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RESEARCH NOTES AND COMMENTARIES

THE CEO PERFORMANCE EFFECT: STATISTICAL ISSUES AND A COMPLEX FIT PERSPECTIVE

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How CEOs affect strategy and performance is important to strategic management research. We show that sophisticated statistical analysis alone is problematic for establishing the magnitude and causes of CEO impact on performance. We discuss three problem areas that substantially distort the measurement and sources of a CEO performance effect: (1) the nature of performance time series, (2) confounding and (3) the discovery of many interactions associated with the CEO performance effect. We show that the aggregate of empirical research implies complex interdependency as the driver of the CEO performance effect. This suggests a 'fit' model requiring new research approaches. Copyright © 2011 John Wiley & Sons, Ltd.

INTRODUCTION

> *''The greatest challenge today, not in cell biology and ecology, but in all science, is the accurate and complete description of complex systems. Scientists have broken down many kinds of systems. They think they know most of the elements and forces. The next task is to reassemble them, at least in mathematical models that capture the key properties of entire ensembles."*
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> E.O. Wilson (1998: 85)

An important aspect of strategic management research concerns how leaders—and specifically chief executive officers (CEOs)—affect strategy and performance (dating back to Barnard, 1938). However, the measurement of a CEO performance effect continues to be problematic; using either variance component analysis (VCA) or fixed effects is susceptible to three sets of issues. We conducted an empirical study of the U.S. passenger trunk airline industry for the period of 1978 to 2005 to illustrate some of these problems. The Appendix, which is available on the *Strategic Management Journal* Web site, provides examples from this study. Expanding from these empirical issues to underlying theory, we show how the aggregate of current research implies a complex interdependency or 'fit' model as the causal driver of the CEO performance effect. *By complex*

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interdependency we mean that the many variables associated directly or indirectly with the CEO performance effect are interconnected to a meaningful degree. Thus, the behavior of each variable is dependent on the behavior of many others. This complex system of variables behaves in a nonlinear fashion over time. Understanding the CEO performance effect requires going beyond the study of the independent binary relationships, simple interactions, and sums of these that are characteristic of statistical models using regression equations.

There are a number of unresolved measurement issues regarding the CEO effect. Table 1 points out the key facts, findings, and limitations of nine major studies or replications that seek to directly measure a CEO performance effect or similar construct. Four key studies in this stream (Crossland and Hambrick, 2007; Lieberson and O'Connor, 1972; Thomas 1988; Weiner and Mahoney, 1981) use VCA, while two (Bertrand and Schoar, 2003; Mackey, 2008) use fixed effects. Two major problems identified in Table 1 are the confounding of CEO and firm effects and the order in which the components enter the VCA analysis. Bertrand and Schoar (2003) and Mackey (2008) overcome the latter by using samples with only CEOs who have served in that capacity in multiple firms. Crossland and Hambrick (2007) overcome the former by using simultaneous analysis of variance (ANOVA).

While some problems with the measurement of a CEO effect have been overcome, three areas which current statistical technology cannot surmount remain: issues that involve the stochastic nature of the time series of firm returns, confounding issues beyond CEO and firm, and issues that are raised by the presence of many interactions.

Stochastic nature of the time series of firm returns

Empirical research has established that firm performance (measured by accounting ratios such as return on assets [ROA], or financial market returns) fits a mean reverting random walk (e.g., Denrell, 2005). For the mean reversion component, the farther a random walk gets from equalization (or equilibrium) the stronger the 'pull' to revert to the equilibrium/equalization value.

Random walks have some interesting properties that impede interpretation of a CEO effect. It is a well-established property of random walks that they can wander away from equalization (equilibrium returns, which need not be zero) for long periods of time and to great distances with probabilities much greater than observers expect (Feller, 1968: 78–84). Table 3 in the Appendix illustrates aspects of this phenomenon. At least some of the CEO fixed-effect coefficients in the Appendix are more plausibly the result of the random walk characteristic of returns than the impact the CEO has on performance. Fixed-effect methods cannot recognize such phenomena as the outcomes of random walks. This is not to say that they are definitely the result of random walks as opposed to being truly associated with actions of CEOs. It is, however, to say that we cannot tell based on fixed-effect models. In general, it is reasonable that both may be involved to different degrees for different individual CEOs. Other undefined causes may also be at work.

It is well known that high performance of firms generally does not last over extended periods of time. Firms with performance above their mean often remain there for several years but then revert to roughly the mean due to the mean reversion property. In particular, the coefficients of CEOs of American Airlines show an apparent pattern that is consistent with this phenomenon (see Table A3 in the online Appendix). Casey is not significantly different from the median CEO in the sample, then Crandall is significantly better, then Carty drops back to median performance, followed by significantly above-median performance by Arpey. Similarly, shorter patterns are visible in the CEO data for America West, PanAm, and TWA. This mean reversion phenomenon suggests that being the CEO immediately following a period of performance substantially above equilibrium may bias one to 'achieving' (i.e., be attributed) equilibrium performance in spite of CEO capabilities. Similarly, being a CEO after a period of performance substantially below equilibrium may bias one to 'achieving' improved performance regardless of capabilities. Of course there are other possibilities, but current statistical technology cannot adequately separate these from CEO fixed effects.

It is also worth noting that very high performance is more likely for firms engaged in practices that can *ex ante* produce high variability in outcomes, that is, high risk strategies. Hence, a very high and a very low performance may be more a function of luck than skill and is unlikely to

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Table 1. CEO effect—overview

Study	Sample	Method	Conclusions	Limitations
Lieberson and O'Conner (1972)	167 major publicly owned corporations (1946–1965)	VCA	(1) 6.5% of the variance of performance was explained by a leadership effect (2) Leadership effect depends on the differences of strategic options across industries	Limited performance measures Exclusion of companies that were either highly diversified or radically altered by mergers Arbitrary effect of the order of entry of the independent variables Absence of organization-specific measures Internal inconsistencies in the results
Salancik and Pfeffer (1977)	Budget variance of 30 cities over an 18-year period (1951–1968)	VCA	Variance in budget items was most heavily influenced by city, 55–91%, next by year, 3–17%, and then by mayor, 5–15%	Sequential apportionment of variance to year, industry, organization, and leadership influence the outcome since variables are dependent on each other
Weiner and Mahoney (1981)	193 randomly selected manufacturing corporations; 19-year period (1956–1974)	Multiple regression analysis (VCA could not be performed due to computer limitations)	Stewardship accounts for 12.8% of variance of profit, 43.9% of profitability, 47 % of stock price	Stewardship is defined by specific year-company combinations. (residuals, i.e., non-random influences that have been omitted from the regression model)
Thomas (1988)	12 large retail firms in the United Kingdom	VCA	Firm effects accounted for 72.7% to 89.6% of the variance in firm performance, and the CEO effect accounts for 3.9 to 7% of this variance	Limitations of sample (size of sample and fact that it comprises only one industry and country) Limited comparability of sample with Lieberson and O'Connor (1972)
Thomas, Litschert, and Ramaswamy (1991)	224 firms from the electric computing equipment industry	Regression analysis	(1) Different CEO profiles are associated with different strategy types (2) Match between executive characteristics and strategy has performance implications	Associations rather than causal inference Other variables could influence the relationship Examination not on the corporate level
Wasserman, Nohria, and Anand (2001)	531 companies across 42 industries	VCA	CEO effects accounted for 14.7% of variance in firm profitability (ROA)	Causal inference cannot be made
Bertrand and Schoar (2003)	manager-firm matched panel data set; 500 managers	Fixed-effects model	Managers in top quartile of the distribution increases the rate of ROA by about 3%	Study design does not allow the authors to estimate the causal effect of managers on firm policies or performance

Table 1. (*Continued*)

Study	Sample	Method	Conclusions	Limitations
Crossland and Hambrick (2007)	15-year matched samples of 100 U.S., 100 German, and 100 Japanese firms	VCA and simultaneous ANOVA	CEO effect varying from 4.6% (Japan) to 13.4% (US) on firm profitability (ROA)	Sample size Cross-national measurement equivalence Limitations of a simultaneous ANOVA analysis
Mackey (2008)	520 firms over a 10-year period (1992–2002)	Simultaneous ANOVA	CEO effect is 12.9% while industry is 18% and firm influences are 29.5% with ANOVA With methodological corrections, CEO effect is 29.2%, while corporate effect is 7.9% and industry is 6.2%	Bias in sample (data requirements of study lead to the creation of a sample where CEO discretion is systematically high) Limitations of a simultaneous ANOVA analysis

last long (Denrell, 2005). Of course, in the case of extremely low performance, bankruptcy may result. Hence, periods of either very high or very low performance (relative to equilibrium performance) may correspond to the tenure of particular CEOs who adopted high risk strategies. Any *ex post* measure of CEO risk, such as variability of returns, does not capture the risk taken *ex ante*.

The problems introduced by the mean reverting random walk nature of returns are at least partially beyond the capabilities of current statistical technology and especially so for CEO fixed effects. The *ex ante* risk taking issues would have to be tackled by developing reliable *ex ante* measures of risk taking for large samples of firms and would have to account for survivor bias. This would be extremely difficult, but not out of the realm of possibility.

Confounding of CEO, firm, and time

CEOs usually serve in that capacity in only one firm. This results in a complete confounding of CEO and firm. Such studies, including the one reported in the Appendix, measure the effect of a particular CEO in a particular firm at a particular time, but do not generalize to a CEO effect that is independent of firm and time (and the interaction of firm and time). Bertrand and Schoar (2003) and Mackey (2008) use samples of only CEOs who served in more than one firm to overcome confounding of CEOs and firms. However, experience as a CEO in one firm inevitably alters the CEO performance in subsequent firms. Furthermore, there may be only certain types of firms or firms under certain conditions that prefer to hire outsiders with previous CEO experience. These issues can likely be addressed with current statistical technology, but other aspects of confounding will be more difficult to address.

CEO tenure and firm effects are inevitably confounded with a particular time period, and time period can make a substantial difference in performance. Time fixed effects are important, as shown in the Appendix. However, these are the average fixed effects by year across the sample. Each firm is different to some degree in each time period, and this is not uniform across time. The firm, its strategy, and the environment change over time. At any given time, some firms are better equipped to deal with the contemporaneous environment than others. Hence, there is an interaction effect

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between individual firms and the contemporaneous environment that is not captured by a fixed year effect. It is possible to capture the interaction of firm and year fixed effects, but this will add many additional interaction terms, one per year that each CEO served. These interaction terms grow faster than proportionately as the number of CEOs increases, quickly swamping the degrees of freedom. Furthermore, it is not just interaction of these two fixed effects, but the interaction among specific firm characteristics (e.g., strategy and culture) with the specific characteristics of the contemporaneous environment (e.g., uncertainly and rate of change) that are important.

Hence, a CEO performance effect in a certain firm will be contingent to some degree on various unique combinations and interactions of environmental events, trends, and forces, and on the internal configuration of the firm. Unlike confounding of CEO effects with firm effects, *we cannot have different CEOs serving in the same firm at the same time*. Another way of thinking about this is to consider that having two CEOs with the same numerical fixed-effect CEO performance coefficient does not mean that the same performance would be achieved by both CEOs in the same firm at the same time. The CEO performance effect is not modular.

There are current statistical approaches based on sampling that can overcome some simple confounding issues. However, for triple confounding of firm, CEO, and time, degrees of freedom problems will be difficult or impossible to overcome with current statistical technology.

Finally, the CEO effect for any particular CEO is to some degree dependent on (or confounded with) the actions of past CEOs. For example, a decision by a previous airline CEO may lock the firm into a particular fleet configuration or hub structure that is not easily altered and interacts with the environment to substantially impact performance. At a general level, this issue is known as the credit assignment problem of who gets credit when the impact of a decision or action is distant in time (or in organizational space or physical space) from the decision or action. Current CEOs may benefit or be damaged by actions of their predecessors, but will still be credited with performance effects. Qualitative research may be beneficial here, but we see no way to correct a large sample for credit assignment issues.

Interactions and the CEO performance effect

Recent empirical research has been successful in discovering a wide variety of interactions that are associated directly with the CEO performance effect or indirectly through other variables that are directly associated with the CEO performance effect. Researchers have found a substantial number of such interactions and it is likely that many others will be discovered.

Table 2 summarizes 17 major interaction studies. Recent examples of variables interacting with CEO demographics/psychographics include strategic flexibility (e.g., Nadkarni and Herrmann, 2010), strategic change (e.g., Zhang and Rajagopalan, 2010), generic competitive strategies (e.g., Beal and Yasai-Ardekani, 2000), organizational culture (e.g., Berson, Oreg, and Dvir, 2008), and industry dynamism (e.g., Henderson, Miller, and Hambrick, 2006).

In these interaction studies, theories are developed that are relevant specifically to the detailed interaction studied. Such theories include alignment hypotheses (Beal and Yasai-Ardekani, 2000), leadership theories (e.g., Berson *et al*., 2008), and person-pay interaction/expectancy theory (Wowak and Hambrick, 2010). The attraction-selection-retention framework—commonly used for person-environment fit in organizational behavior (for an overview see Edwards, 2008)—is also mentioned in some studies as another theoretical motivation (Berson *et al*., 2008). In summary, a large number of different individual theories are used to hypothesize specific interactions, but these relationships in sum are not seen as being driven by any overall theory or model. This incremental approach to testing for possible interactions raises important issues regarding model specification. Once an interaction (or a relationship) is found in one study, it seldom becomes a control variable in subsequent studies. Also, it should be noted that there are many other ways in which interactions can occur beyond the standard two variable jointly distributed variety.

This means that specification of a comprehensive model of the CEO performance effect is neither developed nor tested. Furthermore, independent variables in some studies are dependent variables in other studies. This raises an interesting question: how many interactions, variables, and relationships in how many simultaneous equations will be necessary to specify and test a comprehensive empirical model of the CEO performance

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Table 2. Interaction studies—overview

Study	Sample	Method	Conclusions	Limitations
Gupta and Govindarajan (1984)	58 strategic business units (SBUs) within eight Fortune 500 firms from different industries (survey)	Regression analysis	Greater marketing/sales experience, greater willingness to take risk, and greater tolerance for ambiguity contribute to effectiveness in the case of build SBUs but hamper it in the case of harvest SBUs	Self-report measures for strategy and effectiveness of strategy implementation Causal inferences cannot be drawn because not longitudinal data Limited variables (e.g., competitive posture of firm is not considered)
Govindarajan (1989)	121 SBUs	Regression analysis	Hypotheses relating experience and performance	Causal inferences cannot be drawn Measurements of the indicator variables
Beal and Yasai-Ardekani (2000)	101 small manufacturing firms (survey)	Regression analysis	Support of alignment hypothesis When CEO experience is congruent with the requirements of generic or hybrid strategies, firms will have superior performance	Use of subjective measures of performance Exclusive focus on the effect of demographic variables rather than including psychological variables
Hambrick and Cannella (2004)	404 firms in 21 industries (1987–1996)	GEE	CEOs who have COO showed substantially lower performance	Incidence of the COO position yielded only limited predictive power
Henderson, Miller, and Hambrick (2006)	98 CEOs in branded foods industry and 228 CEOs in highly dynamic computer industry (both 1955–1994)	GEE	Differences in performance trajectory over the CEO tenure for the stable food industry from the dynamic computer industry	Generalizability of industry background
Chatterjee and Hambrick (2007)	111 CEOs in the computer hardware and software industries (1992–2004)	GEE	Narcissism is associated with extreme and irregular company performance	Partial and indirect proxies of narcissism Characteristics other than narcissism may be at work Industry focus Measurement error, measurement static but narcissism may vary over time
Karaevli (2007)	Longitudinal investigation of U.S. airline and chemical industries (1972–2002)—140 succession observations	OLS hierarchical regression	Hypotheses relating CEO outsiderness and environmental munificence	Sample and hence results are specific to two industries (airline and chemical industry)

Sanders and Hambrick (2007)	950 firms selected from Standard & Poor's 500, Mid-Cap and Small-Cap indexes in 1998	Cross-sectional time series Regression with GLS estimators	The more a CEO is paid in stock options, the more extreme the subsequent performance of the CEO's firm, and the greater the likelihood of extreme performance will be a big gain	Focus on CEO stock options only rather than package Not clear how CEOs transmit their risk propensities Features of stock option plans not investigated Impact of different business conditions or contexts on the effectiveness of CEO stock options
Simsek (2007)	632 CEOs of manufacturing and service firms with between 20 and 500 employees	SEM	CEO tenure influences performance through its influences on TMT risk taking and the firm's pursuit of entrepreneurial initiatives	Generalizability to larger publicly-owned firms not clear
Berson, Oreg, and Dvir (2008)	26 CEOs, 71 senior vice presidents, and over 185 organizational members from 139 Israeli publicly traded companies	PLS SEM	CEO characteristics were related to organizational culture and organizational culture was related to performance	Specific country context; national culture influences organizational culture
Richard, Wu, and Chadwick (2009)	579 U.S. banks	Hierarchical regression	CEO industry tenure positively moderates, and CEO position tenure negatively moderates, the Entrepreneurial Orientation to performance relationship	No inference of causality Limited generalizability of results Other CEO characteristics or TMT characteristics may also be relevant
Delgado-Garcia and De La Fuente-Sabaté (2010)	51 survey responses from Spanish savings banks	Hierarchical regression	Negative affective traits of CEOs are related to more conformist strategies and more typical performance, whereas positive affective traits seem to promote outcomes that deviate from tendencies of the industry	Sample size Other personality traits such as risk aversion can influence strategic and performance conformity Industry focus (managerial discretion does not vary)
Wowak and Hambrick (2010)	167 CEOs (1993–2002)	Regression analysis	Interaction effect between executive characteristics and pay arrangements affects behavior and organizational outcomes	Sample characteristics
Zhang and Rajagopalan (2010)	Tenure histories of 193 CEOs who left office (1993–1998)	GLS Regression Analysis	Hypotheses related to the impact of CEO outsiderness and tenure on the relationship between strategic change and firm performance	Archival data (underlying reasons are not clear) Combined index of strategic change Sample of large non-diversified firms

Table 2. (*Continued*)

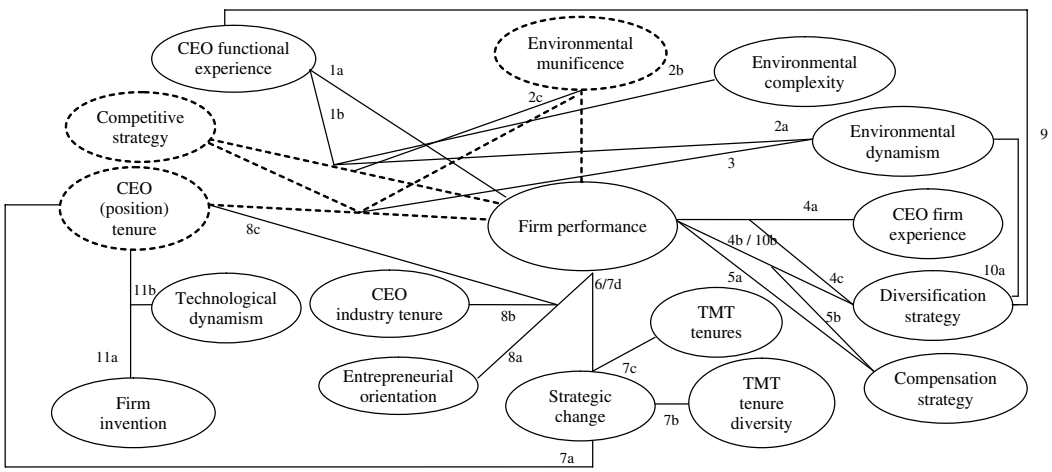
Study	Sample	Method	Conclusions	Limitations
Nadkarni and Herrmann (2010)	195 small and medium enterprises (SMEs) in the Indian business process outsourcing industry	SEM	Each factor of the Five Factor Model (FFM) of CEO personality influenced strategic flexibility Strategic flexibility mediated the relationship between CEO personality and firm performance	Use of SMEs limits generalizability Single industry Single cultural context Particular growth at that period in India Only direct relationship between FFMs of CEO personality and strategic flexibility (had to be controlled for by using only relatively young, service-oriented firms in a specific segment)
Haynes and Hillman (2010)	236 firms in 97 industries	Linear regression	The presence of powerful CEOs weakens the effect of board capital breadth on strategic change	Strategic change measures Only board capital measures that are disclosed in proxy statements Generalizability of study post-Sarbanes Oxley Act period
Li and Tang (2010)	2790 CEOs of diverse manufacturing firms in China	Logit model, regression	Managerial discretion moderates the relationship between CEO hubris and firm risk taking Market munificence and market complexity, research and development intensity, Chair-CEO duality are also moderators (positive) and firm age and firm size and state-ownership, political appointment (negative)	National context Operationalization of CEO hubris Potential moderators (e.g., executive job demands)

effect? Given the number of variables and relationships already discovered, one cannot be optimistic that a comprehensive model constructed from them can be tested using current statistical technology. In sum, research, including that which has been briefly reviewed in this section, identifies an increasing number of variables, interactions, and relationships that are related to other variables, interactions, and relationships; hence directly or indirectly to the CEO performance effect. A wide variety of variables have been identified that seem to have some impact in some way on the CEO performance effect. These results are important. At the same time, one cannot help but experience some confusion when trying to comprehend what the research literature and the large number of individual theories are saying in aggregate about the overall CEO performance effect.

A COMPLEX 'FIT' PERSPECTIVE ON THE CEO PERFORMANCE EFFECT

We believe that when viewed together, *the extensive current studies of relationships and interactions relevant directly or indirectly through intervening relationships imply that the CEO performance effect is determined in aggregate by a complex set of interdependencies*. In other words, a model of complex interdependency can be induced by viewing these previous studies in aggregate. This is illustrated in Figure 1, where we show graphically some of the relationships among variables from a sample of 11 empirical studies, including the one described in the online Appendix. The variables and relationships in this figure are related to many more relevant variables and relationships that appear in hundreds of studies that are not shown.

As an example of the nature of complex interdependency, consider a change in the level of 'CEO position tenure' in Figure 1. Note that a change in 'CEO position tenure' if achieved through replacement will almost certainly change many other CEO demographic/psychographic variables. These will subsequently cause adjustment or change the level of many other variables. This will in time alter the level of firm performance, which will alter the level of strategic change, but this will feed back into the level of CEO position tenure and thereby change it again (recursively). The impact of 'top management team [TMT] tenure' and 'TMT tenure diversity' will also be altered over time by the change in 'strategic change.' Also, the moderation



1. (a, b): Impact of the interactive effect of CEO functional experience and competitive strategy on firm performance (Beal and Yasai-Ardekani, 2000).
2. (a, b, c): Impact of strategy on performance is moderated by environmental dynamism, complexity, and munificence (McArthur and Nystrom, 1991).
3. Impact of CEO tenure on organizational performance is moderated by environmental dynamism (Henderson *et al*, 2006).
4. (a, b, c): Impact of CEO firm-specific experience on performance is moderated by diversification strategy (Guthrie and Datta, 1998).
5. (a, b): Interactive effect of compensation strategy and diversification strategy on performance (Gomez-Mejia, 1992).
6. Impact of strategic change on performance (e.g., Zajac and Kraatz, 1993).
7. (a –d): Impact of performance, CEO tenure and TMT tenures, high diversity in TMT tenures on strategic change (Boecker, 1997).
8. (a, b, c): Impact of entrepreneurial orientation on firm performance is moderated by CEO industry and position tenure (Richard *et al*., 2009).
9. Impact of functional experience on diversification (Song, 1982).
10. (a, b): Impact of environmental dynamism on diversification and performance (Keats and Hitt, 1988).
11. (a, b): Impact of CEO tenure on firm invention is moderated by technological dynamism (Wu, Levitas, and Priem, 2005).

Figure 1. Partial CEO map

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level of 'CEO position tenure' on the relationship between entrepreneurial orientation and firm performance will change. The changes that have already occurred in firm performance will alter the effect of variables such as CEO functional experience and compensation strategy. More generally, most changes in variables will reverberate through much of this figure over time, and, more importantly, to the much larger network of many statistical models from studies relevant to the CEO performance effect.

In such a world as in this simplified diagram (Figure 1), isolating individual relationships for study can lead to identifying variables that play some role, but cannot accurately capture the aggregate nature of the causality. Furthermore, if all the studies relevant in some way to the CEO performance effect were included in this diagram, it would spread to a much wider and denser (and more accurate) network of relationships of much greater complexity. This 'complex interdependency' (or 'complexity') refers to systems where each part strongly depends on the behavior of others. *The theories that describe the behavior exhibited by complex interdependency in aggregate are different from those that describe the individual constituent relationships* (e.g., Vicsek, 2002). We have numerous theories about various individual constituent relationships associated with the CEO performance effect, but no aggregate theory of these relationships. Complex interdependency is characterized by highly nonlinear behavior and is common in the hard sciences and increasingly recognized and studied in the social sciences. It is often called 'fit' in the strategy literature. As Figure 1 illustrates, using a 'fit' model to understand the CEO performance effect is not a speculative proposal. It formalizes what the aggregate of current empirical research related to the CEO performance effect is showing us.

The quality or appropriateness of fit (or 'alignment') has long been a key concept in strategic management, primarily with regard to the firm and the environment: fit of strategy and structure (Chandler, 1962), fit between internal strengths and weaknesses and environmental opportunities and threats (Andrews, 1971), and fit between organization and environment (Lawrence and Lorsch, 1967). Beginning roughly with Mintzberg's (1979) study of 'configurations' and Miller's (1981) discussion of 'gestalts,' it became increasingly formalized that fit involved complex interdependencies. Porter (1996) discussed the nature of complex fit among a firm's activities and illustrated it with a highly successful firm with strong interdependencies, Southwest Airlines. Siggelkow (2001, 2002) further developed the relationship between fit and sustainable competitive advantage. His approach emphasized that, following both Miller (1981) and Mintzberg (1979), firm *internal fit* should not be thought of as pairwise associations between variables, but as gestalts or configurations describing sets of elements and their relationships. Such relationships are logical and coherent (not random), but may or may not be appropriate for the firm at a particular point in time. Siggelkow (2001, 2002) viewed the firm's *external fit* as the appropriateness of the firm's internal fit with the environment, which corresponds to usual measures of performance. Hence, in rough parallel to Siggelkow, *we define 'CEO' internal fit (as opposed to 'firm' internal fit) as a system (or network) of coherent interdependent relationships among CEO psychographic and/or demographic variables and firm variables.* Again, by parallel, *we define external CEO fit as the appropriateness of CEO internal fit with the contemporaneous external environment of the firm as measured by the component of performance attributable to the CEO. CEO internal and external fit, therefore, are the ultimate drivers of the CEO performance effect. It is important in all that follows to clearly note where we are talking about firm internal and external fit versus where we are talking about CEO internal and external fit.* A particular CEO internal fit may be entirely logical and coherent (and often is), but inappropriate for the environment the firm faces, resulting in poor CEO external fit as measured by the CEO performance effect. Overall, this CEO fit view as just defined is consistent with what empirical research related to the CEO performance effect suggests to us in aggregate about the underlying causal structure.

DISCUSSION

Given complex interdependency, there are some difficult empirical and theoretical issues in moving much farther along the current statistical modeling research trajectory. Below we discuss: concepts and models of fit, research implications, some preliminary propositions suggested by a fit

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perspective, and managerial implications. We conclude by noting complex interdependency may characterize many other phenomena relevant to strategic management.

With complex interdependency, the constituent relationships cannot be *adequately* studied in isolation from the entire web of interdependencies. Empirical studies can be the basis for counterfactuals (e.g., Falato, Li, and Milbourn, 2011), but this has limited usefulness in the presence of complex interdependency. Attempting to statistically model complex interactions (fit) with a series of variables and simultaneous equations would quickly swamp current statistical technology. Understanding causality for the CEO effect will likely require an aggregate theory that uses the properties such as 'degree of ruggedness' that emerge from complex interdependency. In general, we suggest that analytical modeling and simulations of such models are a promising way forward at this stage. Simulations (computational models) can pose and answer different questions than statistical studies (Burton, 2003). They provide an ideal medium in which theoretical insights can be discovered. As Miller and Page (2007: 88) put it, '... artificial worlds are fully observable, recoverable, and repeatable, and thus they are a fertile playground from which theories can be created, refined, and tested.' Three general classes of such models that seem promising are problem spaces (or landscapes), system dynamics models, and agent-based models.

A multidimensional problem space or landscape enumerates all possible combinations of variables and their interdependencies and associates a 'performance value' with each combination. In the strategy literature, there are two examples of such problem spaces: the 'NK landscape' (analytical) and the 'performance landscape' (conceptual). Levinthal (1997) brought the concept of NK landscapes into the strategy literature based on Kauffman's (1993) NK model of genes. NK landscapes have been found very useful as theory development tools in modeling and understanding various forms of interdependency (e.g. Lenox, Rockart, and Lewin, 2007; Levinthal, 1997; Rivkin and Siggelkow, 2007). Siggelkow (2001) introduced the similar conceptual 'performance landscape' as a multidimensional space in which each dimension represents the values of a particular choice (e.g., degree of vertical integration) that a firm can make and a final dimension that indicates the performance value of each combination.

A key aspect of all landscape models is the amount of interdependence among variables, or ruggedness. The more interrelated the variables are, the tighter the fit is, and the more rugged the landscape. Ruggedness closely parallels Weick's (1976) binary concept of loosely and tightly coupled systems. Rugged landscapes can have only one global maximum, but may have many local maxima. On a rugged landscape, changing a single variable changes the value of other (often many) variables. Rugged landscapes make it abundantly clear that there is no such thing as holding some variables constant while others are studied. Ruggedness, or degree of coupling, is an example of an emergent property of complex systems. Complex interactions lead to the emergence of phenomena that cannot be seen in the individual variable or in binary relationships. An example from organizations is a norm or more generally organizational culture.

With obvious changes in nomenclature, simulations of landscape models can be used to study the CEO performance effect. Such studies, though largely metaphorical, could be a good starting point. Using such simulation and conceptual models to assist in research will be very different from current empirical investigation, but should be a vital complement to empirical study.

A second category of simulation models comprises the techniques of systems dynamics (Sterman, 2000), which are much more general and flexible than NK landscape models but require more detailed model specifications. They go much farther than NK models in incorporating more realistic assumptions and allow for general specification of causality and timing (Davis, Eisenhardt, and Bingham, 2007). The tools usually associated with systems dynamics allow models of complex systems to be built up from simpler constituent relationships without a deep understanding of the underlying mathematics.

A third category of simulation models is made up of the agent models (Harrison *et al.*, 2007; Miller and Page, 2007) where aggregate, emergent properties can be studied by specifying the rules by which individual agents interact. These models would seem to be appropriate for studying aspects of social interaction between the CEO and the TMT or the entire organization.

An empirical starting point is to suggest some informal propositions. These propositions, though generally consistent with theory and logic, are not

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formally developed due to space considerations. Subsequently, the results of empirical study can be used to build more complete and useful simulations that can lead to new empirical studies. To illustrate the logic of such propositions while staying at the level of firm internal fit (as opposed to CEO internal fit), we suggest the following: outside CEOs with primary experience in firms with a similar level of firm internal fit will, on average, outperform CEOs whose primary experience is in firms with a dissimilar degree of such fit.

We now turn to propositions involving CEO fit. These propositions imply the development of measures for *the degree of internal fit of CEO psychographic and/or demographic variables with firm variables (CEO internal fit)*. Three complementary approaches for such variables could be development and validation of a survey instrument(s), the use of qualitative research within firms, and surrogate measures.

When changes occur that destroy the external firm fit, CEOs will have to take actions that are novel for them and thereby difficult and risky. This will be impeded by the degree to which CEO internal fit is tight. By contrast, loose CEO fit implies more freedom of action.

Proposition 1: When firm external fit is invalidated by environmental changes, CEOs with tight internal fit will experience lower performance than CEOs with loose fit.

Proposition 2: When firm external fit is invalidated by environmental changes, CEOs with loose internal fit will also experience lower performance but to a lesser extent than CEOs with tight internal fit.

The final two propositions address the issues raised by retirement, death, or departure of a CEO in firms with either loose or tight CEO internal fit.

Proposition 3: The departure of CEOs in firms with tight CEO internal fit will, on average, be associated with relatively lower performance in the short run than those with loose internal fit.

Proposition 4: The departure of CEOs in firms with loose CEO internal fit will, on average, be associated with relatively higher performance in the short run than those with tight internal fit.

Beyond using statistical analysis on emergent properties (e.g., ruggedness or coupling) of the complex interdependence between firm and CEO variables, there are some statistical techniques that may be useful in dealing directly with the total set of interdependent variables or the output of these systems. Principal components can sometimes give insights into aspects of the causal structure of interdependent data and are often recommended in commercial data mining of large, complex databases (Hastie, Tibshirani, and Friedman, 2009). More generally, data mining and statistical learning from computer science and statistics is concerned with drawing insights from very large interdependent datasets and has developed several useful new techniques (see Hastie *et al*., 2009). Vector autoregression (Greene, 2003) can be used to study the evolution of a vector of a few interdependent variables. Generally, the techniques of time series analysis on nonlinear processes (Sprott, 2003) provide useful insight into the aggregate causal structure of complex processes. Time series analysis of nonlinear processes is currently an important research topic in a number of fields—most notably statistics—and further developments can be expected. All of these tools are built on an understanding of the mathematics of nonlinear dynamics (Kaplan and Glass, 1995) and are applicable to both simple and complex nonlinear systems. The authors believe that a baseline understanding of the mathematics of nonlinear systems is crucial to future progress in the study of manifestations of complex interdependency in strategic management.

We think there are other systems (perhaps many) of variables studied in the strategic management literature characterized by complex interdependency beyond the fit models of organization and environment and the CEO fit model developed in this paper. Two examples illustrate this: five-force industry analysis (Porter, 1980) and organizational capability or competence. For both of these topics, there are a wide range of empirical studies using various and often overlapping dependent and independent variables that are suggestive of complex interdependency. Furthermore, it seems reasonable that any causal theory of the origin and evolution of industry profit potential in the first case or capability-based competitive advantage will involve complex interdependency among many 'independent' variables appearing in relevant regression models.

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There are at least two important implications of the current research for managers involved in corporate governance. First, effective corporate governance implies reliable measures for the financial impact of CEOs that are not currently available. More subtle measures that incorporate an understanding of the three issues discussed in this paper are needed. Second, selection of CEOs would benefit from a better understanding of the role of complex interdependency, or fit, in determining performance. For well-performing firms, choosing a CEO based on fit with a wide variety of current firm features seems appropriate. However, for underperforming firms, choosing a CEO with a 'fit gap' is more likely to result in appropriate changes.

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