Strategic Management Journal
Strat. Mgmt. J., **25**: 1279–1295 (2004)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/smj.432

A BAYESIAN OPERATIONALIZATION OF THE RESOURCE-BASED VIEW

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This paper argues that the gap between the theoretical utility and the practical utility of the resource-based view (RBV) may be narrowed by operationalizing the theory more consistently with Penrose's original framework. The operationalization proposed here is a twofold approach. First, the RBV may be enhanced by the explicit recognition of Penrose's two classes of resources, namely, administrative resources and productive resources. This distinction suggests a focus on the administrative decisions of managers that lead to economic performance. Second, we argue that the RBV is a theory about extraordinary performers or outliers—not averages. Therefore, the statistical methods used in applying the theory must account for individual firm differences, and not be based on means, which statistically neutralize firm differences. We propose a novel Bayesian hierarchical methodology to examine the relationship between administrative decisions and economic performance over time. We develop and explain a measure of competitive advantage that goes beyond comparisons of economic performance. This Bayesian methodology allows us to make meaningful probability statements about specific, individual firms and the effects of the administrative decisions examined in this study.

INTRODUCTION

The resource-based view of the firm (RBV) offers a theoretical explanation of competitive advantage which is based on differences in firm resources (Barney, 1991; Peteraf, 1993; Rumelt, 1984; Wernerfelt, 1984). RBV logic is nearly ubiquitous as a *practical* tool as evidenced by its coverage in strategy classes, textbooks, and journals with largely managerial audiences (e.g., Collis and Montgomery, 1995; Hitt, Ireland, and Hoskisson, 2001). Scholars have also relied upon the RBV in examining the relationship between firm resources and economic performance (Bergh, 1998; Deephouse, 2000; Hult and Ketchen, 2001). And yet, challenges continue to be registered by some academicians about the *theoretical* validity of RBV explanations of competitive advantage (Priem and Butler, 2001a). The apparent gap between the utility of the RBV as a practical tool and its utility as a theoretically sound explanation of competitive advantage deserves attention.

We argue that this gap can be most effectively narrowed by operationalizing the RBV in a way that is consistent with Penrose's (1959) original framework. Specifically, we suggest shifting the focus of RBV research away from the measurement of the value and/or amount of resources (Powell, 2001) to the administrative decisions that managers make in the process of converting

Keywords: resource-based view; Bayesian methodology; theory and methodology alignment; competitive advantage
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Received 2 March 2003
Final revision received 7 June 2004

resources to services.[1] Important to this revised operationalization of the RBV is the explicit acknowledgement of Penrose's two classes of resources: 'productive' and 'administrative' resources. The value of administrative resources is reflected in the quality of administrative decisions which ultimately affect firm performance.

In addition, an argument is made for more careful alignment of theory and methodology when applying the RBV. The RBV is fundamentally a theory about extraordinary performers or outliers. The statistical methods used in applying the theory must account for individual firm differences, and not be based on means, which statistically neutralize firm differences. A Bayesian hierarchical modeling methodology is proposed because of the congruency between this methodology and the focus of the RBV on firm-level differences. Using longitudinal data we demonstrate how the RBV can be effectively operationalized with a Bayesian hierarchical model.

TWO CLASSES OF RESOURCES

In southeastern Idaho, farmers who grow potatoes have access to essentially the same resources. Sources of seed potatoes, fertilizers, equipment, and labor are common to all farmers in the region. Weather, air quality, and water quality are likewise common to all these farmers. Soil quality varies only slightly depending on the amount of sand in the soil. These farmers have access to the same markets. However, some farmers clearly enjoy a competitive advantage as evidenced by their survival, expansion, and wealth relative to their neighbors, some of whom are forced into bankruptcy. Current conceptualizations of the RBV would explain the observed competitive advantage by focusing on the management abilities of the farmers as resources that *must* have met the value, rareness, costly to imitate, and absence of substitutes criteria (VRIS) (Barney, 1991). Even if this explanation is correct, how can it be tested? This conundrum has led to debates in the strategy literature as to whether the argument is falsifiable and/or merely tautological (Barney, 2001; Powell, 2001; Priem and Butler, 2001a, 2001b).

Moving from the farm to the firm, Penrose (1959) makes a distinction between resources and the administration of those resources. Administration, of course, refers to the role of the managers (or entrepreneurs) of the firm in determining how the resources of the firm are to be used. Early on in the development of her theory, Penrose is careful to distinguish between productive resources and the 'administrative decisions' that govern the use of resources. Later in her theoretical development she clearly includes managerial talent as a resource. Thus, in Penrose's framework two classes of resources are implied: 'productive' resources and 'administrative' resources that exercise discretion over the use of 'productive' resources. Makadok's (2001) treatment of managers' role in selecting and deploying resources is consistent with this view.

Penrose also discusses a firm's 'subjective productive opportunity,' which refers to what the firm 'thinks it can accomplish' given its resources (Penrose, 1995: 41). This is consistent with Barney's (1986) reasoning that some firms are better than others in recognizing sources of potential value in factor markets. Coming at it from a slightly different angle, but making substantially the same point, Alchian and Demsetz (1972: 793) observed that 'efficient production with heterogeneous resources is a result not of having better resources but in knowing more accurately the relative productive performances of those resources.' Miller (2003) also argues that, over time, firms may develop beneficial asymmetries from 'valueless and even burdensome resources.' The influence of managerial resources on rents has been examined empirically (Castanias and Helfat, 1991). These views lead us to conclude that what a firm *does* with its resources is at least as important as *which* resources it possesses—the subtle, yet profound, implication being that firms with homogeneously distributed productive resources can realize competitive advantage.

The subtle shift in emphasis toward administrative decisions and away from resources and the measurement of their value does not constitute a revision of the RBV—it is merely a restatement that suggests a new way to operationalize the theory. This revised operationalization of the RBV assumes that superior administrative decisions are based on the resource bundles they create and the

[1] Penrose (1959) made a distinction between resources and services, with services being the output of resources—be they products or services in the traditional sense. Mahoney and Pandian (1992) recognize this important distinction. The term 'services' is used throughout the paper in the Penrosean sense.

market appropriateness of services created from bundled resources. For example, people at Nucor Steel, most notably Kenneth Iverson, acquired new productive resources—a Whiting electric arc furnace, a Concast continuous-casting machine, and a Swedish rolling mill—to pioneer mini-mill steel-making in the United States. USX, on the other hand, continued to deploy conventional steel-making technologies while taking aggressive steps to increase mill efficiency (e.g., labor efficiency improved from more than 9 labor hours per ton of steel produced in 1980 to just under 3 hours per ton in 1991). The limitation for USX was not a resource limitation per se; its resources far surpassed those of Nucor. Rather it is the limited effectiveness of the administrative decisions exercised over those resources. The managers of Nucor Steel appeared to realize that the productive resources associated with new mini-mill technology had the potential of reshaping the market demand characteristics of the steel industry, while the leaders of USX appeared to make decisions that assumed no such industry change (see Christensen, 1997, regarding 'disruptive technologies'). Therefore, the actual value created by Nucor Steel has far surpassed that of USX (now United States Steel) over the last two decades.

Modeling the RBV to account for the administrative decisions that convert resources to services helps greatly with its operationalization (see Figure 1). These administrative decisions may consist of: (1) redirecting (rebundling)[2] the existing resources of the firm; (2) adding new resources; (3) discarding resources; or more likely (4) some combination of the three. Services are generated as a result of the administrative decisions that configure the firm's resources in a particular way. The services thus generated may result in competitive advantage and possibly superior economic performance if the services meet the VRIS criteria.

Most RBV scholars would agree that there is an implicit understanding that services provided by resources are what actually generate value, but explanations of competitive advantage typically link observed superior economic performance directly to resources without considering the services that are immediately proximal to the competitive advantage. Differences in services

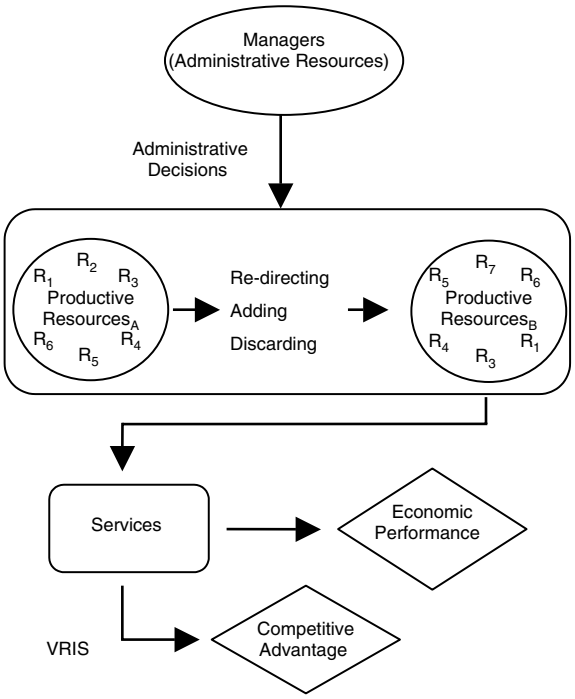

Figure 1. The RBV logic flow

stem primarily from differences in the administrative decisions made concerning productive resources—resources that are often widely available to competing firms.

Conceivably, all the elements of the framework depicted in Figure 1 could be measured either directly or through some proxy. However, such measurement would be fraught with confounding effects (Powell, 2001). More importantly, such measurement of each element of the model may be unnecessary. The pivotal point in the model displayed in Figure 1 is the administrative decision(s) that leads to services, and ultimately to economic performance. The general firm-level question suggested by this operationalization of the RBV is: What are the effects of administrative decisions on the economic performance of firms? Thus, this question can be addressed by modeling the relationship between administrative decisions and economic performance. This approach makes sense in a framework where the focus is on *how* a firm directs the use of its resources as opposed to *which* resources a firm possesses.

Resources and services are noticeably absent from this operationalization of the RBV. Although this may seem illogical given the focus of our

[2] Even though rebundling has become a popular term, redirecting is used here in an effort to adhere to Penrose's (1959) notion that managers 'direct' the use of a firm's productive resources.

research is the RBV, it is precisely this distinction that makes the focus on administrative decisions sensible. The distinction between resources and services is recognition that a transformation of a firm's productive resources must take place in order for services to be generated. Administrative decisions are critical to this transformation. By examining administrative decisions and economic performance we can learn about a firm's ability to transform productive resources into services even if we do not measure resources and services. Furthermore, some of the most important resources and services of a firm may well be intangible and/or unobservable (Barney, 1991). These unobservable phenomena are nevertheless accounted for in this operationalization of the RBV because we know they exist, even if we are unable to observe them (Godfrey and Hill, 1995). The use of evidence in court proceedings and the study of quantum mechanics are examples of observable phenomena being used to link together the elements of a model, some of which are unobservable phenomena. Examining administrative decisions and economic performance can likewise inform us about a firm's ability to convert resources into services.

Also note that in our revised operationalization of the RBV we account for the observations of both Priem and Butler (2001a) and Barney (2001) that resource value is determined from a source exogenous to the RBV. Knowledge about exogenous sources, however, is not particularly interesting to strategists when compared to knowledge about how superior economic value is created through the transformation of resources into services. Analogously, knowing something about how specific cards end up in the hands of specific poker players may ultimately enhance our understanding of the game of poker, but it would require much more effort and is likely to yield much less understanding than efforts to learn about how poker players win by playing the cards they are dealt. In many ways, strategists are like poker players—on a given night they are either lucky or unlucky in terms of the cards they are dealt, but those with superior abilities playing the game of poker will often find ways to win even when they are unlucky. It is the superior poker player's choices about discarding and drawing cards, the recognition of when and how to play for a winning hand, or decisions about when to fold that would be of prime interest to a strategist.[3] RBV theorists argue that competitive advantage results from superior knowledge, or luck, or some combination of the two (Barney, 1986; Dierickx and Cool, 1989; Rumelt, 1984), but their attention naturally ebbs toward superior decisions, because they recognize that strategists can do something with insights about superior decisions (i.e., Thomas and Tymon, 1982, would assert they have the potential for 'operational validity'), while there is little strategists can do with insights about luck. This interest in superior decisions is the fundamental reason why the primary focus of this operationalization of the RBV is on the relationship between administrative decisions and economic performance.

A BAYESIAN METHODOLOGY AND THE RBV

A second major purpose in this paper is to demonstrate that questions naturally arising from the application of the RBV to organizational phenomena may be addressed and answered using a methodology that is consistent with RBV theory. This approach is not intended to be a 'test' of RBV theory. There are no hypotheses developed linking any resource to competitive advantage. There are no hypotheses developed concerning relationships between administrative decisions and economic performance. Rather, the point of the paper is to demonstrate that such relationships *can be* operationalized with a more theoretically congruent approach. Thus, our focus is on the operationalization of the RBV, not on the testing of any specific relationship.

A logical next step in rethinking the way RBV research is operationalized is the identification of a more appropriate methodology—one that recognizes the nature of the theory itself. Indeed the RBV is intended to explain why some firms do better economically than others (Barney, 1991; Collis and Montgomery, 1995). Clearly the RBV is a theory of outliers—firms that are different enough from other firms that competitive advantage accrues to these outlier firms. Thus, an appropriate methodology would be one that allows for a focus on truly firm-specific phenomena.

[3] While not fitting well within our framework, bluffing strategies of poker players would also be of interest to strategists.

Although considerable empirical research has been done using RBV reasoning, the congruency between the theory and the methods used deserves a closer look. Several studies examine the relationship between resources and/or capabilities possessed by a firm and the economic performance of the firm (Bergh, 1998; Hult and Ketchen, 2001; Maijoor and van Witteloostuijn, 1996; Miller and Shamsie, 1996; Perry-Smith and Blum, 2000). Most of the empirical studies done in this area are based on traditional (classical) statistical approaches, generally a form of regression analysis. These studies typically focus on whether there is a statistically significant association between a resource and/or capability and economic performance.

A statistically significant, positive association between a resource and performance in a study using regression analysis indicates that, on average, the more of that resource a firm possesses, the more positive the economic performance of that firm. Such a result provides evidence that a relationship exists between a resource and performance, and it informs us about the confidence we can have in the relationship existing across repeated samples (Cohen and Cohen, 1983). However, no comment can be made as to a specific probability that such a relationship exists in a given firm.

There are other important issues to be considered in terms of the congruency between such results and RBV theory. First, the results are based on averages across the sample. A regression approach is not intended to focus on the effects of specific firms. In fact, if an observation (firm) is found to be influential and it can be demonstrated that the observation is an outlier, then the observation could justifiably be removed from the analysis. This seems to be incongruent with RBV logic. Furthermore, random and fixed effects models are used to control for the 'firm effect' in panel data (Johnston and DiNardo, 1997) to ensure that the lack of independence among variables and observations due to a firm being in the sample repeatedly does not bias results. Although these random and fixed effects could conceivably be used to examine individual firms, the interpretation of results would be subject to the same limitations of regression analysis. Additional analysis, including graphing, could be done to identify influential observations in order to determine how widely held the resource is among firms in the sample (Cohen and Cohen, 1983). Without such additional analysis there is no way of knowing if an association is the result of a widely held resource or if the resource is held by only a very few firms that are able to achieve extraordinary economic performance because of the resource. We, however, know of no study in which this type of additional analysis has been done.

In addition, a positive association between a resource and performance says nothing about superior economic performance or competitive advantage. Such a finding does suggest that firms without that resource may be at a disadvantage, but one cannot conclude that possessing that resource confers a competitive advantage. These characteristics of traditional statistical approaches lead to the conclusion that there is an important lack of congruency between RBV theory and regression-type analysis.

As Rumelt suggests: 'strategy analysis must be situational. Just as there is no algorithm for creating wealth, strategic prescriptions that apply to broad classes of firms can only aid in avoiding mistakes, not in attaining advantage' (Rumelt, 1984: 569). Congruency between RBV theory and an empirical methodology requires a methodology that can isolate the effects of individual firms and allow for meaningful interpretation of firm-level results. We propose a Bayesian approach because it allows such an examination of firm-specific phenomena.

The Bayesian approach

Bayesian methods are ideal for operationalizing the types of relationships inherent in the RBV, and more specifically for those examined in this paper.[4] A helpful overview of basic concepts in Bayesian methods is provided by Berry (1996). The Bayesian class of methods is characterized by the use of sources of data external to the data of immediate interest. This external information is often called *prior* information, and it is usually captured in terms of a probability distribution based on such things as previous studies, expert opinion, and historical information.

[4] Mosakowski (1997) used Bayesian reasoning in her explanation of how managers deal with causal ambiguity by 'updating their priors' based on experience.

Bayesian methods get their name from Bayes' theorem, which asserts

$$\Pr(A|B) = \frac{\Pr(B|A)\Pr(A)}{\Pr(B)}$$

where A represents the unknown parameter (vector), and B represents the data. The formula asserts that the probability of observing unknown parameters conditional on the observed data is proportional to the probability of the data conditional on the unknown parameters, $\Pr(B|A)$ (more commonly known as the likelihood function) multiplied by the prior probability of the unknown parameters, $\Pr(A)$, which represents the prior information referred to earlier.

Bayesian hierarchical models (Draper *et al.*, 1992) are general and powerful modeling tools that extend basic Bayesian methods to allow a rich class of models. The central idea behind hierarchical modeling is that each observation (or group of observations) is allowed to have a separate parameter or distribution. In the present case, the parameter of each firm is assumed to come from a population of such parameters.

The primary distinctions between Bayesian hierarchical models and classical alternatives (such as regression models, including random and fixed-effects models (Cohen and Cohen, 1983; Haveman, 1993; Johnston and DiNardo, 1997)) are that (1) Bayesian hierarchical models provide complete distributional estimation (instead of point and/or interval estimates); (2) Bayesian hierarchical models allow full probabilistic predictive inference for firms observed (i.e., in our dataset) and unobserved (i.e., not in our dataset), while classical methods allow a much more limited predictive capability with only point and interval estimation; and (3) Bayesian hierarchical models allow decision-makers to make probability statements about decisions on a firm basis with the inclusion of uncertainty, while classical procedures do not allow such statements (Berry, 1996).

For example, a study of the effect of resource X on market returns using a classical approach such as regression analysis would yield point (beta) and interval estimates. Suppose the model resulted in a beta of 0.50 and a standard deviation of 1.0 for resource X, meaning that a one-unit increase in resource X is associated with a 0.50 percent increase in market returns. This result can be appropriately interpreted to mean that with a 95 percent confidence interval the association of resource X with market returns lies somewhere in the range of 0.50 plus or minus two standard deviations. In other words, a one-unit increase of resource X could be associated with a change in market returns of anywhere between -1.5 percent and 2.5 percent. No inference can be made as to whether a change of 0.50 percent is more or less likely than a change of -1.5 percent, 2.5 percent, or any value in between. The interval for any subsequent sample would be different and there would be no way of knowing how different. A Bayesian model using the same data would yield a probability distribution that would indicate the actual probability of a given percentage change. Thus, the Bayesian model allows full probabilistic predictive inference.

A key element of this Bayesian methodology is the notion of a 'borrowing of strength' across observations made possible by the fact that the parameters come from the same distribution (Carlin and Louis, 1996). Besides better estimation of individual- (or firm-) specific parameters, the distribution of parameters provides a predictive capability that is often desirable in management problems. For example, this method allows for specific probability statements as to the effects of one or more constructs (variables) on other constructs. In other words, the probability that a particular action will affect an outcome can be known. As explained above, such interpretation is not possible with a classical approach.

Data collection

The phenomena of interest in this paper are administrative decisions and the resulting economic performance of firms. We chose to study the administrative decisions made within firms that had recently appointed new CEOs. This context was chosen in an attempt to capture a portion of a firm's history in which a new set of 'administrative resources' (Penrose, 1959) has been given responsibility for the management of the firm's productive resources. We recognize that a change in CEO does not represent a completely new set of such administrative resources. The CEO may have been promoted from within the firm and many of the top executives may likewise be veterans of the firm.

However, a new CEO, by definition, has inherited a set of productive resources and has been

given the responsibility of managing those productive resources. A newly appointed CEO has the opportunity and challenge to: (1) redirect the existing resource base of the firm; (2) change the resource base of the firm through acquisition and divestiture; or (3) do nothing, or very little, to the resource base of the firm. Although all CEOs have these same opportunities and challenges throughout their tenure, new CEOs face a more immediate challenge, perhaps even a mandate, to adjust the firm's productive resource bundle. Therefore, the first several years of a CEO's tenure are likely to be a period during which a firm's productive resources are managed more actively. Indeed, ongoing data collection in this stream of research indicates that the rate of administrative decisions appears to decline in subsequent years of a CEO's tenure.

The decision to examine the first several years of a CEO's tenure was motivated primarily by a desire to capture a very active period of productive resource management. This decision was *not* motivated by any expectation that the outcomes of new CEO's decisions would be any different from the outcomes of more seasoned CEO's decisions. That remains an empirical question that we intend to examine in a later paper.

The set of administrative decisions examined in this paper was chosen based on our intent to examine administrative decisions that could reasonably be classified as: (1) redirecting a firm's existing productive resources; (2) changing a firm's productive resource base through acquisition and/or divestiture; or (3) changing a firm's administrative resource base. There was neither intent nor effort to choose administrative decisions based on whether their effect on economic performance would be positive or negative. Again, our intent here is not to argue for or against any particular relationship between any administrative decision and economic performance. Rather our intent is to demonstrate a theoretically congruent operationalization of the RBV which depends on linking changes in a firm's resource base to economic performance by measuring administrative decisions.

Two of the authors and a graduate research assistant developed a list of 10 categories that capture the vast majority of administrative decisions made by management as suggested by both the strategic management literature and the popular business press. For example, scholars have extensively examined acquisitions and divestitures (Capron and Pistre, 2002; Capron, Mitchell, and Swaminathan, 2001; Karim and Mitchell, 2000) and the *Wall Street Journal* reports on such activities almost daily. Decisions to buy business units and to sell business units thus made the list as two categories of administrative decisions that would change the resource base of a firm. Using similar reasoning lay-offs and hiring were also chosen as administrative decisions that change the resource base of a firm. Likewise, financial restructuring, organizational restructuring, new product introductions, and new market entry were chosen as categories that indicate a redirecting of a firm's resources. Key personnel (executive-level) changes and alliance formation were selected as measures of changes in a firm's administrative resources.[5]

Admittedly these are coarse-grained categorizations. Subsequent studies in which specific relationships are being tested can and should utilize more fine-grained data. Each category may be expanded into several categories depending on the relationship of interest. For example, a category that is not included in this revised operationalization of the RBV is that of diversification. Buying units, selling units, new products, and new market entry could be further divided to allow a focus on diversification.

Annual *Fortune* 500 listings and 10-K reports were used to identify 195 firms that had experienced a change in CEO during the period 1980–96. Research assistants then used the *Wall Street Journal Index* to search, by company, every article that mentioned the firms in our sample during the year before the change in CEO and during each of the 3 years following the change in CEO. Actions that were either announced by the firm or reported by the *Journal* were included in the appropriate category. Firms' industry affiliations were categorized using four-digit SIC codes. These data were gathered and cross-checked by two graduate students to ensure that administrative decisions were accurately and consistently categorized. These categorizations were then reviewed by one of the co-authors. These data were converted to count data for the analysis. Thus, the data indicate by

[5] Alliances are multifaceted and may also include elements that would represent a change in a firm's resource base. At the margins, other categories may also span the boundaries of redirecting versus changing the resource base of a firm. In any case, these administrative decision categories all represent management's 'directing' of a firm's resources.

year the number of actions taken by a firm in each category.

Financial performance data were gathered from COMPUSTAT for each firm. An accounting measure of returns and a market measure of returns were chosen so that differences in the effects of administrative decisions on different measures of economic performance could be demonstrated. Return on sales (net income/sales) was used as the accounting measure of economic performance. This may be viewed as an efficiency ratio that inherently adjusts for size. Other accounting ratios such as ROI or ROA would have served our purposes equally well. COMPUSTAT's 'Return' variable was used as the market measure of economic performance. This measure includes changes in stock price and payment of dividends and is adjusted for stock splits. These data were also gathered for the year preceding the new CEO's appointment and for the first 3 years of each new CEO's tenure. Missing financial data reduced our sample size to 175 firms.

Bayesian hierarchical model

In our case we have employed a somewhat complex Bayesian hierarchical model to address the question posed above. We employ a Bayesian hierarchical linear model (Broemeling, 1985) for examining the effects of administrative decisions, firms, and industries on economic performance. We model two types of economic performance: an accounting measure and a market measure. Here, both response variables are continuous and a normal hierarchical model is reasonable. The performance parameter is expressed as a function of the firm (where each firm has its own effect), the industry in which the firm operates, and the set of administrative decisions made by the firm (actions). The model we pose is:

$$\text{performance} = \text{firm (industry)} + \text{industry} + \text{year} + \sum_{j=1}^{10} \beta_j \text{action}_j$$

where we allow each industry and each firm to have its own effects (making the model a Bayesian hierarchical model). A more general form of this model has been explored in Berry, Reese, and Larkey (1999), and a more detailed explanation of the model is presented in the Appendix.

All computation was done using Markov Chain Monte Carlo methods as reviewed in Gilks, Richardson, and Spiegelhalter (1996). The priors used in these calculations have little, if any, effect on the results for two reasons. First, prior distributions were assumed to be relatively 'flat,' which has the effect of ensuring that the influence of the prior distributions on the posterior distributions will be minimal (Berry, 1996). Second, due to the reasonably large sample size the effect of prior distributions was minimal. Several choices for prior distributions were also analyzed and found to have little effect on the resulting posterior distributions. Thus, although priors are necessary to perform the calculations, the priors that were chosen minimally influence the results of the analysis. Posterior predictive checks of the model (analogous to residual analysis) presented in Gelman *et al.* (1995) indicated a good fit.

RESULTS AND DISCUSSION

Although the focus of interest is at the firm level, the Bayesian hierarchical model used here can also provide information about average effects across the sample. We present several sample-level results and compare these results to those one would obtain from a classical statistical approach. We then present firm- and industry-level results.

One of the advantages of the Bayesian approach is that much of the information generated by the analysis can be graphically represented as posterior distributions. These graphical representations contain much more information than a single metric. However, probability statements can also be represented in a single metric. Table 1 indicates the probability that each of the administrative decisions (actions) measured will have a positive effect on accounting measures of economic performance and market measures of economic performance. Probabilities below 0.5000 indicate a greater likelihood of a negative effect. Thus, the probability of 0.0516 of a positive effect of Financial Restructuring on Accounting Returns indicates a probability of 0.9484 of a negative effect. The probabilities in Table 1 give no indication of the size of effect.

These same results can also be shown graphically. Notice in Table 1 that the probability is 0.8111 that buying a business unit will have a positive effect on accounting measures of performance.

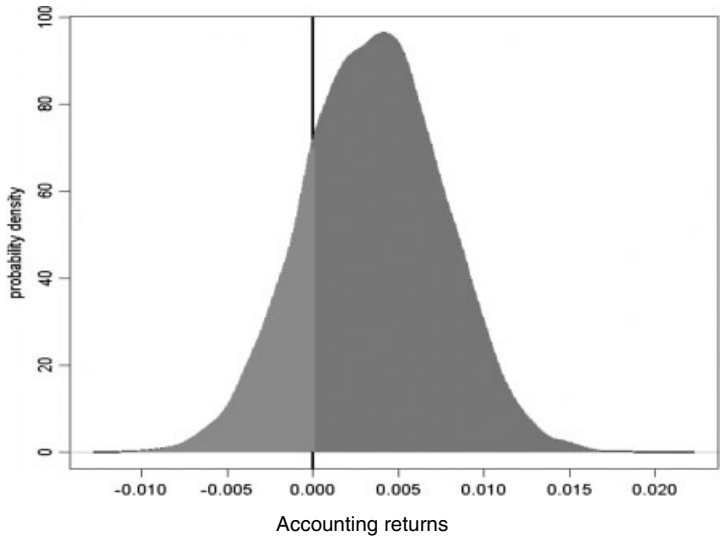

Figure 2. Effect of buying units on accounting returns

Table 1. Probabilities of effects of actions on performance

Actions	Accounting returns	Market returns
Buying units	0.8111	0.9671
Selling units	0.5584	0.0791
Org. restructuring	0.9274	0.4781
Alliances	0.4571	0.0519
Hiring	0.5867	0.8848
New markets	0.4646	0.5983
Financial restructuring	0.0516	0.9828
Personnel changes	0.1169	0.0032
Lay-offs	0.3082	0.4341
New products	0.7434	0.9687

The graph in Figure 2 shows how that probability is distributed.

The peak of the curve appears to be centered over approximately 0.005, indicating that the most likely effect on accounting returns of buying a business unit is an increase in performance of about one-half of 1 percent. There is a small area under the curve that lies to the left of zero, representing the 0.1889 probability that the effect of buying a business unit is negative. It is important to note that these results do not represent a confidence interval, nor are they 'significant' because they have passed a '*p*-value' threshold. These results are the actual probabilities based on the data in this sample.

The probabilities reported in Table 1 may be used to answer a variety of questions about which actions, on *average*, are likely to lead to which outcomes. Such results may serve as a useful point of departure in theory building focused on the pathway from resources to economic performance. These results may also give pause to our previously held convictions concerning the effects of certain actions on economic performance. For example, recent studies examining the cumulative abnormal returns (CAR) of acquirers indicate that acquiring firms usually experience a negative effect on market returns (Anand and Singh, 1997; Capron and Pistre, 2002; Hayward, 2002; Wright *et al*., 2002).

Table 1 indicates that there is a probability of 0.8111 that buying a business unit will have a positive effect on accounting returns and a probability of 0.9671 of a positive effect on market returns. These results appear to be directly opposed to recent CAR studies. However, the results obtained in this operationalization of the RBV may not be as different as the comparison of simple metrics would indicate. Two points deserve examination. First, given that most of the CAR studies find a small negative effect, the confidence interval in these CAR studies may extend above zero, meaning that small positive values are just as likely as small negative values. If small positive values are equally likely, then the results shown in Table 1 should not be surprising. Second, the data in our sample are fundamentally different from the data used in CAR studies. The present study examines year-end returns over several years as opposed to stock market reaction during a brief window

surrounding the announcement of the acquisition. This study is also based on data from the first 3 years of a new CEO's tenure. Whereas CAR studies attempt to meticulously avoid confounding effects by using a brief window, this model offers a probability distribution of the effect of buying units, in the presence of other significant actions, over a several-year period. Given this difference in time horizon, different results should also not be surprising. More substantial differences in results emerge when the Bayesian results are shown graphically.

Figures 3 and 4 show the probability distributions for the effects of each action on accounting returns and market returns, respectively. The dark-shaded area (to the right of zero) under the curve represents the probability that the effect on performance is positive, and the light-shaded area (to the left of zero) indicates the probability of a negative effect. Graphs in which the dark- and light-shaded areas are roughly equal indicate that the probability of a positive vs. a negative effect is roughly equal. Note that this is different from saying that there is no effect. For example, in Figure 3, the probability distributions for both selling units and hiring indicate that the probability of a positive vs. negative effect is roughly equal. However, the shape of the distribution for selling units indicates that the effect is almost certain to lie between −1 percent and 1 percent, while the shape of the distribution for hiring indicates that the effect is spread from −3 percent to 3 percent. These graphs convey a tremendous amount of information in a straightforward manner that simply cannot be done with a single metric.

The results reported in Table 1 and Figures 2–4 are similar in nature to other empirical RBV work in that they reflect the *average* effect of the various administrative decisions. However, these results are fundamentally different in terms of their interpretation. In a classical approach we would be highly confident that the actual effect fell somewhere in the confidence interval, but there would be no probability associated with where in that

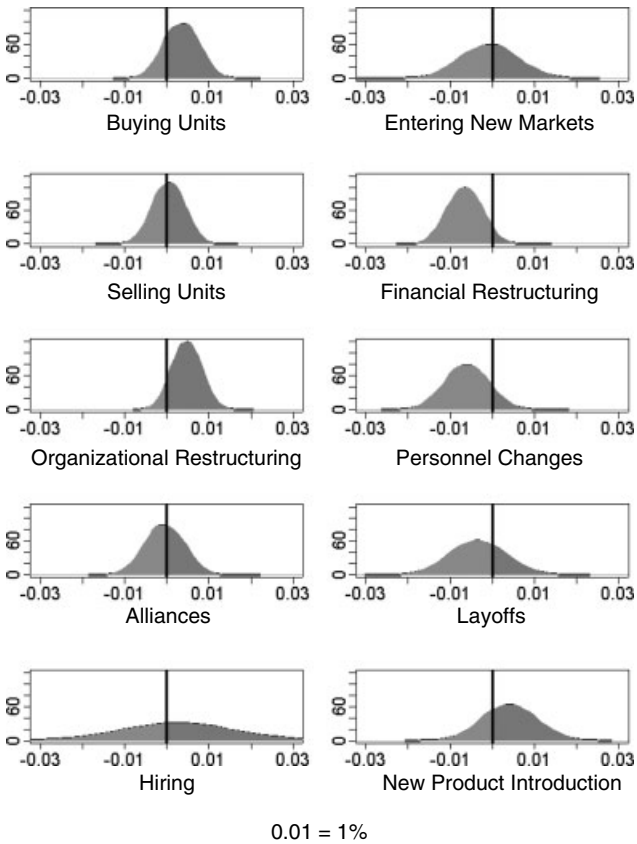

Figure 3. Probability distribution of effect on accounting returns

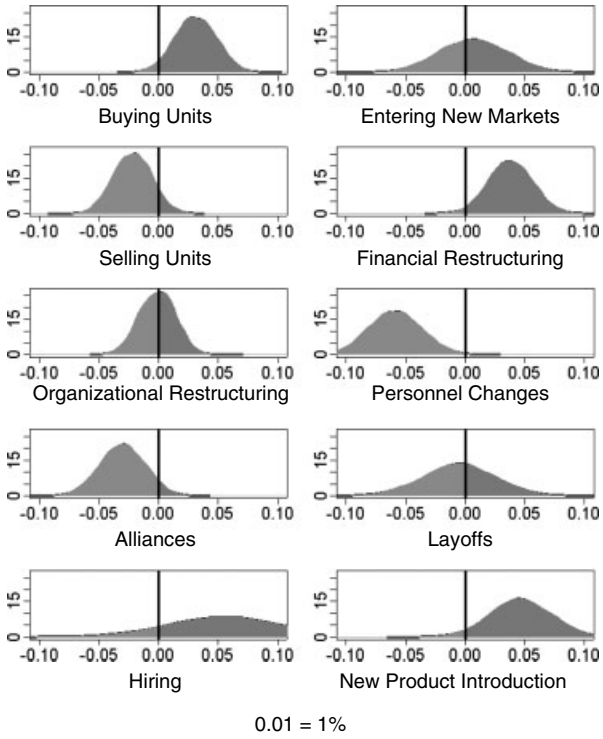

Figure 4. Probability distribution of effect on market returns

interval the actual effect fell. On the other hand, the Bayesian results reported here show a probability distribution of the predicted effect.

Firm effect: Operationalizing firm-level competitive advantage

The unique value of this Bayesian approach is *not* the ability to predict average effects across firms—it is the ability to generate probability distributions for individual firms and specific industries. Competitive advantage is an important element of the RBV framework (see Figure 1). The RBV suggests that competitive advantage will be generated by the services flowing from productive resources as a result of administrative decisions. Any competitive advantage a firm may have will be latently present in the administrative decisions and the economic performance achieved by that firm, assuming that competitive advantage has not been bid away by stakeholders (Coff, 1999). In the Bayesian model proposed here, we are able to isolate the firm effect on economic performance through the 'borrowing of strength' from the data contained in the entire sample (Carlin and Louis, 1996).

We propose that this firm effect may be viewed as an indicator of any competitive advantage that a specific firm may possess. In short, the firm effect is the probability that the focal firm will achieve economic performance that is either less than or greater than what would be expected of a firm that took exactly the same administrative decisions or actions as those taken by the focal firm. A positive firm effect thus indicates the probability that the focal firm possesses some competitive advantage that will allow that firm to achieve economic performance greater than what would be predicted by the actions taken by that firm. The firm effect calculated from the data in this study indicates that a competitive advantage exists, but it cannot specifically identify the source of that advantage. However, with additional, finer-grained data the source of the advantage could be identified.

The ability to estimate a directly unobservable competitive advantage without relying on a pair-wise, direct comparison of that firm's economic performance with the performance of other firms is an important contribution of this Bayesian approach. Although the economic performance of each firm in the sample enters into the calculation of the firm effect, competitive advantage is

estimated in light of other factors influencing economic performance. Concerns of tautology diminish when competitive advantage and economic performance can be considered separately (Powell, 2001).

The Bayesian model developed here also allows for the calculation of an industry effect. This measure is the probability that the industry in which a firm operates affects the economic performance of that firm. The firm effect and the industry effect calculated in this model are not merely a matter of controlling for firm and industry effects as would be done in a classical statistical approach. Here, these effects are calculated for each individual firm and for each industry in the sample. Again, this modeling is congruent with the firm-level nature of RBV theory.

Figure 5 shows the probability distribution of the firm effect of Micron and the industry effect of the primary industry in which Micron operates (SIC 3674) on market measures of economic performance. Micron had a larger firm effect on market returns than any other firm in the sample. The firm effect distribution in Figure 5 peaks around 63 percent, indicating the most likely effect on economic performance. Also, the distribution lies almost completely to the right of zero, suggesting that the probability of a positive effect on market returns is nearly 1.0 (above 0.9999). Specifically, the distribution shown in Figure 5 indicates that Micron is virtually certain to achieve higher market returns than would be expected for an 'average' firm in the sample taking the same actions that Micron actually took. We interpret this as strong evidence of a competitive advantage for Micron at the time (1993–96).[6]

The firm effect of Micron and its industry effect are both stronger than any of the administrative decisions studied. There is a difference between the firm effect and industry effect for Micron of nearly 30 percent (63% firm effect vs. 33% industry effect). The differences in these two distributions have potentially interesting implications for the debate of industry vs. firm effects (McGahan and Porter, 1997; Rumelt, 1991; Schmalansee, 1985) because there are many firms in the sample whose firm effect was less than the industry effect. This Bayesian approach facilitates a comparison of individual firm effects to industry effects. It is

[6] Micron reported losses of over $1 billion for fiscal 2003 (Micron Technology, Inc., 2003) even though the company is second in DRAM market share worldwide (www.micron.com/ir/profile.html).

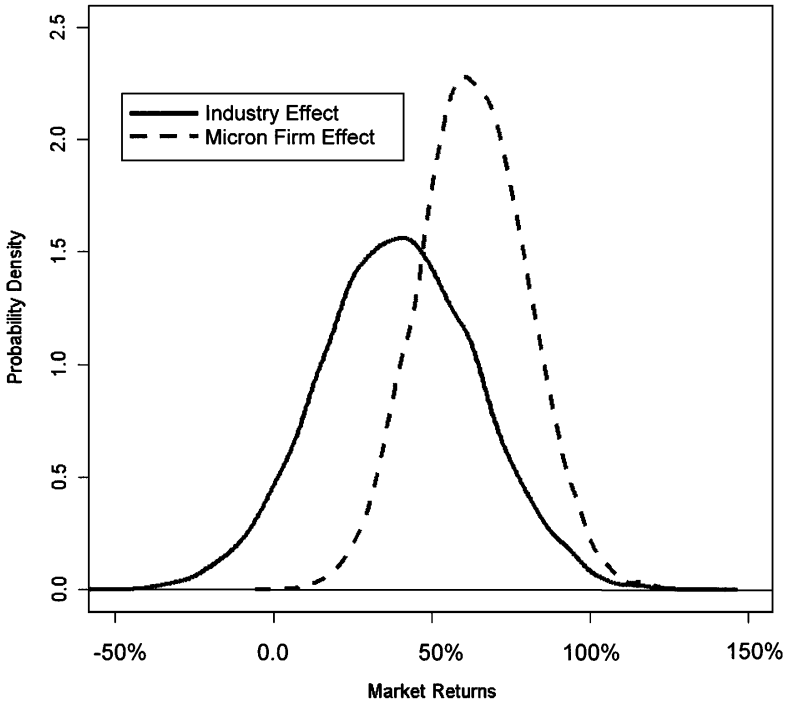

Figure 5. Industry and firm effect

also possible to compare industry effects across industries. Such a comparison may also be useful in industrial organization research (e.g., tests of Porter's Five Forces Model (Porter, 1990)).

We are able to calculate the probabilities of firm effects and industry effects for each firm and industry in the sample. However, we are unable to calculate the probabilities for the effects of specific administrative decisions for specific firms because our data are currently limited to 4 years. With data from several more years, we will be able to calculate the probabilities of the effects of specific actions on the economic performance of individual firms.

Firm-level strategic scenarios

Perhaps the most powerful implication of the firm effect is that it can be combined with a set of hypothetical actions to answer 'What if?' questions. For example, a probability distribution can be calculated for the economic effect of a firm taking a set of specific actions. Such a probability is based on the actions of the firm in the past, the economic performance of the firm in the past, the actions of all other firms in the sample, and the economic performance of all other firms in the sample. This ability to make predictions about a specific firm is the very essence of the RBV, both theoretically and practically.

We constructed two strategy scenarios: a 'refocusing' scenario and a 'diversification' scenario. The refocusing scenario consisted of selling two business units, one organizational restructuring, one key personnel change, and one lay-off. The diversification scenario included buying two business units, one financial restructuring, one key personnel change, one hiring, and one alliance. The probability distributions for the effects of these scenarios on the market performance of individual firms can be calculated, taking into account the relevant firm effect and industry effect. The distribution of the firm effect for Micron was centered over 63 percent before being combined with the scenarios, indicating a considerable competitive advantage. The diversification scenario moved the distribution to the right, indicating an improvement in the effect for Micron of about 9 percent. The refocus scenario moved the distribution to the left by about 8 percent. Thus, for Micron there is a difference in effect of about 17 percent between the two scenarios. Again, the point is not to demonstrate that one strategy is better than another. Rather, the point of the analysis is to show that this Bayesian methodology can be used to see which strategy is likely to produce the most favorable results for a specific firm.

We can also compare the effects of the diversification strategy on different firms. For example, Micron, Cisco, and Hewlett-Packard (HP) each had unique firm effects before being combined with the effects of the diversification scenario. The distribution of the firm effect combined with the diversification scenario for Micron is centered over 72 percent, while the distributions for Cisco and H-P peak at 45 percent and 33 percent, respectively. Each firm has a distinct probability distribution of effects.

A wide variety of analyses may be performed by combining firm effects, industry effects, and the effects of administrative decisions. Hypothesis testing of relationships may be done using a Bayesian approach (Berry, 1996). Indeed, Bayesian methods have been used to examine a diverse set of phenomena (Berry, Reese, and Larkey, 1999; Gelman *et al*., 1995; Reese *et al*., 2001).

Limitations

Measures of administrative decisions used in this study are admittedly coarse-grained given that administrative decisions and the impact of those decisions may vary greatly across firms. However, the Bayesian approach used here assumes that each firm has its own distribution of parameters; therefore, the effect of an action is treated with specific regard to the firm that took the action. The fact that buying a business unit is of different significance to different firms is thus captured and accounted for in this methodology. Of course more fine-grained measures would allow researchers to study more specific details of administrative decisions.

The generalizability of this study is limited by our choice to study firms with newly appointed CEOs. It would be inappropriate to generalize the relationship between an administrative decision and economic performance in this study to a population of firms whose CEOs were not newly appointed. However, on an individual basis the results obtained for a given firm are generalizable to other firms if the other firms are 'exchangeable' (Berry, 1996), meaning that the other firms are substantially similar to the firm in this sample. Of

course, this begs the question, 'How similar is substantially similar?' There is no test for this, and it remains a question of judgment. Having stated the limitation, it is important to note the congruency between appropriate generalization and the RBV. If a relationship could be appropriately generalized to a larger population, such a generalization would seem to violate the rareness notion inherent in the RBV.

CONCLUSION

This study is a first step in a research stream that will hopefully increase the usefulness of the RBV and bring greater clarity to important organizational phenomena. Although this study is exploratory and coarse-grained, it will hopefully encourage others to develop finer-grained analyses of the relationships among resources, services, competitive advantage, and economic performance.

We urge scholars to consider the implications of shifting the focus of RBV research from the relationship between resources (and capabilities) and the economic performance of the firm to the relationship between administrative decisions and firm-level economic performance. We also hope that scholars will be motivated to develop increasingly satisfying explanations of competitive advantage derived from administrative decisions that convert resources to services.

The Bayesian methodology introduced in this paper is much more consistent with the RBV as a theory of outliers than traditional classical statistical approaches. The ability to focus on individual firms is one of the greatest strengths of the Bayesian approach. It is our hope that researchers and managers alike will recognize the power of being able to make probability statements at the actual firm level. As suggested by the pattern of results reported in Table 1, this approach may also call into question some long-held assumptions about the effects of particular administrative decisions on firm performance. We encourage research efforts aimed at examining these long-held assumptions using emerging tools such as the Bayesian hierarchical modeling used in this paper.

The history of Micron juxtaposed against the results obtained in this study suggests some interesting avenues for research. As Micron grew from a four-person start-up, the firm began to amass resources. We suspect that early on in the history of the firm most of these resources were widely available in the market. Over time, Micron developed proprietary technologies for manufacturing and testing chips. Do we have adequate theoretical explanations for the development of heterogeneous productive resources from homogeneous productive resources? Another interesting pattern in Micron's history is that it has had substantial losses in 5 of the last 6 years, even though the company appeared to have a competitive advantage in the mid-1990s. Does Micron still have a competitive advantage? Can a firm with a history of financial losses have a competitive advantage? The firm continues to enjoy high market share and to win quality and innovation awards (www.micron.com/ir/profile.html). Are there better measures of competitive advantage that could capture organizational successes that may not immediately fall to the bottom line? These issues represent significant research opportunity.

This work should be viewed as an operationalization of existing RBV theory, and the beginning of an exciting methodological path for researchers and practitioners. Finally, the potential for deconstructing and re-examining decades-old management research using the Bayesian approach should be recognized as a means of improving theoretical understanding and modern management practice.

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APPENDIX

Bayesian approaches are characterized by a probabilistic specification of the problem. The fundamental notion behind any Bayesian analysis is Bayes' theorem, which states:

$$\pi(\theta/y) = \frac{f(y|\theta)\pi(\theta)}{\int f(y|\theta)\pi(\theta)\partial\theta},$$

where θ represents the unknown parameters we wish to estimate and y represents the response or dependent variable. The left-hand side of Bayes' Theorem, $\pi(\theta|y)$, is called the posterior distribution and represents the state of knowledge about θ after observing the data. The right-hand side of Bayes' theorem consists of three pieces of information:

a likelihood function, $f(y|\theta)$;

a prior distribution, $\pi(\theta)$;

and a normalizing constant, $\int f(y|\theta)\pi(\theta)\partial\theta$.

The likelihood function is commonly used in classical statistical analyses and represents the information contained in the data. The prior distribution represents the state of knowledge about the unknown parameters before any data have been collected. The normalizing constant ensures that the posterior distribution is, in fact, a probability distribution. The normalizing constant is also the piece that made application of Bayesian methods difficult until the early 1990s. Gelfand and Smith (1990) present a computational tool called Markov Chain Monte Carlo, which allows a very general-purpose technique for simulating values from the posterior distribution. These simulated values can then be used to make inferences based on the posterior distribution. That is, the simulated observations essentially act as a surrogate for calculation of the normalizing constant (and can, in fact, be used to estimate the normalizing constant). This realization was made possible by advancements in computational speed and accuracy.

In the case of RBV theory, we call economic performance (market returns and accounting returns) for company $i (i = 1, \ldots, 175)$ in year $j (j = 1, \ldots, 4)$, Y_{ij}, and use as our model

$$Y_{ij} \sim N(\mu_{ij}, \sigma_j^2)$$

where the notation above indicates a normal distribution with mean μ_{ij} and variance σ_j^2. Our model seeks to estimate not only aggregate measures of the effect of specific actions, $X_{ijk} (k = 1, \ldots, 10)$, but also a firm-specific effect. The model we propose then is

$$\mu_{ij} = \eta_{ij} + \sum_{i=1}^{k} \beta_{jk} X_{ijk}$$

where the important point in the model is that each firm is given its own effect. While this type of modeling can be couched in so-called fixed-effects models (Johnston and DiNardo, 1997) (these are commonly called random effects models in the statistics literature), a compelling argument can be made that what is really desired is a probability distribution for each of the firm-specific effects. This probability distribution can be obtained through the use of Bayes' theorem, presented above. In the case of economic performance, the likelihood function is

$$f(y|\theta) = (2\pi\sigma_j^2)^{-\frac{175}{2}} \exp \times \left(-\sum_{i=1}^{175}\sum_{j=1}^{4} (y_{ij} - (\eta_{ij} + \sum_{k=1}^{10} \beta_{jk} X_{ijk})^2 / 2\sigma_j^2) \right)$$

where $\theta = (\eta_{11}, \ldots, \eta_{4,175}, \beta_1, \ldots, \beta_{10}, \sigma_1, \ldots, \sigma_4)$ is the entire set of parameters for which inference will be made.

The prior distribution must be specified for the entire set of parameters. It is this next step that distinguishes our hierarchical Bayesian approach from a standard Bayesian approach. Our prior distributions for market returns are as follows:

$$\eta_{ij} \sim N(\lambda_j, \tau_j^2)$$
$$\lambda_j \sim N(0, 10)$$
$$\tau_j^2 \sim IG(3, 1000)$$
$$\beta_{jk} \sim N(0, 10)$$
$$\sigma_j^2 \sim IG(3, 1000)$$

The interpretation of this formulation is that the firm-specific effects are modeled by a conditionally independent hierarchical model. It suggests that the firm-specific effects vary according to a normal distribution and that the mean of that distribution has a normal distribution with mean 0 and variance 10. In other words, this prior distribution suggests that the effect of any one firm on market returns, with only a very small probability, results in more than a 300 percent change (increase or decrease). This is a very diffuse prior given that no observed market return was greater than 160 percent. Furthermore, our prior distribution assumes that each action taken will have an effect of no more than a 300 percent change in market returns (again, a fairly liberal assumption). The variance prior distributions (σ_j^2, τ_j^2) are both inverse gamma distributed (abbreviated above as IG). They each assume that the standard deviation of both the firm effects (τ) and the error standard deviation (σ) are, with only very small probability, larger than 50 percent. Again, this prior distribution is very diffuse. We used more diffuse distributions and found little to no difference in the results and were satisfied that this choice was not critical given the appreciable sample size. For more discussion on sensitivity to these choices, Reese *et al*. (2001) presents a good discussion for how one would address this issue in a more rigorous manner.

The choices above give rise to the following formula for the prior distribution, $\pi(\theta)$:

$$\pi(\theta) = \prod_{i=1}^{175}\prod_{j=1}^{4}(2\pi\tau_j^2)^{-1/2}\exp(-(\eta_{ij}-\lambda_j)^2/2\tau_j^2)$$
$$\times (2\pi 10^2)^{-1/2}\exp(-(\lambda_j)^2/2(10^2))$$
$$\times \frac{1}{1000^3\Gamma(3)}(\tau_j^2)^{-(3+1)}\exp(-1/1000\tau_j^2)$$
$$\times \prod_{j=1}^{4}\prod_{k=1}^{10}(2\pi 10^2)^{-1/2}\exp(-(\beta_{jk})^2/2(10^2))$$
$$\times \prod_{j=1}^{4}\frac{1}{1000^3\Gamma(3)}(\sigma_j^2)^{-3+1}\exp(-1/1000\sigma_j^2)$$

The last piece of information that is necessary to find is the normalizing constant. As mentioned earlier, there are many problems where this is difficult, if not impossible, to compute. Given the formula for the likelihood function and the prior distributions above, this calculation is infeasible for our model. Thus, we employ a Markov Chain Monte Carlo (MCMC) procedure to estimate the joint posterior distribution. The details of this computational procedure can be found in the article by Gelfand and Smith (1990). It is worth noting that the computations used in this paper (after debugging and original coding) took about 10 hours of computational time on a fast desktop computer. This time includes the model comparison made using Bayes factors.

The result of applying such a procedure is a sample of observations from the joint posterior distribution of the CEO action effects, the variance parameters, and, most important to our particular model, the firm-specific effects. These posterior distributions provide a fully probabilistic assessment of the contribution of each firm to the return on investment. This effect is estimated in the presence of the actions that could be taken, and represent all of the actions/features of each firm that add (or subtract) value above and beyond that which the actions taken reveal. An important difference between this posterior distribution of firm effects and traditional statistical inference is that traditional statistical inference makes statements about these effects over a long-run average and in repeated sampling. Bayesian inference allows a more direct interpretation based on probability, which is a highly effective tool for decision-makers.