(0.044)	(0.043)	(0.043)
Firm Age	0.068***	0.069***	0.067***	0.067***
	(0.009)	(0.009)	(0.009)	(0.009)
Log(Assets)	0.067***	0.066***	0.062***	0.063***
	(0.021)	(0.021)	(0.021)	(0.021)
Relevant Statistics				
Observations	5601	5601	5601	5601
Number of Firms	886	886	886	886
Wald Statistic	570.963	575.999	574.381	573.187
Hansen J Statistic p-value	0.193	0.180	0.226	0.246
Arellano-Bond *m2* Statistic p-value	0.908	0.890	0.907	0.899

Notes: Arellano-Bond dynamic panel data estimation (difference-GMM).Unbalanced Panel. Range 1992 – 2003. All specifications contain year fixed effects. Additional pre-determined variables used as instruments in the estimation: CEO tenure, volatility, R&D/K, Advertising/K, book leverage, and R&D and Advertising dummies. Windmeijer (2005) robust standard errors are reported in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%. The Hansen J test is a test of over-identifying restrictions. The Arellano-Bond *m2* test is a test of lack of serial correlation in the error term. For both tests, p-values less than 0.10 reject the validity of the instruments. *Delta*1=*Delta* if 0< *Delta* ≤ P1, and equals P1 if *Delta* > P1. *Delta*2=0 if 0< *Delta* ≤ P1, equals *Delta* –P1 if P1< *Delta* ≤ P2, and equals P2-P1 if *Delta* > P2. *Delta*2=0 if P1=P2. *Delta*3=0 if *Delta* ≤ P2, and equals *Delta*-P2 if *Delta* > P2. Top percentiles (P1 and P2) for *Delta* are the following: 95th= $2.26M, 96th=$2.69M, 97th=$3.34M, 98th=$4.34M, 99th=$8.24M.

TABLE 6
INFLUENCE OF CEO VEGA
Dependent Variable: Productivity Index

	(1)	(2)	(3)
CEO Incentives			
Delta ($M)	0.065***		
	(0.022)		
Delta Squared	-0.007***		
	(0.003)		
Vega ($M)	0.031	0.038	0.174**
	(0.053)	(0.052)	(0.075)
*Delta*1 [0< *Delta* ($M) ≤ P]		0.034***	0.038***
		(0.012)	(0.012)
*Delta*1**Vega*			-0.081***
			(0.027)
*Delta*2 [P < *Delta* ($M)]		-0.025*	-0.036**
		(0.013)	(0.015)
*Delta*2**Vega*			0.079**
			(0.033)
Control Variables			
Lagged Productivity Index	0.300***	0.304***	0.314***
	(0.043)	(0.043)	(0.041)
Firm Age	0.069***	0.070***	0.073***
	(0.009)	(0.009)	(0.009)
Log(Asset)	0.053**	0.053**	0.047**
	(0.023)	(0.023)	(0.022)
Relevant Statistics			
Observations	5248	5248	5248
Number of Firms	877	877	877
Wald Statistic	516.959	519.273	532.465
Hansen J Statistic p-value	0.400	0.421	0.346
Arellano-Bond *m2* Statistic p-value	0.835	0.812	0.828

Notes: Arellano-Bond dynamic panel data estimation (difference-GMM).Unbalanced Panel. Range 1992 – 2003. All specifications contain year fixed effects. Additional pre-determined variables used as instruments in the estimation: CEO tenure, volatility, R&D/K, Advertising/K, book leverage, and R&D and Advertising dummies. Windmeijer (2005) robust standard errors are reported in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%. The Hansen J test is a test of over-identifying restrictions. The Arellano-Bond *m2* test is a test of lack of serial correlation in the error term. For both tests, p-values less than 0.10 reject the validity of the instruments. *Delta*1=*Delta* if 0< *Delta* ≤ P, and equals P if *Delta* > P. *Delta*2=0 if 0 *Delta* ≤ P, and equals *Delta*-P if *Delta* > P. The threshold point, P, for *Delta* is the 98th percentile ($4.34M). Similar results are obtained using threshold values equal to the 95th, 96th, and 97th percentiles.

TABLE 7
ROBUSTNESS TESTS
Dependent Variable: Productivity Index

	(1)	(2)	(3)	(4)	(5)
CEO Incentives					
Holdings (%)	0.080***	-0.070			
	(0.028)	(0.059)			
Holdings Squared	-0.006***	0.001			
	(0.002)	(0.003)			
Delta ($M)		0.823***	0.405*		
		(0.319)	(0.221)		
Delta Squared		-0.131**	-0.100**		
		(0.066)	(0.045)		
Vega ($M)			0.966*	0.942*	-2.094
			(0.550)	(0.564)	(1.974)
Delta1 [0< Delta ($M) ≤ P]				0.210*	-0.063
				(0.129)	(0.219)
Delta1*Vega					-0.899*
					(0.570)
Delta2 [P < Delta ($M)]				-1.089**	2.374*
				(0.431)	(1.326)
Delta2*Vega					-0.456
					(3.655)
Control Variables					
Firm Age	0.017***	0.008*	0.00001	0.002	0.012
	(0.003)	(0.005)	(0.007)	(0.007)	(0.018)
Log(Asset)	0.074***	-0.002	0.088***	0.086***	0.075
	(0.015)	(0.040)	(0.023)	(0.023)	(0.064)
Lagged Log(R&D)	0.006	0.006	0.001	0.002	-0.005
	(0.006)	(0.007)	(0.007)	(0.007)	(0.010)
Lagged Log Industry	-0.167***	-0.082*	-0.151***	-0.136***	-0.120*
Concentration Index	(0.034)	(0.049)	(0.045)	(0.048)	(0.066)
Relevant Statistics					
Observations	5523	5522	5332	5332	5332
Number of Firms	801	800	797	797	797
Wald Statistic	6593.852	4754.558	4235.505	4007.224	2655.937

Notes: Fixed effects instrumental variable panel data estimation.Unbalanced Panel. Range 1992 – 2003. All specifications contain year fixed effects and a constant term. Instruments in the estimation: CEO tenure, volatility, R&D/K, Advertising/K, book leverage, and R&D and Advertising dummies. Standard errors are reported in parentheses: * significant at 10%; ** significant at 5%; *** significant at 1%. *Delta*1=*Delta* if 0< *Delta* ≤ P, and equals P if *Delta* > P. *Delta*2=0 if 0 *Delta* ≤ P, and equals *Delta*-P if *Delta* > P. The threshold point, P, for *Delta* is the 98th percentile ($4.34M). Similar results are obtained using threshold values equal to the 95th, 96th, and 97th percentiles.

TABLE A1

PRODUCTION FUNCTION ESTIMATES BY INDUSTRY: OLLEY-PAKES (1996) METHODOLOGY

Manufacturing Industries (SIC codes 2000-3999)

Factor Inputs	Food	Toys / Recreation	Books	Consumer Goods	Clothing	Medical Equipment	Drugs	Chemicals	Rubber & Plastics	Textiles	Building Materials
Capital	0.429***	0.278***	0.370***	0.544***	0.376***	0.287***	0.065**	0.266***	0.314***	0.191**	0.216***
	(0.024)	(0.056)	(0.061)	(0.044)	(0.042)	(0.052)	(0.027)	(0.010)	(0.044)	(0.077)	(0.018)
Labor	0.399***	0.689***	0.419***	0.165***	0.398***	0.708***	1.152***	0.482***	0.778***	0.713***	0.745***
	(0.033)	(0.085)	(0.081)	(0.059)	(0.067)	(0.060)	(0.024)	(0.024)	(0.078)	(0.093)	(0.025)
Observations	444	154	256	389	292	506	801	605	110	188	484

Factor Inputs	Steel	Machinery	Electrical Equipment	Autos & Trucks	Aircraft	Petroleum & Gas	Computer Hardware	Electronic Equipment	Lab Equipment	Business Supplies
Capital	0.324***	0.247***	0.005	0.013	0.265**	0.362***	0.058	0.079***	0.144***	0.210***
	(0.023)	(0.031)	(0.039)	(0.031)	(0.118)	(0.028)	(0.042)	(0.018)	(0.013)	(0.010)
Labor	0.507***	0.622***	1.045***	0.939***	0.750***	0.904***	0.874***	0.798***	0.733***	0.813***
	(0.041)	(0.034)	(0.040)	(0.037)	(0.148)	(0.064)	(0.048)	(0.019)	(0.018)	(0.019)
Observations	508	799	249	445	103	182	302	1396	450	438

Notes: The production function is estimated separately by industry. Productivity is calculated as the residual between the predicted and actual output. We follow the Fama-French 49 industry classification taken from Ken French's website. Data is from Compustat and ExecuComp for the period 1992-2003.

TABLE A2

PRODUCTIVITY INDEX VALUES BY INDUSTRY AND YEAR

Manufacturing Industries (SIC codes 2000-3999)

	1993		1998		2003	
Industry	Mean	Median	Mean	Median	Mean	Median
Food	0.03	0.05	0.21	0.23	0.29	0.22
Toys / Recreation	0.03	0.00	0.14	0.17	0.52	0.32
Books	0.06	0.04	0.12	0.09	0.12	0.05
Consumer Goods	0.07	0.04	0.34	0.29	0.54	0.63
Clothing	-0.04	-0.13	0.17	0.17	0.34	0.14
Medical Equipment	0.00	-0.09	0.17	0.19	0.45	0.51
Drugs	0.06	0.04	0.29	0.19	0.28	0.29
Chemicals	0.01	0.00	0.06	0.09	0.17	0.12
Rubber & Plastics	0.01	0.01	0.32	0.40	0.30	0.29
Textiles	0.02	-0.02	0.17	0.12	0.24	0.20
Building Materials	0.05	0.07	0.17	0.21	0.29	0.31
Steel	0.09	0.14	0.39	0.38	0.44	0.43
Machinery	0.04	-0.02	0.29	0.32	0.30	0.27
Electrical Equipment	0.04	0.03	0.07	0.03	0.20	0.18
Aircraft	-0.06	-0.09	0.28	0.24	0.24	0.18
Petroleum & Gas	0.04	-0.10	0.20	0.29	0.30	0.26
Computer Hardware	0.08	0.08	1.00	1.10	1.36	1.44
Electronic Equipment	0.15	0.18	0.54	0.49	0.83	0.86
Lab Equipment	0.06	0.05	0.33	0.29	0.35	0.31
Business Supplies	0.03	0.00	0.10	0.12	0.21	0.26
Full Sample						
	1992	**1993**	**1994**	**1995**	**1996**	**1997**
Mean	0.00	0.06	0.13	0.20	0.27	0.29
Median	0.00	0.05	0.12	0.17	0.24	0.26
	1998	**1999**	**2000**	**2001**	**2002**	**2003**
Mean	0.31	0.35	0.43	0.40	0.38	0.43
Median	0.28	0.30	0.37	0.36	0.34	0.36

Notes: The productivity index is constructed as follows: $pindx_{it}=prodv\_est_{it} - prodv\_est_{j,1992}$, where $prodv\_est_{it}$ is the productivity estimate for firm i in year t and $prodv\_est_{j,1992}$ is the mean productivity estimate for industry j in 1992. We follow the Fama-French 49 industry classification taken from Ken French's website. Data is from Compustat and ExecuComp for the period 1992-2003.