CEO-Firm Match Quality and Firm Performance

By

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Abstract

Much of the empirical research on CEO pay is based on agency theory and has studied the incentives executives have to make decisions that benefit shareholders. This study takes a different look at CEO success by focusing on the quality of the match between the CEO and the firm’s needs. Highly productive matches are characterized by executives that have long tenures as CEOs and better per period firm performance over their time as CEO compared to lower quality matches. A simple modification of a widely used Bayesian model of learning (DeGroot 1970) predicts the firm learns about the quality of the CEO-firm match each period as the BoD observe a new signal of match quality. CEO turnover occurs when the BoD’s estimate of match quality leads it to conclude that the probability true firm-CEO match quality falls below a critical match quality threshold is greater than a threshold probability. This separation decision rule means surviving CEOs are positively selected on match quality so that average match quality is higher for CEOs that serve for a longer time period. The empirical results confirm this prediction and find a statistically and economically significant relationship between the total time an executive serves as CEO (completed tenure) and monthly stock returns. We also find that stock returns in period t are correlated with completed tenure for CEOs that survive to period t. These results suggest investors are making valid judgments about firm-CEO match quality and boards of directors are making CEO retention decisions as they learn about CEO productivity in the firm. The results are inconsistent with models that predict long tenured CEOs become entrenched in their positions at the expense of shareholders.
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“…new CEOs are likely to have been selected with at least some consideration for their skills and how those skills match the perceived needs of the firm and its context.”

Finkelstein, Hambrick & Cannella (2009, p. 201)

Much of the research on executive performance has focused on the central issue raised by agency theory (Jensen & Meckling 1976); how successfully do CEO compensation contracts and corporate governance mechanisms manage the conflicting objectives of executives and shareholders? An important strand of research on this topic has focused on estimating the financial returns CEOs receive when they make decisions that increase shareholder wealth (Jensen & Murphy 1992, Hall & Lieberman 1998, Hall & Murphy 2002, Frydman & Jenter 2010). These studies suggest the financial returns earned by CEOs when they make decisions that benefit shareholders have increased substantially over the last 20 years because of the growing use of stock options in executive compensation packages (Murphy 1999, Frydman & Jenter 2010, Murphy 2012). Other studies suggest that CEO power over boards of directors (BoD) has decreased as boards have gained greater independence because of more outside directors, the introduction of incentive pay for board members, greater monitoring by boards and stronger voices in the boardroom from large institutional investors (Hermalin 2005).

While this evidence suggests that on average firms may now be better managed for the benefit of shareholders than was the case 30 years ago, this conclusion is not undisputed. The evidence of a causal link between the design of CEO compensation
plans and firm performance is more limited (Daily, Dalton & Cannella 2003, Lazear & Gibbs 2009) and others (Bertrand & Mullainathan 2001, Bebchuk & Fried 2004) have argued CEO pay represented successful rent seeking by executives made possible by CEO dominance over the pay-setting process that produced results contrary to the interests of shareholders.

Instead of studying how incentives might motivate CEOs to make decisions that benefit shareholders, we investigate how the match between CEO skill, ability and leadership needs of the firm influence firm performance. This analysis is based on a simple modification of a widely used (Farber & Gibbons 1996, Altonji & Pierret, 2001, Lange 2007) Bayesian model of learning (DeGroot 1970) where the firm learns about the quality of the CEO each period as the BoD observe a new noisy signal of match quality. CEO turnover is added to this model by assuming a CEO is replaced when the BoD’s estimate of match quality leads it to conclude that the probability true firm-CEO match quality falls below a critical match quality threshold is greater than a threshold probability. This separation decision rule means surviving CEOs are positively selected on match quality so that the estimated expected and actual match quality is higher for CEOs that serve for a longer time period. Thus, the model predicts higher quality matches produces CEOs with longer completed tenures and these matches generate superior outcomes for shareholders.¹

¹ We define firm-CEO match quality slightly differently from the definition used in labor economics where unobserved match quality represents the part of worker productivity distinct from that due solely to either unobserved firm or worker characteristics. To identify firm-employee match quality requires data on CEOs that serve as CEO for different firms within the study time frame. We lack these data in the ExecuComp sample used in this study. We prefer to use the term match quality because CEOs that are not firm founders typically come into this position late in the careers with proven management experience. We
Our empirical tests of the matching model focus on the relationship between the total time an executive serves as CEO of a firm (“completed tenure”) and average monthly stock returns over an executive’s tenure as CEO. We find a statistically and economically significant positive relationship between completed tenure and mean monthly stock returns calculated over a CEO’s tenure for a subsample of CEOs and executives included in the ExecuComp survey through 2008. Our preferred estimates show the mean predicted monthly return calculated over the tenure of an executive that serves for four years is .12 percent versus .92 percent for a CEO with completed tenure equal to eight years. For a $4 billion company these differences in monthly returns produces an expected $409 million difference in market value over a 12 month period.\(^2\)

While a positive relationship between average annual compensation and completed CEO tenure is predicted by both the matching model and models where longer tenured CEOs become entrenched to the detriment of shareholders, the economically significant positive relationship found between completed tenure and average monthly returns over a CEO’s tenure is consistent with only the matching model.

An additional prediction from the matching model describes how estimated match quality changes with CEO tenure based on a CEO’s completed tenure. BoDs update their estimates of match quality each period as they observe a new, imperfect signal of true match quality. Each period the BoD obtains a more precise estimate of match quality based on the cumulative effect of the signals observed over the previous periods and each

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\(^2\) $409 million=\left[\left(1+.00924\right)^{12} -\left(1+.0012\right)^{12}\right] \times ($4 billion). Over the sample of firm-year observations in ExecuComp over the 1992–2008 period, the median firm market in 2010 prices was $1.8 billion and the mean was $8.36 billion. A firm-year with a market value of $4 billion was at the 68\(^{th}\) percentile among the firm-year observations included in 1992–2008 ExecuComp.
period the BoD decides whether or not the CEO will be replaced based on the separation rule described above. The probability the information contained in a new signal will be sufficient to end the CEO’s job is negatively related to the BoD’s estimate of match quality prior to receiving a new signal; CEOs with the lowest estimated match quality prior to a new signal will have the highest probability of being separated following the new signal in the next period. This occurs, in part, because the CEO with the lowest estimated match quality is closest to the discharge threshold prior to the new signal. Also, because the new signal of match quality the BoD observes is described by a random draw from a normal distribution centered around true match quality, the CEO with the lowest estimated match quality is more likely to draw a new signal from a distribution with a lower mean relative to CEOs with higher estimated match quality going into a period. In other words, the CEO most likely to have his/her CEO tenure end at the end of the next period has the lowest expected match quality in the earlier period and is most likely to receive a large negative signal that ends his/her tenure as CEO.

The preceding argument implies that at any value of current CEO tenure the estimated match quality of surviving CEOs is positively correlated with “completed tenure” or the total time these CEOs will eventually serve in the position. If investors observe a noisy signal of match quality each period so that firm value at the end of period $t$ partially reflects the market’s estimate of match quality, for CEOs that have survived to the end of period $t$, firm returns over period $t+1$ will be positively correlated with the total length of time these executives will eventually serve as CEO. In other words, the market can predict, with error, the length of time a CEO will serve in the position. This
prediction is confirmed by data for executives that serve as a CEO for up to about 10 years.

The data required to test the empirical implications of the matching model requires information on a subsample of CEOs where stock returns are observed over the entire time an executive serves as CEO. By definition this excludes all CEOs in ExecuComp who were still in office at the end of 2008, the end of the study period. This sampling frame differs from the sample of CEOs in ExecuComp because it under-samples CEOs that will serve for “long” time periods.

We performed several supplemental analyses to assess how this sampling frame may have impacted our results. Models were estimated using the sample of firm-CEO pairs where the CEO served for 10 or fewer years in the position. This removes the impact of long-tenured CEOs on the estimates in case the long-tenured CEOs in our sampling frame are not representative of the population of long serving CEOs. We also test a weaker implication of the matching model for CEOs that were still in office at the end of 2008; identifying if average monthly returns up to this censoring point were larger for CEOs that had served for a longer period of time at this censoring point. Each of these supplemental analyzes were consistent with the predictions of the matching model and the results using all ExecuComp CEOs that had left office by the end of 2008.

**A Simple Model of Firm-CEO Match Quality**

The model used to describe how firm’s learn about CEO match quality applies a standard Bayesian learning model (DeGroot 1970) using the normal distribution where employers and the CEO do not know the quality of the match when the CEO is hired and
both parties update their estimates of match quality as they observe the firm under the CEO’s leadership. Over time the parties updated beliefs about match quality become more precise as CEO tenure increases and eventually beliefs about the match converge on the true match quality between the firm and the CEO. While this model has motivated empirical literature on employer learning and wages (Farber & Gibbons 1996, Altonji & Pierret 2001, Gibbons et al. 2002, Lange 2007), it has received little attention in studies of CEO pay.

Five variables are relevant for understanding the model’s application in this study: (1) \( \alpha_{i,f} \) is the true productivity of the match between CEO “i” and firm “f” and this value is constant over the executive’s tenure as CEO, (2) \( \hat{\alpha}_{t,i,f} \) or \( E(\alpha_{i,f} | \text{tenure} = t) \) is the mean of the distribution describing the BoD’s best estimate of CEO-firm match quality given the information available to the BoD at the end of the \( t \)th period in the CEOs tenure on the job, (3) \( \bar{\alpha}_{t,i,f} \mid CT = T \) is the mean of distribution describing the BoD’s beliefs about match quality at the end of period \( t \) for CEOs that have survived to the end of period \( t \) and who ultimately serve in the position for \( T \) periods (completed tenure = CT), and (5) \( \bar{\alpha}_{t,i,f} \mid CT = T \) is the market’s estimate of \( \hat{\alpha}_{t,i,f} \mid CT = T \) at the end of period “\( t \)”.

3 In Jovanovic (1979) “ability” is not an innate characteristic of the employee (like cognitive ability), but a characteristic of the quality of the match between a firm and worker. Since Jovanovic’s theoretical work and starting with Farber and Gibbons (1996), labor economists have sought to test if firm learning about worker ability is an important factor in the evolution of wages where worker ability is either an employee trait valuable to many employees or a trait that is more productive to a particular firm, industry or occupation (Gibbons et al., 2002).

4 See Murphy (1986) for an early application of this model to the CEO labor market.
The normal learning model assumes that true match quality, \( \alpha_{i,f} \), is unknown to the parties when the CEO begins his/her duties at \( t=0 \) but is equal to a constant value determined by a random draw from a normal distribution with a known mean of \( \text{mm} \) and variance of \( \sigma_v^2 \). \( \alpha_{i,f} \sim N(\text{mm}, 1/p_v) \) where \( p_v \) is the precision of the estimate and equal to \( 1/\sigma_v^2 \) and \( \text{mm} \) is the best estimate the parties’ have about match quality at \( t=0 \) because the parties are assumed have no specific information about match quality when the CEO begins in the position.\(^5\) At the end of the first period the BoD observes \( S_{t,i,f} \), an imperfect signal of match quality that is also normally distributed with a mean equal to the CEO’s true match quality, \( \alpha_{i,f} \), with precision \( p_{\epsilon} \):

\[
S_{t,i,f} = \alpha_{i,f} + \epsilon_t \text{ where } \epsilon_t \sim N(0, \sigma_{\epsilon}^2).
\]

The quality of the signal depends on \( \sigma_{\epsilon}^2 \) or the validity of the information about \( \alpha_{i,f} \) contained in the signal. The mean of the posterior distribution of the BoD’s beliefs about firm-CEO match quality following the signal (\( \hat{\alpha}_{1,i,f} \)) is normally distributed with a mean equal to (DeGroot 1970):

\[
\hat{\alpha}_{1,i,f} = \frac{(mm)(p_v)+(S_{t,i,f})(p_{\epsilon})}{p_v+p_{\epsilon}} \text{ where } p_v = 1/\sigma_v^2 \text{ and } p_{\epsilon} = 1/\sigma_{\epsilon}^2.
\]

and precision equal to \( p_v + p_{\epsilon} \) or \( (1/\sigma_v^2 + 1/\sigma_{\epsilon}^2) \) or \( ((\sigma_v^2 + \sigma_{\epsilon}^2)/(\sigma_v^2 \sigma_{\epsilon}^2)) \). Eq. (2) can be rewritten as the weighted sum of the uninformed estimate of match quality before the signal (\( \text{mm} \)) and the signal:

\[
\hat{\alpha}_{1,i,f} = (1 - K) * \text{mm} + K * S_{t,i,f}
\]

\(^5\) Investors and a BoD may have prior information about match quality and this information may vary based on, for example, if the new CEO is an inside hire or brought into the firm from the external labor market. We leave the exploration of the implications of prior information for future research and test a very simple variation of the Bayesian model that ignores this prior information.
where $K = \sigma_v^2/(\sigma_v^2 + \sigma_e^2)$.

As $K \to 1$ or $\sigma_e^2 \to 0$ more weight is placed on the signal when the firm updates its estimate of match quality and less weight is given to average match quality in the population of firm-CEO pairs. Note also that $K^{1/2}$ is equal to the simple correlation ($r$) between the signal and true match quality.\(^6\)

The BoD observes an additional signal of match quality each period and updates its estimate of match quality with the information contained in the signal. The revised estimate becomes more precise as tenure increases and converges to $\alpha_{i,f}$. If “$t$” is the number of signals observed by the BoD then the estimate (DeGroot 1970, p 167) of match quality after the $t^{th}$ signal is (DeGroot 1970, Lange 2007):

\[
\hat{\alpha}_{t,i,f} = (1 - K_t)\overline{mm} + K_t \hat{S}_{t,i,f}, \quad \text{where } K_t = \frac{t \sigma_v}{\sigma_e + t \sigma_v}
\]

$K_t$ converges to one as $t$ increases and measures how quickly $\hat{\alpha}_{t,i,f}$ converges to $\alpha_{i,f}$ with additional observations of CEO performance. The precision of $\hat{\alpha}_{t,i,f}$ is $p_v + p_e$ or the variance of $\hat{\alpha}_{i,f}$ equals $(\sigma_v^2 + \sigma_e^2)/(t \sigma_v + \sigma_e)$. Two firm-CEO pairs could have identical values for true match quality but the two firms could have different estimates of match quality at time $t$ because $\hat{\alpha}_{t,i,f}$ depends on the unique history of signals of match quality observed by each firm.

Since employers and CEOs are assumed to know mean match quality (mm) in the population of firm-CEO matches, as tenure increases the parties have greater confidence

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\(^6\) Since $K$ measures the validity of the signal this links to the industrial psychology literature which has long studied the validity of selection tests (signals of future job performance) and performance appraisal instruments (measures of job performance). See Campbell et al (1970) for an early modern discussion of these concepts as applied to managerial employees.
in concluding if they are in a low or high quality match by comparing $\hat{\alpha}_{t,f}$ with mm or the match quality they could expect from a new CEO. In the Jovanovic’s (1979) matching model there is no involuntary turnover (from the worker’s perspective) because wages adjust upward or downward as the parties revise their estimates of match quality and the match dissolves when wages decline sufficiently in a poor quality match such that both parties recognize they could both do better in a different employment relationship.

In a poor match involving managerial employees the firm may respond by moving a manager to a lower position in the firm where he/she has less impact on the performance of the firm. This is not an option for an incumbent CEO so we assume the BoD will ask the CEO to leave the firm when it is “confident” the CEO’s true match quality ($\alpha_{i,t}$) falls below a threshold value $Z$ such that the $\Pr(\alpha_{i,t} < Z \mid \hat{\alpha}_{t,i,f}) > Q^*$. The firm faces a trade-off when setting $Q^*$ or how confident the BoD beliefs must be about the quality of the match before firing a CEO. A low value for $Q^*$ increases the probability the BoD will make a false-negative decision and dismiss a CEO that would have eventually been a very good CEO. The largest opportunity costs associated false-negative decisions are likely to be reputational costs in the executive labor market that may make it difficult to attract high quality applicants to the firm if it is thought the BoD does not give a new CEO sufficient time to show he/she is a high quality match. These reputational concerns might cause the firm to set a high value for $Q^*$. On the other hand, a high $Q^*$ increases the probability the firm will be in a low quality match for several years which is also costly to the firm.

From Eq 5 the distribution of true match quality conditional on estimated match quality is:
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\( f(\alpha_{i,f} | \hat{\alpha}_{t,i,f}) \sim N[(1 - K_t)mm + K_t S_{t,i,f}, \ (\sigma_\alpha^2, \sigma_\epsilon^2)/(\tau \sigma_\epsilon^2 + \sigma_\epsilon^2)] \)

and the probability true match quality conditional on estimated match quality is less than \( Z \) equals:

\[
Pr(\alpha_{i,f} < Z | \hat{\alpha}_{t,i,f}) = \Phi \left( \frac{Z - ((1 - K_t)mm + K_t S_{t,i,f})}{\sqrt{(\sigma_\alpha^2 \sigma_\epsilon^2)/(\tau \sigma_\epsilon^2 + \sigma_\epsilon^2)}} \right).
\]

Since the variance of \( f(\alpha_{i,f} | \hat{\alpha}_{t,i,f}) \) declines as tenure increases, the critical value that \( \hat{\alpha}_{t,i,f} \) must equal, \( \hat{\alpha}_{t,i,f}^* \), such that \( Pr(\alpha_{i,f} < Z | \hat{\alpha}_{t,i,f}) = Q^* \) also increases with tenure; the BoD will only dismiss a CEO in an early period if the early signals indicate an extremely poor match because of the high level of uncertainty about true match quality. However, the BoD becomes more confident of its estimate of \( \alpha_{i,f} \) and the critical value of \( \hat{\alpha}_{t,i,f} \) that leads to dismissal increases as more information becomes available about match quality.

Separating CEOs where the probability that true match quality falls below a threshold probability generates positive selection on \( \hat{\alpha}_{t,i,f}^* \) such that \( (\hat{\alpha}_{t,i,f}^* | CT = T) < (\hat{\alpha}_{t,i,f}^* | CT = T + 1) \) over plausible values for signal validity and tenure. The strength of this selection bias favoring higher quality matches among surviving CEOs depends on the validity of the signal. Figure 1 shows results from the model using simulated data (500,000 firm-CEO pairs, 20 periods) with parameter values of \( mm=0, \sigma_\alpha^2 = 1, \sigma_\epsilon^2 = 3, Z = -.1 \) and \( Q^* = .8 \). The positively sloped line in the bottom of the figure is the critical value of \( \hat{\alpha}_{t,i,f}^* \) that increases from -.73 in period 1 to -.40 in period 10. The positively

\[7\] The values of \( \sigma_\alpha^2 \) and \( \sigma_\epsilon^2 \) imply the correlation between the first period signal and true performance is .5. This is a plausible value given the industrial psychology literature on the validity measures used in selecting managers.
sloped line in the top of the figure plots the mean of estimated match quality for the CEOs that survived a certain number of periods. This increases from .05 at the end of period 1 to .50 at the end of period 10. This selection bias generates the first empirical test of the matching theory. If investors observe $\hat{\alpha}_{t,F}$ or a noisy signal of $\hat{\alpha}_{t,F}$ ($\tilde{\alpha}_{t,F}$) then mean monthly stock returns calculated over an executive’s tenure will be positively related to CEO completed tenure. This prediction from the model also implies the mean cumulative changes in firm returns through CT are greater for executives that serve more periods.

Among CEOs in office at the end of period t, the executive most likely to be fired at the end of period t+1 following the t+1 signal is the executive with the lowest estimated match quality at the end of period t because he/she is the executive most likely to be pushed over the discharge threshold after the period t+1 signal. As noted earlier, this occurs because (a) the CEO with the lowest estimated quality match at the end of period t is closest to the discharge threshold and (b) the signal in period t+1 for this executive is likely to be of lower quality than the signal observed for executives with higher estimated match quality at the end of period t because each signal is correlated with true match quality. In other words, the CEO most likely to end his/her tenure next period has the lowest expected match quality in the current period and is expected to receive a large negative signal in the next period.

The preceding discussion implies that the market’s estimate of match quality at the end of period t, $\hat{\alpha}_{t,F}$, is positively correlated with the total length of time the CEO will serve as CEO or $\rho(\hat{\alpha}_{t,F}|CT > t), CT] > 0$. For example, expected match quality at the
end of the second period of tenure for a sample of CEOs that survive to period two will be greater for CEOs that eventually serve five periods on the job compared to CEOs that will turnover in period three. This leads to a second testable hypothesis; if 
\[ \rho(\hat{\alpha}_{t, f} | CT > t, CT) > 0 \]
then stock returns in period t should predict, with error, the length of time an executive will serve beyond period t as CEO. This is a strong prediction because market efficiency predicts returns in period t that should not be correlated with returns in future periods, yet the matching model predicts estimated mean match quality at time t is correlated with CT where CT>t and firms with longer serving CEOs earn higher returns. Thus, an empirical result consistent with both market efficiency and the matching model requires a statistically significant relationship between \( \hat{\alpha}_{t, f} \) and CT but not sufficiently large or precise enough to generate a relationship between \( \hat{\alpha}_{t, f} \) and returns after period t.

Figures 2 and 3 show the predicted relationship between estimates of match quality in period t conditional on how long a CEO will survive beyond period t from simulated data generated by the model. The signals investors receive about match quality that determine \( \hat{\alpha}_{t, f} \) will be capitalized into the firm’s stock price in period t based on the market’s beliefs about how match quality affects the future cash flows of the firm. After conditioning on other factors that affect monthly stock returns, expected returns or expected changes in firm value over period t+1 for the subsample of CEOs that have not turned-over at the end of period t will equal the expected impact on firm value of the mean change in expected match quality or \( (\hat{\alpha}_{t, f}^{t+1} | CT \geq t + 1) - (\hat{\alpha}_{t, f}^t | CT > t) \) or \( \beta(\Delta \hat{\alpha}_{t, f}) \) where \( \beta \) is a parameter that describes the change in firm value caused by the change in
mean expected match quality from period t to period t+1 for CEOs that turnover sometime after period t. \( \Delta \alpha_{t,f} \) is positively correlated with completed tenure and is less than zero for plausible values of signal validity and many values of tenure and completed tenure observed in the ExecuComp sample used in this study. Figure 2 reports the mean values of \( \left( \alpha_{t,f}^T \right| CT = T \) for integer values of current and completed tenure from the simulated data.\(^8\) Each downward sloping line in Figure 2 connects the values of \( E(\alpha_{t,f}^T|CT = T) \) as current tenure (t) increases from one to CT.

Figure 3 reports \( \Delta \alpha_{t,f} \) from the simulated data in Figure 2 and shows that \( \Delta \alpha_{t,f} \) is positively correlated with completed tenure at each value of t. A key empirical test of the matching model follows from Figure 3. The estimated impact of tenure and completed tenure on firm returns will generate a pattern of monthly returns conditional on tenure and completed tenure consistent with Figure 3; expected returns in month t are greater for CEOs that will eventually serve as CEO for a longer time period.

**Data, Sample and Econometric Methods**

The sample of firm-CEO pairs needed to test the implications of the matching model requires data on the total time a CEO served in this position in a single firm. For this reason, the sample used in this study comes from Standard and Poor’s ExecuComp database (accessed through WRDS) that reports the date CEOs in the sample began their tenure as CEO and the date they left the firm if they left office before the end of the study period. Since completed CEO tenure is a critical variable for this analysis, the subsample

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\(^8\) In Figures 2 and 3 we assume \( \left( \alpha_{t,f}^T \right| CT = T \) = \( \left( \alpha_{t,f}^T \right| CT = T \).
of CEOs from ExecuComp includes executives that completed their tenure as CEO by the end of 2008. From this universe a small number of CEOs were excluded who worked for firms that did not have monthly stock return data for the executive’s entire tenure in the CRSP (Center for Research in Security Prices, Booth School of Business, University of Chicago) dataset. The final sample includes 1579 completed CEO spells where the CEOs were employed at 989 different firms. The median (mean) number of CEOs per firm in the sample was 3 (2.84) and the maximum number was 7; five firms had seven different CEOs that completed their tenure as CEO from 1992-2008.

Table 1 reports descriptive statistics for the sample. The 1579 firm-CEO pairs fall into two subsamples, based on whether they began their role as CEO before or after January 1, 1992. 1160 CEOs were hired after 1991 and had mean (median) completed tenure of 4.33 (3.75) years and 419 CEOs were hired before 1992 and had mean (median) tenure of 11.65 (10.68) years. The CEOs in ExecuComp that were matched to CRSP and not included in our study sample were executives with unobserved completed tenure because they were still serving as a CEO at the end of 2008. There are 1753 firm-CEO pairs in this excluded sub-sample of ExecuComp.

The sample of CEOs used in our analysis is not ideal because of the limited time frame (1992-2008) covered by ExecuComp and the requirement that completed tenure is observed within this time frame. The sample of CEOs where completed tenure is observed is composed of two distinct groups, those that were appointed prior to 1992 and those that came to office in 1992 or later. The subsample of CEOs that took office after

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9 This study was begun in 2009 and the latest version of ExecuComp available at that time reported separation dates to the end of 2008.
1991 and are included in the study is not a random sample of all CEOs in the ExecuComp database because executives with longer completed tenures are under-sampled as they are more likely to still be in office at the end of 2008. The severity of this under-sampling increases with completed tenure. For example, no CEO in this sub-sample could have served for more than 17 years and the only CEOs with 15-17 years of completed tenure had to have begun their tenure sometime in the 1/1/1992 – 1/1/1994 interval.

The set of CEOs in our sample that were hired prior to 1992 and left the position by the end of 2008 provide data on longer serving CEOs that are under-represented among the post 1991 hires. Mean completed tenure for the CEOs that were appointed prior to 1992 is 11.65 years and mean completed tenure was 4.33 years for those appointed after 1991. However, these CEOs are also not a random sample of CEOs that began their careers prior to 1992 because shorter tenured CEOs are under-represented in this subsample. For example, the only CEOs that started their tenure as CEO on January 1, 1982 that are also included in ExecuComp had to have 10 years of tenure on January 1, 1992 and will, therefore, have at least 10 years of completed tenure. Equivalently, no CEO starting on January 1, 1982 with completed tenure of less than 10 years is included in the ExecuComp sub-sample. Thus, there are two sampling problems for the sample of CEOs that ended their tenure by the end of 2008. The executives with shorter completed tenures come disproportionately from the post-1991 appointees and as completed tenure increases the sample is increasingly dominated by pre-1992 appointees.\(^{10}\) Figure 4

\(^{10}\) One might be tempted to try and use the results in Figure 4 to weight the data. Unfortunately, the data in Figure 4 cannot be used for this purpose because we don’t know the shape of the underlying completed tenure distribution for all CEOs appointed on or after a particular date. The completed tenure distribution for those appointed after 1991 is unobserved because completed tenure is unobserved for those in office at
shows the proportion of CEOs appointed before January 1, 1992 as a function of completed tenure. At four years of completed tenure over 90 percent of the sample were hired after 1991, while at 14 years of completed tenure about 80 percent of the CEOs took office before 1992. This feature of our sample could affect our estimates if, for example, there are economy-wide factors affecting CEO survival correlated with calendar time. To partially control for this we include a complete set of calendar year indicators. We suspect the potential impact of this sampling process may have its largest impact on the results for CEOs with longer completed tenures. This issue is evaluated later in the paper where the robustness of our results is evaluated using executives with 10 or fewer years of completed tenure.

**Measuring and Estimating Firm Performance**

Firm performance over an executive’s tenure was measured using monthly firm stock returns, including dividends ($\ln(1 + \text{Ret}_{i,f,t}) = \ln(\frac{P_{f,t} + \text{Div}_t}{P_{f,t-1}})$), for each month an executive was in office. The following basic regression model was estimated by pooling the monthly data across firm-CEO pairs:

$$
\ln(1+\text{Ret}_{i,f,t}) = \beta_0 + \beta_1 \ln(1+\text{RF}_t) + \beta_2 \ln(1+\text{MKT}_t) + \beta_3 \text{SMB}_t + \beta_4 \text{HML}_t + \beta_5 \text{MOM}_t + f(\text{Current Tenure}_{i,f,t}, \text{Complete Tenure}_{i,f,t}) + \text{g(Year indicators)} + \epsilon_{i,f,t}
$$

The first set of variables is the four financial market factors identified by Fama & French the end of 2008. The completed tenure distribution of CEOs appointed after, say, 1980 is also unobserved because shorter serving CEOs are under-represented among the CEOs in office in 1992.

11 The line in Figure 4 is based on a probit model predicting the probability a firm-CEO match in the sample began after 1/1/1992 as a function of 3rd order polynomial in completed tenure. A linear probability model gives identical predictions. The horizontal line at zero probability and completed tenure greater than 17 is not estimated because the sampling frame prevents any executive hired since 1/1/1992 who will eventually serve more than 17 years from having their completed tenure observed by the end of 2008.

12 These data were obtained from the CRSP dataset (University of Chicago) that was accessed through WRDS (The Wharton School, University of Pennsylvania).
The four Fama-French factors are: the risk free return ($RF_t$), the return to the market portfolio of stocks ($MKT_t$), the difference in returns between a portfolio of large firms and small firms ($SMB_t$) and the difference in the returns between a portfolio of high book-to-market ratio and low book-to-market ratio ($HML_t$). The fourth factor captures market momentum ($MOM_t$) which has been found to be a significant predictor of returns after controlling for the Fama-French factors (Carhart 1997). These variables are now often used to model abnormal returns in event studies (Greenstone, Oyer & Vissing-Jorgensen 2006). We also estimated a model based solely on the CAPM that only includes $MKT_t$ and $RF_t$. The estimated effect on returns that reflect learning by the market about match quality are captured by functions of current and completed tenure. The year dummies denote the calendar year for an executive’s $t^{th}$ month and capture unobserved calendar year effects on returns that may not be captured by the market factors. To make the tenure parameters easier to interpret, all of the non-tenure exogenous variables were transformed by deviating the value for each variable for each observation from the overall sample mean for each variable. This “centering” of the data means the predicted estimated returns based only on the estimated intercept term and the estimated tenure coefficients describe the mean predicted monthly return for an “average” firm-CEO pair where average is defined as an observation with mean values for the five market model variables and the

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13 Fama and French report a model with three factors where $RF$ and $MKT$ are combined in a single variable equal to $MKT_t – RF_t$. We estimate the less constrained model that allows the absolute values of the coefficients on these variables to differ. Data for these four factors were downloaded from Kenneth French’s web page at mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html on February 5, 2010.

14 Risk free returns were measured using the yield on a 3 month U.S. Treasury bill in month $t$ and $RF_t$ equals $\ln(1 + T$-bill yield).

15 The estimates from this specification are very similar to the reported results and are available from the author.
year dummies; $\hat{\beta}_0 + \hat{\beta}_{CT}CT_{T_f}$ is the estimated mean monthly return over an executive’s entire tenure where the values for $\ln(1+\text{MKT})$, $\ln(1+\text{RF})$, SMB, HML and MOM and the year dummies are all equal to their sample means.\textsuperscript{16}

Estimating Eq. 7 using OLS on the pool sample of firm-CEO pairs constrains the coefficients on $\ln(1+\text{MKT})$, SMB, HML and MOM to be the same across all firms which is inconsistent with theoretical models of firm returns and empirical evidence showing the effects of these variables differ across firms.\textsuperscript{17} For example, constraining $\beta_2$ to a single value is inconsistent with the CAPM because $\beta_2$ in the CAPM for a particular firm measures the price of risk from investing in the particular firm relative to investing in the overall market. Constraining the coefficients on these four variables across firms also reduces the precision of the estimated tenure effects. Two alternative estimation methods were used that relax these constraints. The first statistical model is a random coefficient model where $\beta_2 - \beta_5$ vary across firm-CEO pairs and the coefficients for each firm-CEO pair are assumed to have been drawn from normal distributions:

$B_{j,i,f} = \beta_j + v_{j,i,f}$ and $v_{j,i,f} \sim N(0, \sigma_{j,i,t}^2)$ and $j = \ln(1+\text{MKT}), \text{SMB}, \text{HML}, \text{MOM}$.\textsuperscript{18}

The second estimation method relaxes the constraints on four of the financial market variables by adding to Equation 7 a complete set of firm-CEO specific dummy

\textsuperscript{16} The estimate for this “average” CEO can be thought of as the mean weighted estimate for a CEO with mean values for the five market variables plus a weighted mean of the calendar year coefficients where the weights are equal to the fraction of the total number of observations in each of the calendar years. We could have chosen an arbitrary base year when reporting the predicted effects which would simply change the constant or the predicted level of returns but would not change the estimated relationship between returns and tenure.

\textsuperscript{17} The coefficient on the risk free return is constrained to be the same across firms because the market requires each firm earn a firm specific premium above the constant risk-free returns investors have as an alternative to investing in the stock market.

\textsuperscript{18} We do not use the variation in the random coefficient parameters for the four financial market measures when calculating and reporting predicted estimates for different random coefficient models. For example, when calculating $\hat{\beta}_0 + \hat{\beta}_{CT}CT_{T_f}$ our interest in in an estimate of the mean career returns for subsamples of CEOs that have equal values for CT.
variables that are each interacted with each of the four market factors. In this model the standard errors were clustered on the calendar month to account for common unobserved market shocks correlated with calendar time. This model will be referred to as the fixed effect model.\textsuperscript{19} The fixed effect model estimates are less efficient than the random coefficient model if the normality assumptions of the random coefficient are met. However, in the random effect model the standard errors are not clustered on the calendar day of the return.\textsuperscript{20} We report results for all three statistical models but the results are very similar across the three statistical models so most of the discussion will refer to the random coefficient estimates.

\textbf{CEO Tenure and Stock Returns}

The first results we report test whether or not mean monthly stock returns calculated over the completed tenures for our sample of CEOs is positively related to CT. Three different methods that imposed different levels of structure on the relationship between returns and completed tenure were estimated. The first method imposes very little structure and provides a very transparent graphical presentation of the relationship between the two variables. For each firm-CEO pair the average monthly firm risk

\textsuperscript{19} This is not the usual fixed effect model because the set of firm dummy variables were not included separately in the model because the financial models supporting these variables predicts \( E(\epsilon_{f,t}) = 0 \) for all firms. Separate firm intercept terms were also excluded to reduce the number of parameters that had to be estimated. The 1578 indicator variables denoting a unique firm-CEO pair were interacted with the four market variables or a total of 6312 parameters for just the four market variables - Ln(1+Mkt), BmS, HmL and Mom. The model was estimated using Stata on a 64 bit dual processor desktop with 32G of memory and there were no problems estimating these fixed effect models.

\textsuperscript{20} The program used to estimate the random coefficient models (Stata) does not allow standard errors to be cluster by calendar month.
premium was calculated over an executive’s tenure as CEO by comparing each monthly return with the risk free return or:

\[
AVG(RET - RF)_{i,f} = \frac{\sum_{t=1}^{12*C_{T,i,f}} \left( \ln(1 + RET_{i,f,t}) - \ln(1 + RF_{i,f,t}) \right)}{12 * C_{T,i,f}}
\]

The mean of AVG(RET-RF) was then calculated over all the firm-CEO pairs in each one month interval of completed tenure. The data points in Figure 5a plot the cell means of AVG(RET-RF) for each of these one month intervals of completed tenure and it shows a very strong positive linear relationship up to about 6-7 years of completed tenure and then no relationship beyond these points. The line in the graph is an OLS regression line with a 4th order polynomial through the mid-point of each one month time interval and where each data point is weighted by the number of CEOs in the cell.

The second semi-parametric method plots the conditional returns in each one month interval of completed tenure after conditioning on a set of year dummies and the five financial market variables in Equation 7 (\(\ln(1+Rf)\), \(\ln(1+Mkt)\), BmS, HmL and MOM). All of the market factors except \(\ln(1+Rf)\) were allowed to vary across firms in a random coefficient model that also included a set of completed tenure dummies \(I_{i,f,k}\) where \(I_{i,f,k}\) was set equal to “1” if the CEO served for a total of \(K\) months and \(k \leq K < k + 1\), otherwise \(I_k = 0\). The estimation equation was then:

\[
(8) \quad \ln(1+Ret_{i,f,t}) = \beta_0 + \beta_1 \ln(1+Rf_t) + \beta_{2,i,f}(\ln(1+MKT_t)) + \beta_{3,i,f}(SMB_t) + \beta_{4,i,f}(HML_t) + \beta_{5,i,f}(MOM_t) + \sum \beta(I_{i,f,k}) + \epsilon_{i,f,t}
\]

The coefficient on each of the \(I_k\) dummies is an estimate of the mean monthly returns for the firm-CEO pairs in the \(k^{th}\) completed one month tenure interval relative to the
excluded bin and conditional on the year effects and market controls. Since all of the
market financial variables and year dummies were deviated from their sample means, the
estimate mean monthly returns for firms in each interval where all the other variables are
set equal to their sample means is simply $\beta_0$ for the “excluded” interval and $(\beta_0 + \beta_k)$ for
each of the other 246 values of $k$. The data points in Figure 5b plots the estimates of $\beta_0$
and $(\beta_0 + \beta_k)$ for each completed tenure interval. The variability conditional on
completed tenure is less in Figure 5b compared to Figure 5a because the conditioning
variables include the four additional financial market controls. However, the pattern of
data points is very similar to Figure 5a; a strong positive relationship between CT and
mean returns over an executive’s tenure as CEO up to about 8 years.

The third statistical model used to test $H_1$ is a standard parametric regression
model where monthly returns are estimated to be a function of the market variables, the
year dummies and polynomials in completed tenure. A fourth order polynomial in
completed tenure best describes the data; the completed tenure coefficients were
individually significant and a fifth order CT term was not significant. The estimated
mean career monthly return for an “average” CEO that was in the position for CT years
is:

$$E(\ln(1+\text{Ret}_{i,t}|\text{CT}=ct) = \tilde{\beta}_0 + \tilde{\beta}_6 * ct + \tilde{\beta}_7 * ct^2 + \tilde{\beta}_8 * ct^3 + \tilde{\beta}_9 * ct^4$$

The line in Figure 5b show the estimates from this equation values of completed
tenure up to 34 years and the shaded area defines the 95 percent confidence for the
estimated conditional mean monthly return. The estimates show a strong positive
relationship between mean returns and completed tenure up to about 8 years and then the
relationship goes to zero.
The differences in returns based on completed tenure through about eight years are economically significant. The predicted mean of $\ln(1+\text{Ret})$ for a firm with a CEO that serves for 8 years is $0.00956$ (SE=$0.00045$) or an annual return of 12.15 percent ($\exp(12 \cdot 0.00956) - 1$). This compares to an expected return of $0.00211$ (SE=$0.0005$) or 2.58 percent per year for a CEO that serves for 4 years.$^{21}$

The results reported Figures 5a and 5b provide strong support for the matching model for executives serving up to about 8 years; over this range firms are learning about match quality and longer serving executives earned higher monthly returns compared to CEOs that had shorter tenures. Beyond about 8 years there is no relationship between the two variables.

**Do Returns Predict Completed Tenure?**

The matching model predicts expected returns in month $t$ for firms where the CEO serves $t+k$ months are smaller than the returns for a firm where the CEO will serve for $t+k+j$ months where $j > 0$. This prediction implies returns in period $t$ predict, with error, the length of time an executive will serve as CEO.$^{22}$ We first construct very simple semi-parametric tests similar to Figures 5a and 5b that graphically show the relationships between returns and CT. Figures 6a-6e reports the relationship between completed tenure and estimated mean monthly returns ($\ln(1+\text{Ret})$) calculated over different time intervals ending with month $t$ for executives that serve through at least month $t$. The data

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$^{21}$ The difference in mean monthly returns for these two values of CT is $0.0074$ and highly significant with a standard error of $0.0005$.

$^{22}$ As noted earlier, this assumes investors observe a noisy signal of match quality in period $t$.

$^{23}$ See Figure 2; at any value of current tenure mean match quality is larger for CEOs that will ultimately have longer tenures.
in these figures were constructed using the same methods used to construct Figure 5b. For example, Figure 6a uses the sample of CEOs that served for more than 12 months and shows the relationship between mean returns over the first 12 months of their tenure and the length of time they ultimately served as CEO. Each individual data point is the mean conditional return over the first 12 months of tenure for executives in one month completed tenure intervals greater than a year. Like in Figure 5b, these conditional means were estimated from a random coefficient model of returns for the first 12 months of an executive’s tenure that included a set of dummy variables for each one month interval of completed tenure greater than 1 year. The line and the 95 percent confidence interval around the line are the predictions from a random coefficient model with polynomials in completed tenure. These figure suggest firm returns in the first 12 months of an executive’s tenure can discriminate between executives that serve up to about 7 years. The predicted difference in average monthly returns over the first 12 months of tenure between executives that will ultimately serve 8 versus those that will serve 3 years (CT=4) is .0051 (.01312-.0080) with a standard error of .0017 (p-value=.003).

Figures 6b-6e show the relationship between completed tenure and mean returns over different time intervals up to 36 months of tenure. The conclusions we draw are similar to our interpretation of Figure 6a; mean returns through month t are positively related to completed tenure for 4-6 years beyond month t. Table 2a presents the differences in mean monthly returns for CEOs serving 8 versus 4 years for each of the different time intervals described by the Figures. Over all five time intervals mean predicted returns in each time interval are statistically and economically greater for the executive that serves a longer time period. We take these data to be very consistent with
the predictions of the matching model; even in the third year of tenure (Figures 6d), the market is still learning about match quality of surviving CEOs and differentiating between executives that will turnover within a year versus those that stay in office for another 4-5 years. Figures 6a-6e show returns through period t can differentiate over a limited range the length of time surviving CEOs will serve in their position and the data in Figure 5 show a positive relationship between CT and expected returns over a CEO’s career.

Are the relationships in Figures 6a-6e strong enough to generate a positive relationship between returns through period t and later mean career returns? Such a result could be inconsistent with the efficient market hypothesis because it implies returns early in a CEO’s tenure are correlated with returns later in their career. To test for this possibility returns beyond month t for CEOs with completed tenure greater than t were modeled using a random coefficient model that included mean returns over the time interval through month t. For example, the market model that can be compared to the estimates in Figure 6a includes mean returns for the firm-CEO pair for months 1-12 for all CEOs that served for more than a year. In this model the coefficient on mean returns over the first 12 months was .0199 (SE=.0098). Table 2b reports the results for this test from models that match each of the five time intervals in Figures 6a-6e. While the coefficient on mean returns for months 1-12 is statistically significant at the .05 level, none of the other coefficients come close to being significantly different from zero and all

24 Such a result may still not be sufficient to generate a profitable trading strategy because at time period t the market does not know CT for CEOs that survive to time t. We can perform these tests only because we can observe CT in our sample.
but one of the estimated parameters are negative. Thus, while returns up to period $t$ provide a noisy prediction of completed tenure for CEOs that survive to period $t$, a result consistent with the matching model, mean returns in earlier periods are not strongly related to mean returns for firm-CEO pair beyond period $t$. We take these results to be very strong evidence supporting the matching model.

**The Relationship Between Returns, Tenure and Completed Tenure**

The results shown in Figure 6 provide a relatively weak test of the matching model because the data in these figures do not fully exploit the monthly return data for returns, tenure and completed tenure. Tables 3-5 report estimates of monthly returns using Equation 7 where tenure and completed tenure are parameterized several different ways. Table 3 reports the OLS models, Table 4 reports the fixed effect models and Table 5 reports the random coefficient estimates. Each specification for each statistical model includes the five financial market controls and the set of calendar year dummy variables. Before we discuss the tenure effects, we note other differences and similarities across the three statistical models.

The OLS model that constrains the coefficients on market returns, SmB, HmL and MOM to be the same across firms is clearly the poorest performing model. The $R^2$s for the FE specifications are almost twice the size of the OLS specifications and a likelihood ratio test comparing the OLS estimates with the random coefficient estimates decisively rejects the OLS model across all specifications with p-values less than .0001.

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25 Models were also estimated that included the mean abnormal return over the earlier time period. None of the coefficients on abnormal returns in the earlier time periods were a significant predictor of returns in the later period.
Comparing the random coefficient model with the FE model: (1) the FE model does not assume the market model coefficients that vary across firms are normally distributed, (2) the standard errors in the FE model are clustered on the calendar month while the random coefficient standard errors are not, and (3) if the market model coefficients are normally distributed then the random coefficient estimates are more precisely estimated compared to the FE model.

The normality assumptions regarding the distributions of \( f(\beta_{j,i,f}) \) for the four market model variables in the random coefficient model was evaluated by comparing the estimated distributions of \( f(\beta_{j,i,f}) \) from the random coefficient model with the estimated distribution of the coefficients on the firm by market interaction terms from the fixed effect model. These comparisons are shown in Figures 7a-7d. Each figure refers to the parameters for a different market factor. The normal distribution plotted in each figure is simply a normal distribution with parameters that match the estimated mean and standard deviation of the random coefficient distributions reported in Table 5. For example, the normal distribution of the estimated effects of market returns on firm returns shown Figure 7a has a mean of 1.17 and a SD of .469. The “nearly” normal distribution in Figure 7a is a kernel density estimate of the vector of coefficients on the interactions between the set of firm dummies and \( \ln(1+\text{Mkt}) \).\(^{26}\) Figures 7b-7d were constructed for the other three market variables using the same method. While formal tests reject the

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\(^{26}\) In the model with the complete set of firm-CEO indicators interacted with the four market factors the estimated impact of MKT for the “excluded” firm is equal to the coefficient on MKT and each of the coefficients on the firm dummy by MKT interaction terms estimates the difference between the effect of MKT for the firm identified by the dummy variable relative to the effect of MKT for the “excluded” firm (\( \beta_{\text{MKT}} \)). Thus, the distribution of firm effects for MKT on market returns is obtained by plotting the distribution of following data points: \( \beta_{\text{MKT}}, (\beta_{\text{MKT}} + \beta_{\text{MKT}\times2}), (\beta_{\text{MKT}} + \beta_{\text{MKT}\times3}), \ldots, (\beta_{\text{MKT}} + \beta_{\text{MKT}\timesN}) \) where \( N \) is the total number of firm-CEO pairs in the sample. A kernel density estimator was used to estimate the distribution of firm MKT effects.
hypothesis that the coefficients from the fixed effect model are normally distributed for all four variables, a visual inspection of the pair of densities in each figure shows they are “approximately” normal and the FE distribution overlap substantially with the estimated distribution from the random coefficient model.

These comparisons suggest either the random coefficient or the fixed effect models are plausible statistical models of the relationship between monthly returns, tenure and completed tenure. This conclusion is further confirmed by the very similar coefficients on the tenure variables in the two statistical models. Therefore, the remaining discussion of the results is based on the random coefficient results reported in Table 5.

Although the specifications with just completed tenure reported in Figure 5 are consistent with the matching model, the data support a much richer specification that includes current tenure and completed tenure as predicted by the matching model. Current tenure and completed tenure (CT) are individually and jointly significant across all three statistical models and the data support a quartic term in completed tenure. CT is not statistically significant when added to Model 6 reported in Table 5.

The simplest way to interpret these coefficients is to construct figures that summarize predicted returns for hypothetical “average” CEOs that have different values for current and completed tenure. Since market efficiency implies returns each month reflect the new information learned by investors that is thought to influence future profitability and the matching model predicts the change in estimated match quality over

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27 There are some differences in estimated standard errors across the three models, but none of the differences are sufficient to lead to different conclusions for key null hypotheses using conventional levels of significance (.05 or larger).

28 CT is not statistically significant when added to Model 6 reported in Table 5.

29 The values for the five market variables were set equal to their sample averages in all of these calculations.
the month is based on the new signals of match quality, market efficiency and the matching model jointly predict that returns in a month reflect changes in estimated match quality or $E(\hat{\alpha}_{i,f} \mid CT = T, \tilde{S}_t) - E(\hat{\alpha}_{i,f}^{t-1} \mid CT = T, \tilde{S}_{t-1})$.

Figure 3 shows $E(\hat{\alpha}_{i,f} \mid CT = T, \tilde{S}_t) - E(\hat{\alpha}_{i,f}^{t-1} \mid CT = T, \tilde{S}_{t-1})$ from simulations of the model and Figure 8 shows estimates of mean returns as current tenure varies for integer values of completed tenure from 2 to 10 years using the random coefficient estimates for Model 4 reported in Table 4. Although the estimates in Figure 8 do not show the nonlinear relationship between returns and current tenure for each value of completed tenure reported in Figure 3, the estimates do show that at any level of current tenure predicted returns are larger for surviving CEOs that will eventually serve as CEO for a longer time period for values of current tenure up to 12 years. For example, the mean monthly return in month 36 for CEOs that will leave office one year later was -0.0004 and the return in month 36 for a CEO with CT equal to 8 was .0106. This is precisely the prediction from the matching model.

Each monthly predicted value of $\ln(1+\text{Ret}_t)$ plotted in Figure 8 for month “t” equals the predicted value of $\ln(P_t/P_{t-1})$ where $P_t$ is the firm’s stock price at the end of period t. The predicted total expected change in the firm’s stock price over the tenure of CEOs that serves CT years relative to the stock price at the start of their tenure that is attributable to match quality is the mean cumulative average return:

$$CAR_{CT} = \ln(P_{CT}/P_0) = \sum_{t=1}^{CT} \left( \hat{\beta}_0 + \hat{\beta}_{\text{Tenure}}(t/12) + \hat{\beta}_{\text{Tenure}^2} \left( \frac{t/12^2}{10000} \right) + \hat{\beta}_{\text{CT}}(CT/12) + \hat{\beta}_{\text{CT}^2} \left( \frac{CT/12^2}{10000} \right) + \hat{\beta}_{\text{CT}^3} \left( \frac{CT/12^3}{1000000} \right) + \hat{\beta}_{\text{CT}^4} \left( \frac{CT/12^4}{100000000} \right) + \hat{\beta}_{\text{Tenure} \times CT} \left( \frac{(t+CT)/12}{1000} \right) \right),$$

where both current tenure (t) and CT are measured in years.
Figure 9 plots $CAR_{CT}$ and its 95 percent confidence interval for different values of completed tenure. The figure shows that cumulative average returns for CEOs that serve four years is .056 while the estimates of $CAR_B$ is .883. To illustrate the economic significance of these point estimates, we calculated the predicted impact on firm value over an 8 year period for two hypothetical firms that had a market value of $4 billion at the start of the 8 year period. One firm has two CEOs that each served for 4 years and the other firm had a single executive that served for the entire 8 years. For the firm with two CEOs their estimated market value after 8 years is $4.47 billion or an 11.85 percent change over the entire 8 years. In contrast, the predicted firm value for the firm with a CEO that served the entire 8 years is $9.67 billion or a 142 percent increase in firm value. These estimates show the value to shareholders from a high quality match are substantial.

Understanding the average differences in monthly returns due to match quality over a career from Figure 9 is difficult because the larger $CAR_{CT}$ for longer tenured CEOs confounds the effects of longer tenure and higher returns each month conditional on completed tenure. To adjust for the differences in the total time served as CEO and produce estimates comparable to Figure 5, the expected average monthly return over a CEO’s career was calculated:

$$AR_{CT} = CAR_{CT} / (12 * CT).$$

These estimates and their 95% confidence intervals are shown in Figure 10. This figure shows average monthly returns over a CEO’s tenure increases with tenure up to about

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30 The $4.47 billion equals $4*(1+(exp(.056)-1))^2$ and the $9.67 billion equals $4*(1+(exp(.883)-1))$. 
CT=10. For example, the average monthly percentage change in the stock price for an executive that serves for 4 years is .0012 and .0092 for CEOs where CT=8.

Robustness Checks

The key piece of data about CEOs required to test the matching model is the total length of time an executive served as CEOs. As discussed earlier, this requirement restricts the sample to CEOs in ExecuComp that ended their tenure by the end of 2008. Among CEOs appointed since 1992, CEOs with longer completed tenure are under-represented relative to CEOs with short completed tenures because longer tenured CEOs are more likely to still be in office at the end of 2008. Thus, no CEO in the sample appointed since 1992 is in the sample. The CEOs that came to office prior to 1992 are under-sampled because they are more likely to have left office by 1992.\textsuperscript{31} The usual potential biasing effect of an unobserved factor that is correlated with both completed tenure and returns is potentially more complicated because of this sampling process. For example, if the long bull market of the 1990s gave CEOs coming into office in this period an initial “honeymoon”, then the estimated completed tenure-return relationship we attribute to matching could be biased upward. Several supplementary analyzes were conducted to assess the potential impact of the features of our sample.

The first robustness check performed excluded from the sample all CEOs with CT > 10 years. Figure 4 shows that this produces a sample of CEOs approximately equally split between pre and post 1992 hire dates. For this subsample, we first estimated the preferred model based on the full sample that included current tenure, a 4\textsuperscript{th} order

\textsuperscript{31} See Figure 4.
polynomial in CT and current tenure x CT and found the coefficients on CT^3 and CT^4 were statistically insignificant. These higher order terms were and Table 6 shows the key parameter estimates from a random coefficient model with CT, CT^2, current tenure and CT x current tenure. Figure 11 shows the estimated values of ln(1+Ret) as current tenure changes for integer values of CT from 2 to 10 years and Figure 12 shows the estimated mean monthly career values of ln(1+Ret) for executives that serve as CEO for different time periods. These estimates can be compared to estimates from the full sample shown in Figures 8 and 10. The estimates from the restricted sample are very similar to the full sample. For example, the difference in mean career monthly returns between an executive that serves 8 years and an executive that serves 4 years is .008 in the full sample and .0085 for the restricted to CEOs with CT ≤ 10 years. These results suggest that for CT up to about ten years, the estimates using the entire sample are not seriously affected by the inclusion of longer tenured CEOs that came to office prior to 1992.

We cannot estimate the impact of CT on executives still in office at the end of 2008 because CT is unobserved. However, data from CEOs still in office at the end of 2008 can be used to test a weaker implication of the matching model. The matching model implies that mean monthly returns calculated over a CEO’s tenure up to the censoring point (the end of 2008) are larger for CEOs that have greater tenure at this point in time because longer serving executives in office at the end of 2008 have higher expected match quality and longer expected completed tenure than executives with less tenure at the end of 2008. For example, a CEO that has been in his/her position for 6 years at the end of 2008 has higher expected match quality compared to the CEO that has 3 years of service at the censoring point because the later CEO has a non-zero probability
of leaving the job before his/her sixth year. This expected difference in completed tenure is generated by an expected difference in match quality at the censoring point for the two executives that should generate a difference in mean monthly returns over their observed tenure if the matching model is correct.

To test this hypothesis the following model was estimated on the sample of ExecuComp CEOs with unobserved completed tenure.

\[
\ln\text{Ret}_{i,f,t} = \beta_0 + \beta_1 \ln(1+\text{RF}_t) + \beta_2 \ln(1+\text{MKT}_t) + \beta_3 \text{SMB}_t + \beta_4 \text{HML}_t + \beta_5 \text{MOM}_t + \text{f}(\text{MaxT}_{i,t}) + \text{g}(\text{Year indicators}) + \epsilon_{i,f,t},
\]

where MaxT equals an executive’s tenure at the censoring point, December 2008. A quartic function in MaxT provided the best fit to the data using the random coefficient statistical model. These estimates are reported in Table 7 and Figure 13 plots the predicted relationship between \(E(\ln(1+\text{ret})| \text{MaxT})\) and MaxT along with the 95 percent confidence interval. Up to about 12 years of tenure at the end of 2008 a statistically significant but economically small change occurs in expected returns as MaxT increases. The point estimate for \(E(\ln(1+\text{ret})| \text{MaxT} = 4) = .0011\ (SE=.0004)\) and \(E(\ln(1+\text{ret})| \text{MaxT} = 8) = .0034\ (SE=.0004)\) and the difference is \(.0023\ (SE=.0005)\). These results are consistent with the matching model; expected returns at the end of 2008 for CEOs still in office are greater for longer serving CEOs because their expected match quality is greater compared to CEOs that had served for a shorter time period at the end of 2008.

**Discussion and Summary**
This paper investigates how firms learn about firm-CEO match quality over the careers of a sample of CEOs and then use this information to make CEO retention decisions. We modify a simple Bayesian normal learning model by assuming that each period the firm’s Board of Directors makes a CEO retention decision based on its estimate of firm-CEO match quality and dismisses the CEO if its estimate of match quality falls below a threshold match quality level with a probability greater than a threshold probability. This CEO discharge rule generates several important features about the distribution of match quality among surviving CEOs as their tenure in the job increases. First, if the signals of firm-CEO match quality are positively correlated with true match quality then each period the CEO retention rule will produce a sample of surviving CEOs that are positively selected on match quality. This prediction implies that expected average monthly firm stock returns calculated over a CEO’s tenure will be positively correlated with the total time an executive serves as CEO if investors are also learning about firm-CEO match quality. This prediction stands in contrast to theories that and long-serving CEOs become entrenched in their position to the detriment of shareholders.

The model also predicts expected monthly stock returns conditional on current CEO tenure will depend on the total length of time an executive serves as CEO. Among surviving executives at the end of period t, the executive most likely to be fired at the end of period t+1 is the executive with the lowest estimated match quality at the end of period t. For CEOs that have survived to the end of period t, firm returns in period t+1 will be positively correlated with the total length of time these executives will eventually serve
as CEO if investors observe a noisy signal of match quality. This is shown in Figure 3 using data simulated from the model.

The empirical results using data from ExecComp for CEOs that had left office by the end of 2008 are consistent with the predictions of the model. The results reported in Figures 5a and 5b that impose little structure on the data show mean monthly stock returns over a CEO’s time in the position that increase up to about 7-8 years of completed tenure and remains relatively constant beyond 8 years. These estimates suggest investors continue to learn about CEO match quality over this 8 year period. Constant mean monthly returns for CEOs that serve longer than 10 years is also not consistent with models where long-tenured CEOs are entrenched in their positions to the detriment of shareholders.

Estimates from models that impose more structure and include both current and completed tenure strongly suggest investors continue to learn about firm-CEO match quality through at least 10 years of tenure. The estimates summarized in Figure 8 show monthly returns in month t for a sample of executives that have survived to period t are positively correlated with the length of time they will eventually serve as CEO. We interpret these results as evidence of continued investor learning about match quality up to about 10 years because monthly returns reflect the impact of new information on the value of the firm; mean returns in period t are higher for longer serving CEOs because investors continue to learn about match quality.

The monthly return estimates in Figure 8 were converted to estimated mean monthly returns over a career for executives that serve for different time periods. These estimates, reported in figure 10, imply that for CEOs serving 4 years, investors earn a
mean monthly return of .12 percent. In contrast, the mean monthly return is .92 percent for a CEO that serves for 8 years.

These estimates translate into very large differences in firm value attributable to possible variation in firm-CEO match qualities that firms might experience over a decade. These differences can be illustrated by applying our estimates to the experience Hewlett-Packard (HP) had with CEOs over the period from July 1999 when Carly Fiorina became CEO through September 2011 when Leo Apotheker was fired after serving for less than 11 months. Over this 12+ year time period Hewlett-Packard had 5 different CEOs, including 2 interim CEOs that served 2-3 months following the departure of two non-interim CEOs. This experience suggests HP had great difficulty finding a high quality firm-CEO match and our estimates can put a price on this experience to HP shareholders. Our estimates predict HP’s market value should have increased by just 48.7 percent over the 147 month period from July 1999-September 2011 based on the estimated match quality of the five CEOs. Alternatively, if HP had a found a single executive of higher match quality that had served as CEO for the entire 147 month period, we estimate this higher match quality would have caused HP’s market value to increase by a factor of 4.4. At the end of fiscal year 1999 HP had a market value of $76 billion. These estimates suggest poor firm-CEO match quality cost HP shareholders

32 ExecuComp reports Carly Fiorina served from July 17, 1999-February 8, 2005; Robert Paul Wayman served from February 9, 2005-March 1, 2005; Mark Hurd served from April 1, 2005-August 1, 2010; Catherine Lesjak served from August 6, 2010-November 1, 2010 and Leo Aapotheker served from November 1, 2010-September 22, 2011.
33 HP actually did much worse than predicted from our model. At the end of 2011 HP’s market value had declined to $52.9 billion from $76 billion at the end of FY 1999.
$221 billion relative to the firm value that would have been expected with one high quality CEO that served the full 147 months.\textsuperscript{34}

While there is a large literature showing a negative relationship between firm returns and the probability an executive is fired (Weisbach 1988, Jenson & Murphy 1992, Murphy & Zimmerman 1993, Parrino 1997, Brickley 2003, Taylor 2010, Kaplan & Minton 2012), this paper extends previous research and views firm performance and the total time an executive serves as CEO as joint outcomes of the quality of the match between the firm and the CEO and the process by which firms learn about match quality and make retention decisions based on estimated match quality. The main innovation in this study is the use of completed CEO tenure as an indicator of match quality. This study included all CEOs in ExecuComp where completed tenure was observed and we did not try and distinguish between dismissals and voluntary (from the CEO’s perspective) retirements or departures. The strong relationship between returns and completed tenure across all CEOs suggests that even departures labelled as “voluntary” are influenced by match quality; the utility of retiring versus continuing as CEO is likely affected by labor supply variables such as CEO wealth, health and age but also the returns to not retiring which are a function of match quality.

The results reports in this study suggest CEO quality, as reflected in the firm-CEO match, has an important impact on firm value that may be at least as important as the efforts by BoDs to provide compensation contracts that align the interests of the CEO with the interests of the firm. The monitoring of CEOs by BoDs may be more important as a mechanism for assessing match quality than as a mechanism for managing the firm’s

\textsuperscript{34} These estimates are based on the results reported for model 6 in Table 3.
agency problem. A variety of other potential topics follow from these results that deserve investigation. Do BoDs and the market learn about match quality faster when the CEO is an internal candidate versus an outside hire? Are the signals investors receive about match quality stronger or more valid in different industries or with differences in corporate governance? Does the positive relationship between firm stock returns and completed tenure lead to a positive relationship between CT and realized CEO compensation as firms share with CEOs the benefits of a higher quality match?
References


Murphy, Kevin J. 2012. “Executive Compensation: Where We Are and How We Got There” in Handbook of the Economics of Finance edited by George Constantinides, Milton Harris, and René Stulz. Amsterdam: Elsevier Science North Holland


Figure 1

Mean Estimated Match Quality For CEO By Current Tenure and Critical Value of Match Quality Used for CEO Retention

\[ \hat{\alpha}_{i,t} \]

Posterior Estimate of Match Quality

Current CEO Tenure (Periods)

Feb 2013 simulated data Time 15:43:49, 12 Nov 2013
Figure 2

Mean of the Posterior Distribution of Match Quality Conditional On Current(t) and Completed Tenure Using Simulated Data

Figure 3

Change in the Mean of the Posterior Estimate of Match Quality From (t-1) to t Conditional On Current(t) and Completed Tenure Using Simulated Data
Figure 4

Probability the CEO in a Firm-CEO Pair Was Hired After Jan 1, 1992

Completed Tenure as CEO (years)

Probability

0 2 4 6 8 10 12 14 16 18 20

0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1

Time 13:26:29, 24 Mar 2013 prob_post92_hire.gph
Figure 5a

Mean of ln(1+Ret)-ln(1+Rf) Over a CEO's Career
By One Month Intervals of Completed CEO Tenure

Each Data Point Describes the Mean of ln(1+Ret)-ln(1+Rf) for the Mid-point of a 1 Month Completed Tenure Interval

Figure 5b

Conditional Career Mean of Monthly ln(1+ret) by Completed CEO Tenure

Each Data Point Describes the Conditional Mean Return for CEOs In 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns
Mean Monthly Stock Returns For Months (1,12) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns

Mean Monthly Stock Returns For Months (13,24) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns

Mean Monthly Stock Returns For Months (1,24) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns

Mean Monthly Stock Returns For Months (1,36) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns

Mean Monthly Stock Returns For Months (25,36) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns

Mean Monthly Stock Returns For Months (13,36) of a CEO's Tenure By Completed Tenure

Each Data Point Describes the Conditional Mean Return for CEOs in 1 Month Completed Tenure Intervals and the Lines Are the Predicted Values and 95% CI Using A Random Coefficient Model of Returns
Estimated Distribution of Effects of LnMkt Across Firms in 4-Factor Return Model From the Random Coefficient Model and The Unconstrained OLS Market Model

Estimated Distribution of Effects of LnMkt Across Firms in 4-Factor Return Model From the Random Coefficient Model and The Unconstrained OLS Market Model

Estimated Distribution of Effects of LnMkt Across Firms in 4-Factor Return Model From the Random Coefficient Model and The Unconstrained OLS Market Model

Estimated Distribution of Effects of LnMkt Across Firms in 4-Factor Return Model From the Random Coefficient Model and The Unconstrained OLS Market Model
Figure 8

Estimated Impact on Ln(1+Ret) of Tenure and Completed Tenure

Current Tenure As CEO (years)

Estimate ln(1+Ret)

CT=2  
CT=4  
CT=6  
CT=8  
CT=10
Figure 9

Sum of the Monthly Estimates of $\ln(1+ret)$ Calculated Over Completed CEO Tenure and the 95% C.I.

Figure 10

Estimated Mean of Monthly Returns Calculated Over Completed CEO Tenure and the 95% C.I.
Figure 11

Estimated Monthly Ln(1+Ret) by Tenure and Completed Tenure
For CEOs Serving 10 or Fewer Years

Figure 12

Estimated Mean of ln(1+ret) Over a CEO’s Tenure as CEO
For CEOs That Served 10 or Fewer Years
Figure 13

Estimated Mean $\ln(1 + \text{Ret})$ For Firm-CEO Pairs
Over CEO Career Up To Right Censoring Point
For CEOs With Unobserved Completed Tenure
(With 95% Confidence Interval)
<table>
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<tr>
<th></th>
<th>CT observed, hired before or after 1992</th>
<th>CT observed, hired after 1991</th>
<th>CT observed, hired before 1992</th>
<th>CT is censored, hired after 1991</th>
<th>CT is censored, hired before 1992</th>
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<td>1160</td>
<td>419</td>
<td>1583</td>
<td>170</td>
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<td>CT interquartile Range</td>
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<td>4.267</td>
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<td>58992</td>
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<td>(0.002)</td>
<td>(0.007)</td>
<td>(0.003)</td>
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<td>0.003</td>
<td>0.005</td>
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<td>---------------------------</td>
<td>---------------------------</td>
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### Table 2a

Estimates of the Impact of Completed Tenure on Mean Monthly Returns Over an Earlier Period

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<th>Prediction Period (months)</th>
<th>Estimated Difference in Returns CT=8 v CT=4</th>
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<td>1-12</td>
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<td>(0.0017)</td>
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<td>13-24</td>
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<td></td>
<td>(0.0012)</td>
</tr>
<tr>
<td>25-36</td>
<td>0.0146</td>
</tr>
<tr>
<td></td>
<td>(0.0020)</td>
</tr>
<tr>
<td>1-36</td>
<td>0.0090</td>
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<tr>
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<td>(0.0010)</td>
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### Table 2b

Predicted Impact of Mean Returns in the Prediction Period on Later Returns

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<td>1-12</td>
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<td>(0.0098)</td>
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<tr>
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<td>(0.0100)</td>
</tr>
<tr>
<td>1-24</td>
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</tr>
<tr>
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<td>(0.0149)</td>
</tr>
<tr>
<td>25-36</td>
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</tr>
<tr>
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Standard errors in parentheses.
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Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

N= 119,985
### Table 4

Market Fixed Effect Estimates of CEO Tenure and Completed Tenure on Monthly Stock Returns

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<th>Coefficient</th>
<th>Standard Error</th>
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<td>Complete_tenure^2/1000</td>
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<td>-0.2921***</td>
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<td>(0.0402)</td>
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<td>0.1095***</td>
<td>(0.0310)</td>
<td>0.1127***</td>
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Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

N= 119,985, Number of unique firm-CEO pairs = 1579
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<td>0.0006</td>
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<tr>
<td>Tenure^2/1000</td>
<td></td>
<td>-0.0351*</td>
<td>-0.0357*</td>
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<td>0.0810***</td>
<td>0.0765***</td>
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<tr>
<td>Tenure/1000</td>
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<tr>
<td>R^2</td>
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Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
N= 119,985, Number of unique firm-CEO pairs = 1579
The R^2 is from a regression of ln(1+ret) on the predicted ln(1+ret) that includes the random components for the four market variables.
**Table 6**

Coefficients on CEO Tenure Variables in an RC Model of Monthly Firm Stock Returns ($\text{Ln}(1+\text{ret})$) For CEOs Where Completed Tenure ≤ 10 Years

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
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<tbody>
<tr>
<td>Constant</td>
<td>-0.0205***</td>
<td>(0.0026)</td>
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<tr>
<td>Complete_tenure</td>
<td>0.0114***</td>
<td>(0.0010)</td>
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<td>Complete_tenure$^2$/1000</td>
<td>-0.8496***</td>
<td>(0.1021)</td>
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<tr>
<td>Tenure</td>
<td>-0.0082***</td>
<td>(0.0011)</td>
</tr>
<tr>
<td>Complete_tenure x Tenure/1000</td>
<td>0.8380***</td>
<td>(0.1362)</td>
</tr>
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</table>

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Table 7

Estimates of CEO Tenure at the Censoring Point
On Mean Career Monthly Stock Returns For CEOs Where Completed Tenure is Unobserved

<table>
<thead>
<tr>
<th></th>
<th>Coefficient 1</th>
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<tr>
<td>Constant</td>
<td>-0.0032**</td>
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<td>Max Tenure</td>
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<tr>
<td>Max Tenure^2/1000</td>
<td>-0.0796***</td>
<td>-0.0288</td>
</tr>
<tr>
<td>Max Tenure^3/1000</td>
<td>0.0013**</td>
<td>-0.0015</td>
</tr>
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</table>

N=132,911
Standard errors in parentheses
*** p<0.01, ** p<0.05