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DOES FIRM PERFORMANCE REVEAL ITS OWN CAUSES? THE ROLE OF BAYESIAN INFERENCE

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A central problem in strategic management is how the inference 'sustainable competitive advantage generates sustainable superior performance' can be put into practice. In this article we develop a theoretical framework to understand the causal relationships among (1) sustainable competitive advantage, (2) configuration, (3) dynamic capability, and (4) sustainable superior performance. We propose that a firm's competitive advantage, resource bundle configuration, and dynamic learning capability cannot be comprehended by outsiders. Its operational performance, however, can be captured by financial indicators. We promote an inductive Bayesian interpretation of the sustainable competitive advantage proposition. From this viewpoint, the presence or absence of competitive advantage may be reflected in the causal relationship between resource configuration, dynamic capability, and observable financial performance. We apply this theoretical framework to an example drawn from the global semiconductor industry, an area in which resource configuration and dynamic capability are essential to performance. The paper concludes with a summary of the proposed model and suggestions for future theoretical development of strategic management. Copyright © 2009 John Wiley & Sons, Ltd.

INTRODUCTION

Academics have been debating the epistemological and methodological status of scientific strategic management for the last two decades (Astley, 1985; Montgomery, Wernerfelt, and Balakrishnan, 1989; Mir and Watson, 2000; Powell, 2001; Schendel, 1994; Seth and Zinkhan, 1991). Strategic management is a science—at least in the contexts of industrial organization (Tirole, 1998) and population ecology (Hannan and Freeman, 1989).[1] As with other sciences, it is equal parts mathematics and logic, empirical evidence and testing. Mainstream research in strategic management (Barney, 1991; Christensen and Raynor, 2003; Grant, 1991; Porter, 1980; 1985; Prahalad and Hamel, 1990) has focused on developing tools capable of prescribing a particular course of action for practitioners. To this end, it deploys *inductive logic* to infer principles, theoretical claims, and/or 'takeaway' from particular cases and other empirical evidence. However, the popularity of this approach does not ensure that the generalizations procured from induction are universally tested or even broadly supported. Consider, for example, Porter's (1985) competitive strategy:

> The fundamental basis of above-average performance in the long run is *sustainable competitive advantage.* Though a firm can have

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[1] Industrial organization is deduced from economics, as population ecology is deduced from biology. Both disciplines have been recognized as 'close' to science (Hempel, 1966).

> a myriad of strengths and weaknesses vis-à-vis its competitors, there are two basic types [sources] of competitive advantage a firm can possess: low cost or differentiation. The significance of any strength or weakness a firm possesses is ultimately a function of its impact on relative cost or differentiation (Porter, 1985 : 11).

Although Porter's inference that low cost and differentiation are sources of above-average performance appears to be deductive in nature, competitive advantage is clearly not the whole picture. Scientific inquiry commonly supplements deduction with *hypothetical reasoning*. Consider the case of China, for example, where brand names are not protected by copyright laws. Should we expect to find evidence that branding plays a role in product differentiation strategies? In this context, is superior performance more likely to derive from a firm's relationships with government officials? Is there any other possible source of sustainable competitive advantage? This simple example shows that Porter's generic strategies might not reflect genuine practices in the real business world. Perhaps the above quote is not an example of deductive inference but simply a *truism*, or what philosophers would call a *tautology*.

An alternative to Porter's syllogistic reasoning[2] is the resource-based view (RBV). The RBV replaces Porter's generic strategies with generalized VRIN (valuable, rare, inimitable, and non-substitutable) advantages. That is, 'valuable and rare organizational resources may be a source of competitive advantage' (Barney, 1991 : 107). The premise *VRIN advantages are sources of sustainable competitive advantage* makes the RBV a virtual *tautology* as well. (Or at best an *analytic* such as the statement $a(b + c) = ab + ac$, which requires no empirical evidence outside mathematics and logic.) The assumption that valuable and rare resources are a predictable source of competitive advantage is not empirically falsifiable (Barney, 2001; Priem and Butler, 2001a, 2001b). While tautological propositions are often very plausible, they are ultimately vacuous and should never be taken as gospel (Powell, 2001, 2002, 2003).

Barney and his colleagues (Barney, 2001; Barney and Arikan, 2001; Ray, Barney and Muhanna, 2004), among many others (e.g., Coff, 1999; Hoopes, Madsen, and Walker 2003; Peteraf, 1993), have expended much effort in demarcating tautology. Resource-based reasoning is truly real, as companies with superior resources *are* demonstrably more efficient and perform better than other companies. Likewise, critical or rare resources that can generate high value or lower costs are efficient rent-seekers. Business processes that exploit valuable and rare resources can therefore be a source of sustained competitive advantage. These statements are certainly not mere tautologies.

Powell (2001 : 881) disputed the RBV by proposing the counterfactual condition of *competitive disadvantage*. As noted by Powell, 'The two [competitive advantage and competitive disadvantage] are quite independent—if competitive advantage stems from inimitable, idiosyncratic resources, competitive disadvantage is not merely the non-existence of such resources (which would create economic parity), but rather the failure even to satisfy the minimum success requirements, or "strategic industry factors" (Amit and Schoemaker, 1993), required of any firm' (Powell, 2001 : 877). To say that a firm has an advantage is to say it has certain resources that other firms do not have. Over time, therefore, one expects the firm to exhibit above-average performance. But there is no guarantee that this must be so—a firm may fail to profit from its competitive advantage due to external obstacles. To address this issue, Powell suggested transforming the deterministic, unidirectional proposition *sustainable competitive advantages create sustained superior performance* into a probabilistic inference: *sustainable competitive advantage is more probable in firms that have already achieved sustained superior performance*. The latter proposition does not

[2] A syllogistic statement consists of three terms: a major premise, a minor premise, and the conclusion. Porter's (1985) generic argument can be represented by the following causal path:

Major premise: sustainable competitive advantage leads to above-average performance,

Minor premise: relative cost and differentiation are sources of sustainable competitive advantage,

Conclusion: relative cost and differentiation lead to above-average performance.

The RBV replaces Porter's cost and differentiation with VRIN resources in the *minor premise* and promotes this statement to the *major premise*, thereby forming an incomplete syllogism without minor premise or conclusion.

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assert that effects (evidence of superior performance) must follow from causes (sustainable competitive advantages). Rather, it asks us to infer the prevalence of causal factors by examining an ensemble of observable effects. By this means, Powell showed that disputes over the deterministic proposition 'q implies p' (*competitive advantage* implies *superior performance*) are only partially justified.

Note that the definitions of 'advantage' and 'disadvantage' have always been *relative*, and therefore problematic. 'If all rivals held the same absolute competitive advantage then no relative advantage holds and competitive forces would tend to eliminate available rents' (Arend, 2003 : 280). For example, Toyota's lean production system is usually considered a kind of 'corporate DNA,' very difficult to replicate or transfer and therefore a major source of sustainable competitive advantage (Spear, 2004; Spear and Bowen, 1999). Suppose that all of Toyota's key competitors successfully implement their own version of the lean action plan (Liker, 2004; Wei, 2007). Would Toyota's corporate DNA remain a major source of competitive advantage in this situation? Moreover, can Toyota's competitive advantage really be characterized as 'sustainable' after competitors have sought out the same rent? This fluidity and indeterminacy of *competitive advantage* leads us naturally to Powell's (2001) Bayesian epistemology. The hypothesis of sustainable competitive advantage (or disadvantage) can only be confirmed by empirical evidence, but this evidence provides inconclusive support at best. The *degree* of competitive advantage conferred by Toyota's lean production system ultimately depends on whether Toyota's competitors are successful at implementing or imitating the system, and to what extent Toyota can maintain its advantage.

In this paper, we propose a framework similar to Powell's (2001) Bayesian process, which periodically updates its propositions or hypotheses in the face of empirical evidence. Powell laid out a syllogistic structure describing the relationships between competitive advantage, competitive disadvantage, and superior performance. The inclusion of competitive disadvantage resolves disputes over RBV being a tautology; the issue of competitive advantage's many and heterogeneous sources, however, has not yet been addressed. In essence, we follow Powell (2001) and Porter (1991) by defining *superior (financial) performance* as the dependent variable, and adding an *auxiliary* or *bridge hypothesis* to help define the causal relationship between sustainable competitive advantage and sustainable superior performance. Specifically, we argue that it is the firm's unique configuration of resources (Miller, 1986; Siggelkow, 2002) that mediates between heterogeneous sources and competitive advantages, creating superior performance.

In the empirical section of this paper, we introduce a Bayesian discriminant model to reveal the functional dependence of superior performance on heterogeneous resource bundles. Any primary sources of competitive advantage (a unique business process such as lean production, customer relationships, etc.) are considered embedded in and inseparable from the organization itself, along with its business units and functional departments. It is assumed that the process of managing these resource bundles, variously termed *configuration, strategic fit* (Siggelkow, 2001; Levinthal, 1997), or *causal ambiguity* (Reed and DeFillippi, 1990; Rivkin, 2001), cannot be comprehended or imitated by outsiders. Realized superior performance indicators such as operating revenue, market share, stock prices, and 10-K reports, however, can be thoroughly assessed by the public.

The model is calibrated against the global semiconductor industry, a domain in which resource configuration and dynamic capability are essential to performance. The paper concludes with a summary of the proposed model and suggestions for future theoretical development of this approach to strategic management.

BAYESIAN EPISTEMOLOGY ON TAUTOLOGICAL FALLACIES AND COMPETITIVE ADVANTAGE

Ours is an uncertain world, though fortunately all things are not equally uncertain. (Howson and Urbach, 1991 : 371).

Bayesian epistemology and tautological fallacies

The logical fallacy of empirical studies in strategic management is as follows: researchers or managers *infer* the existence of competitive advantage from *ex post* superior performance, and conclude

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that creating competitive advantages *ex ante* will produce sustainable superior performance (Powell, 2000). This is a circular argument, or rhetorical tautology, because both premise and conclusion are defined in the same manner (Priem and Butler, 2001a, 2001b; Barney, 2001). To resolve this problem, Durand (2002) suggested invoking the concept of what Mackie (1965) deemed an INUS condition (named for the first letters of the italicized words that follow): sustainable competitive advantage is 'an *insufficient* but *necessary* part of a condition [yielding sustained superior performance,] which is itself *unnecessary* but *sufficient* for the result' (Mackie, 1965 : 245, italics in original).

Suppose, for example, that a cigarette butt 'causes' a forest fire. The cigarette butt by itself is not sufficient to cause a fire. An inattentive smoker, a pack of dry cigarettes, and a functional naphtha lighter *are* jointly sufficient for the fire. Furthermore, given the myriad necessary conditions associated with the cigarette butt (e.g., the smoker is in the forest, there is no rain that day, the initial fire spot is dry), we can say that the naphtha lighter is an INUS condition—the forest fire would not have happened if the lighter was not present. The complexity of such a series raises problems for the epistemology of causation.

Consider again Porter's (1985) generic claim that differentiation is a source of sustainable competitive advantage, which in turn yields above-average performance. Consider, for example, the following hypothetical case. We do not know whether Alpha Company's brand or trademark has been pirated in China, or whether its brand manager maintains a good relationship with local officials. What we *can* observe is that Alpha Company has widely recognized branding, differentiating the firm from its competitors, and thus has good odds of generating above-average performance. This is *probabilistic reasoning*, and can be used to evaluate hypothetical claims.

To illustrate this sort of reasoning, we follow Powell's (2001) numerical example of Bayesian analysis by defining events p and q in terms of probabilities as follows (the values are arbitrary):

prob(q) = .10 (10% of all firms have sustainable competitive advantages)
prob(∼q) = .90 (90% of all firms do not have sustainable competitive advantages)
prob(p/q) = .50 (50% of all firms that have sustainable competitive advantages achieve sustained superior performance)
prob(p/∼q) = .05 (5% of all firms without sustainable competitive advantages achieve sustained superior performance) (Powell, 2001 : 880).

With known priors prob(q) and prob(∼q) and conditional probabilities prob(p/q) and prob(p/∼q), the *evidence probability* prob(p) and *posterior probability* prob(q/p) can be estimated as

$$\text{prob}(q/p) = \frac{\text{prob}(p/q) \times \text{prob}(q)}{[\text{prob}(p/q) \times \text{prob}(q)] + [\text{prob}(p/\sim q) \times \text{prob}(\sim q)]} = \frac{\text{prob}(p/q) \times \text{prob}(q)}{\text{prob}(p)}$$
$$= \frac{(0.50)(0.10)}{(0.50)(0.10) + (0.05)(0.90)} = \frac{0.05}{0.095} = 0.53 \quad \text{(Powell, 2001 : 880)} \tag{1}$$

Notice that the universal conditional (i.e., 100% of companies with sustainable competitive advantage have achieved sustainable superior performance) has been factored out. We only claim that 53 percent of firms with *evidence* of superior performance possess the attribute of competitive advantage. The 53 percent of superior performers in this case are Powell's 'quadrant 1' firms, having positive economic rents which may be monopolistic, Ricardian, or Schumpeterian (Powell, 2001 : 878). This example disproves the deterministic claim that *q logically entails p*—that is, that sustainable competitive advantage always leads to sustained superior performance. The very fact that some companies with a competitive disadvantage have achieved superior performance[3] is evidence against this claim.

[3] From probability axioms, we know that if p and ∼q are independent, then the conditional probability of p given ∼q is the same as the probability of p, prob(p/∼q) = prob(p). For the condition prob(p/∼q) >0 to hold (i.e., companies without competitive advantage can still achieve superior performance),

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Subtracting the prior prob(q) = 0.10 from the posterior prob(q/p) = 0.53, we find that the *p is evidence for q* condition prob(q/p) − prob(q) >0 is satisfied (Powell, 2001 : 879). In Bayesian language we deduce that sustained superior performance evidence *confirms* the probabilistic reasoning of sustainable competitive advantage, providing a 43 percent increase in probability. It follows that the sustained superior performance evidence disconfirms (or would disconfirm) the likelihoods of sustainable competitive advantage if prob(q/p) − prob(q) < 0. To put it another way, the fact that *some* firms have sustained superior performance can be taken as evidence for the hypothesis that competitive advantage is a *source* of superior performance *if and only if* the probability that firms possess sustainable competitive advantage is greater among firms that achieved superior performance than in the overall population.

If we repeat the empirical test using 0.53 as the new prior (holding the likelihoods prob(p/q) and prob(p/∼q) constant), we get $\text{prob(q/p)} = 0.50 \times 0.53/(0.50 \times 0.53 + 0.05 \times 0.47) = 0.9185$. The 'trustworthiness' of this probabilistic reasoning *q causes p* has increased by 38.85 percent. This represents a refinement of the reasoning in light of new knowledge. If we repeat the empirical refinement one more time with 0.9185 as the new prior, we get $\text{prob(q/p)} = 0.50 \times 0.9185/(0.50 \times 0.9185 + 0.05 \times 0.0815) = 0.9912$. A new round of evidence further confirms the causal role of sustainable competitive advantage.

This convergence of probabilistic reasoning, or what Powell calls the merging of 'sense-making relations' (Powell, 2003 : 287), depicts an ontological belief change in the Bayesian scheme. Even widely discrepant 'sense-making machineries' about sustainable competitive advantage will almost surely be driven to a consensus after a sufficiently long period of learning, experimenting, and knowledge sharing. This is one way of stating the well-known 'washing out of priors' phenomenon in the Bayesian literature (Edwards, Lindman, and Savage, 1963 : 201): people will eventually assign nearly the same posterior probability to a hypothesis even if they started out with very different priors. In other words, people rationally respond to newly acquired evidence from reality by revising their ontological beliefs (the priors) over time. In the numerical example demonstrated above, evidence supporting the 'false' theory (i.e., that firms without sustainable competitive advantage have achieved sustained superior performance) becomes 'swamped' or 'washed out' (decreasing from 0.05×0.90 to 0.05×0.47 to 0.05×0.0815) as the value of the 'true' theory increases.

Suppose for a moment that such an equifinality of diverging theories exists. That is, suppose that such probabilistic reasoning provides the whole truth on the causal role of sustainable competitive advantages. The end state represents a scenario where the scientific paradigm has greatly advanced (Kuhn, 1962; Lakatos, 1978), or where researchers have arrived at a *utopia* (Laudan, 1984). The 'perfect' hypothesis would predict the observed evidence completely, such that prob(p/q) = 1.[4] That is, whenever we examine a firm with sustainable competitive advantage we will find it achieving sustained superior performance. Now let us assume an extremely low value for the prior, such as prob(q) = 0.000001, so that very few firms have a sustainable competitive advantage in the first place. Plugging these numbers into Bayes' equation, we get

$$\text{prob(q/p)} = \frac{1 \times .000\,001}{(1 \times .000\,001) + (0 \times .999\,999)} = 1$$

The above calculation demonstrates that when prob(p/q) = 1 holds, the prior probability doesn't matter. Whether prob(q) is low or high, we always get a posterior probability of 1. Briefly, almost every new piece of evidence will confirm our theory and the accumulated weight of past data will appear incontrovertible. This is Hempel's (1945) famous 'all ravens are black' paradox: if every sighting of a black raven confirms our theory, so does every sighting of a non-black non-raven.

However, the state of strategic management research is not so bleak. After all, we have not

the following two conditions must be met. (1) p and ∼q are independent, so competitive advantage does not cause superior performance and *vice versa*. The Chinese market mentioned above, where a good relationship with the government can yield superior performance, serves as an example. (2) prob(p) >0, meaning a superior performance outcome is inevitable for some firms without any conditional. This relates to Powell's (2001 : 878) 'quadrant 3' firms, which can achieve superior performance even through wrongdoing or inaction.

[4] prob(p/q) = 1 implies prob(q/p) = 1. We know prob(q) = 1− prob(∼q). Plugging this into Bayes' equation and simplifying it with the prob(q) term, we get prob(q/p) = 1. In this scheme, conclusive confirmation implies prob(q) = 1 while conclusive refutation implies prob(q) = 0.

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yet studied the entire body of empirical evidence available on all firms and industries. The proposition 'all ravens are black' can easily be falsified[5] by the discovery of a newborn white raven. By the same token, our probabilistic reasoning can be decisively refuted if the prediction 'sustainable competitive advantage leads to sustained superior performance' turns out to be false. If we consider Toyota's lean production system its sole source of sustainable competitive advantage, then find that all its competitors have successfully implemented lean production systems, Toyota might not be able to generate superior performance. Similarly, Porter's generic strategy claim would be refuted if the prediction 'differentiation leads to superior performance' (Porter, 1985 : 120) turns out to be false. Microsoft Office and CISCO ISO serve as counterfactual examples to Porter's generic strategy: both are highly differentiated products which have trouble generating sales in China despite their unique brand names, source codes, and status as industry standards.

While no finite amount of empirical evidence can verify that the competitive advantage reasoning is truthful, the idea that empirical evidence can easily falsify this reasoning is likewise flawed. As far as theory falsification is concerned, Bayesian epistemology is very sensitive to the pre-evidential prior probability assumed. A slightly different version of the theory (e.g., 'a copyrighted brand is the source of sustainable competitive advantage' or 'all ravens are brown') must be treated as a new and distinct theory if it differs in its treatment of the original evidence ('some brand names are not protected by trademark law in China' or 'some ravens are black') and the alternative (Porter's [1985] generic strategy, or Hempel's [1945] 'all ravens are black') can easily be falsified.

Thus, according to the arguments laid out above, the falsification of a strategic management theory depends largely on what value is assigned to the pre-evidential prior probability. This number will be different for each proposition or theoretical claim under consideration.

Consider again Powell's (2001) numerical example. A scientific analysis of the probabilistic reasoning will ask *why* the pre-evidential prior probability prob(q) is set to 0.10. Why not 0.13, 0.50, 0.94, or some other number? The answer is that its initial value depends on the researchers' *subjective* choices—in particular, which proxies for competitive advantage (unique corporate DNA, differentiation, cost leadership, copyrighted brand, etc.) they would like to work with. In strategic management, there may well be an infinite number of variants. Testing every possible proposition is tedious and impractical, but Bayesian inductive logic offers a very elegant way to reconcile them by incorporating empirical observations and test cases.

Suppose the number of sources of sustainable competitive advantage is finite, but covers a wide range of probabilities that superior performance will be generated. We can generalize Powell's single event q in equation (1) to the vector $\boldsymbol{\theta}$, which represents an exhaustive set of mutually incompatible competitive advantage hypotheses or theories, and extend the other scalar p to represent a collective set of empirical performance indicators $\mathbf{Y}$. In epistemological terms, this revision promotes Powell's constant probability values to a higher normative theory of competitive advantage. The Bayesian analysis can be written in the following aggregate form:

$$\text{prob}(\boldsymbol{\theta}/\mathbf{Y}) = \frac{\text{prob}(\mathbf{Y}/\boldsymbol{\theta}) \times \text{prob}(\boldsymbol{\theta})}{\text{prob}(\mathbf{Y}/\boldsymbol{\theta}) \times \text{prob}(\boldsymbol{\theta}) + \text{prob}(\mathbf{Y}/\sim\boldsymbol{\theta}) \times \text{prob}(\sim\boldsymbol{\theta})} = \frac{\text{prob}(\mathbf{Y}/\boldsymbol{\theta}) \times \text{prob}(\boldsymbol{\theta})}{\text{prob}(\mathbf{Y})} \quad (2)$$

The epistemological significance of the Bayesian process is that it provides a dynamic and amorphous view about the reasoning of competitive advantage. If $\text{prob}(\mathbf{Y}) = 0$, then the posterior probability $\text{prob}(\boldsymbol{\theta}/\mathbf{Y})$ in Equation (2) is undefined. The inquiry requires no empirical evidence, meaning the unconditional probability $\text{prob}(\boldsymbol{\theta})$ is defined on the basis of a tautology or an analytic statement. If $\text{prob}(\mathbf{Y}) > 0$, however, we can *infer* and

[5] Suppose a white raven is found (a firm has sustainable competitive advantage, but does not achieve superior performance). This will happen if prob(p) = 0. This indicates that the theory is independent of the evidence, prob(p/q) = 0. In this case the posterior probability will be zero for *any* values of prob(q), prob(∼q) and prob(p/∼q).

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revise our belief or hypothesis concerning the possible sources of competitive advantage (θ) in light of new evidence ($\mathbf{Y}$). For the present scientific inquiry, we are interested in characterizing the patterns of *strategic reasoning* employed by successful firms and providing 'rational constructions' of their sustainable competitive advantage given the performance evidence.

Bayesian inference and sustainable competitive advantages

Replying to Priem and Butler's (2001a : 29) contention that 'unique firms possess competitive advantages' is tautological, Barney (2001 : 46) recast the problem in terms of strategic equifinality[6]–if equifinality exists, then firms are *not* unique and therefore competitive advantages cannot exist. Barney redefined equifinality as a *substitutability* characteristic: 'if a resource is valuable, rare, and costly to imitate, ... [but] has strategically equivalent substitutes that are themselves not rare or not costly to imitate, then it cannot be a source of sustained competitive advantage' (Barney, 2001 : 47).

The strategic equifinality debate raises problems for the epistemology of causation among VRIN resources, organizational configuration, and sustainable competitive advantage. For example, can a firm's distinctive accumulation of valuable and inimitable resources be considered a source of competitive advantage even if the firm has achieved value and/or performance similar to that of its competitors? Or to phrase it differently, can the imitated configuration of resource bundles that generate different value or different performance level be considered sources of competitive advantage for the focal firm?

For causal inference and reasoning, including the concept of equifinality requires us to assign auxiliary hypotheses or bridge principles (Hempel, 1966 : 72–75) to mediate between competitive advantage and superior performance. Barney (2001 : 42) would call this *parameterizing* the causal relation. The auxiliary hypotheses have been given many names: *organizational configuration* (Miles and Snow, 1978; Miller and Mintzberg, 1983; Miller, 1986, 1996), *dynamic capability* (Teece, Pisano, and Shuen 1997; Eisenhardt and Martin; 2000; Zollo and Winter, 2002), *organizational routines* (Nelson and Winter, 1982; Rivkin, 2001; Winter and Szulanski, 2001; Zander and Kogut, 1995), and *causal (paths) ambiguity* (Reed and DeFillippi, 1990; Black and Boal, 1994; Rivkin, 2000, 2001) in the literature on organizational management. Their goals, however, are the same: to assert a relationship between 'rational constructions' and the unobserved properties of behavioral theories, and to derive an instance of the relationship based on empirical data that are easier to observe and measure.

In essence, we propose extending the causal relation between competitive advantage and superior performance to a strategy-configuration-performance causal series. At first glance this approach may seem overwhelming, but it can quickly be comprehended by recognizing that certain of the constructs pertain to theoretical claims that we have already discussed. For instance, if the 'configuration' is left out, we can define *focus* or *differentiation* as a source of competitive strategy and transform this reasoning series into Porter's (1985) competitive strategy proposition. Similarly, skipping the 'superior performance' result and treating competitive advantage as the dependent variable leads to Barney's resource-based view (Peteraf and Barney, 2003; Ray *et al*., 2004).

Given that heterogeneous performance deductively entails different configurations, the posterior probability prob($\boldsymbol{\theta}$/$\mathbf{Y}$) in Equation (2) can be extended to the general conditional prob($\boldsymbol{\theta}$, ψ/$\mathbf{Y}$), where ψ is an auxiliary equifinality proposition representing a mixture of heterogeneous resource bundles $\boldsymbol{x}$ and their associated weights $\boldsymbol{\lambda}$, $\psi = (x, \lambda)$. The causal series can be extracted by the Bayesian discriminant model[7] (Sivia, 1996), which assumes that the population of firms is composed of two unaffiliated factions: those with competitive advantage and those without (i.e., having

[6] The equifinality thesis originated in General Systems Theory (von Bertalanffy, 1968), and was adopted in organizational theory to indicate that similar performance outcomes might be achieved by very different typologies, causal paths, or dynamic learning (Doty, Glick, and Huber, 1993; Gresov and Drazin, 1997; Payne, 2006).

[7] Using the probability product rule, Equation (3B) can be rewritten as prob($\boldsymbol{\theta}$, ψ/$\mathbf{Y}$) = prob(ψ/$\boldsymbol{\theta}$, $\mathbf{Y}$)× prob($\boldsymbol{\theta}$/$\mathbf{Y}$). Setting the right-hand side of Equation (3B) equal to this new expression yields prob($\boldsymbol{\theta}$/ψ, $\mathbf{Y}$)× prob(ψ/$\mathbf{Y}$) = prob(ψ/$\boldsymbol{\theta}$, $\mathbf{Y}$)× prob($\boldsymbol{\theta}$/$\mathbf{Y}$). Rearranging the left-hand side gives *Bayes' theorem*, $\text{prob}(\boldsymbol{\theta}/\psi, \mathbf{Y}) = \frac{\text{prob}(\psi/\boldsymbol{\theta}, \mathbf{Y}) \times \text{prob}(\boldsymbol{\theta}/\mathbf{Y})}{\text{prob}(\psi/\mathbf{Y})}$, a generalized form of Powell's (1985) numerical example.

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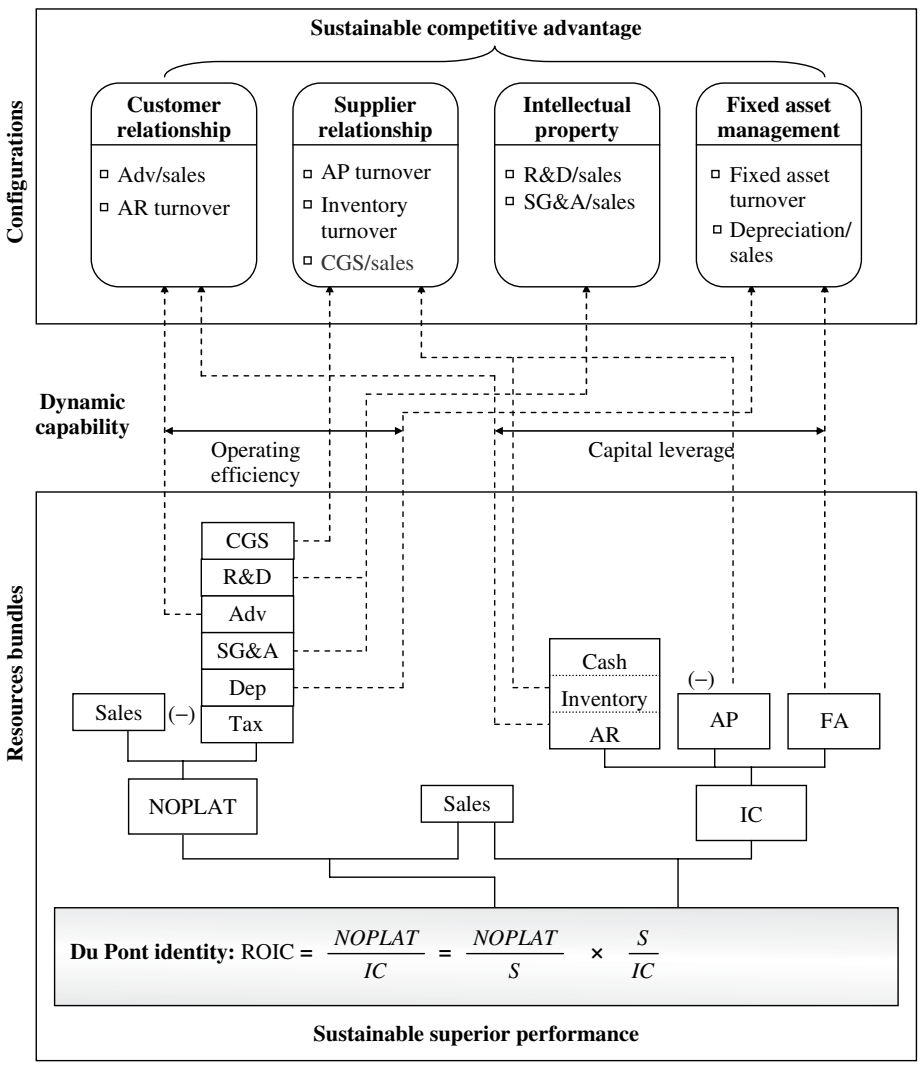
competitive disadvantage).

$$\text{prob}(\theta/\mathbf{Y}) + \text{prob}(\sim\theta/\mathbf{Y}) = 1 \quad (3A)$$

$$\text{prob}(\theta, \psi/\mathbf{Y}) = \text{prob}(\theta/\psi, \mathbf{Y}) \times \text{prob}(\psi/\mathbf{Y}) \quad (3B)$$

The probabilities of the competitive advantage hypotheses θ are straightforward. Statistical inference of competitive advantages (and competitive disadvantages) comes from inductive reasoning based on the unobserved configurations of heterogeneous resource bundles ψ and the empirical evidence of superior performance $\mathbf{Y}$. Bayesian reasoning generates one possible 'rational construction' of sustainable competitive advantage, which is depicted in Figure 1.

For instance, when trying to determine sources of competitive advantage that in turn cause superior financial performance, we may need to consider quite a long list. The result of testing these alternative hypotheses might depend on several of the researcher's choices: (1) how the evidential outcome $\mathbf{Y}$ is assessed; (2) the means by which



Adv- advertising expenses; AR- accounts receivable; AP- accounts payable; CGS- cost of sales; Dep- depreciation and amortization; FA- fixed assets; IC- invested capital; NOPLAT- net profit less adjusted tax; R&D- research and development expenses; ROIC- return on invested capital; SG&A- selling, general, and administration expenses; Tax- corporate income tax.

Figure 1. Explanation of sustainable competitive advantage

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the outcome will be performed; (3) the various paths, devices, or linkages leading to the evidential outcome; and (4) alignments of elements that lead to sustainable competitive advantage. In our case, (1) the return on invested capital (ROIC) is used to measure a firm's sustainable superior performance and/or value creation (Appendix I); (2) the firm's resource bundles $\boldsymbol{x}$, such as advertising and accounts receivable, are treated as driving elements of ROIC; (3) the configuration weights $\boldsymbol{\lambda}$ represent dynamic linkages such as operating efficiency and capital leverage that interconnect resource bundles; and (4) configuration of interconnected resource bundles such as customer relationships, intellectual property, and fixed asset management that might lead to sustainable competitive advantage.

As Durand (2002) suggests, competitive advantage may be a necessary but insufficient condition for performance outcome. If competitive advantage is about value creation and value capturing (Porter, 1980; Brandenburger and Stuart, 1996; Lippman and Rumelt, 2003; Coff, 1999), then we need an acting agency (in our case, the organization) to be responsible for the outcomes. We argue in Figure 1 that a firm's *configuration*, which we consider the causally relevant condition, is a necessary element among a set of conditions (including resource bundles, organizational routines, and operating efficiency) that are jointly sufficient for the superior performance outcome.

The problem of identifying the causally relevant conditions of an observed outcome, or in epistemological terms the 'cause-in-evidence,' is not new in the RBV literature. Barney (1997) makes a similar point by changing his VRIN model into a VRIO model, with organization replacing non-substitutable resources. Peteraf and Reed (2007) take a similar approach by introducing the manager, an actor responsible for bringing the configuration into efficient alignment (or 'fit'). The main difference of Bayesian epistemology is that the causal role of organization is probabilistic. Superior performance thus may still occur in the absence of effective organization, or fail to occur in its presence. Organization is considered a cause if (and only if) it significantly increases the probability of ensuing superior performance.

We now turn the discussion to an empirical test of this Bayesian inference model on sustainable competitive advantage.

EMPIRICAL STUDY: THE SEMICONCUCTOR INDUSTRY

In this section we address the concept of sustainable competitive advantage in the worldwide semiconductor industry. The semiconductor market experienced both downward and upward cycles from 2000–2005 (Semiconductor International, 2005). This is an interesting period to study because many semiconductor manufacturers commenced operations in 2000 but then had to face industry-wide problems such as new product transitions, design patent protection, production overcapacity, price erosion, shorter technology life cycles, global supply chain problems, and other logistical issues. The fierce battleground that resulted is ideal for testing whether superior performance can be traced to sustainable competitive advantages.

There are 208 semiconductor companies (with Standard Industrial Classification code 3674) in our sample, contributing a total of 1,248 records to Standard and Poor's COMPUSTAT database from 2000 to 2005. Sixty-one companies were excluded from our dataset. Ten of these provided fewer than three years of data, while 41 lacked data on various expenditure components (research and development [R&D], selling, general, and administrative expenses [SG&A], cost of goods sold [CGS], depreciation [Dep.], and Tax). In addition, companies were excluded if any of their financial indicators (excluding ROIC) were outliers[8] by more than three standard deviations from the industry mean. This criterion identified 10 more companies, five with positive ROIC and five with negative ROIC.

The final dataset contains 147 companies and 786 firm-year observations. Of these, 118 companies are located in developed countries (the United States, within Europe, and Japan). The other 29 are in the Asia/Pacific region.

[8] Hansen, Perry, and Reese (2004) argue that the central problem with the RBV is that it relies on extraordinary performers (positive outliers) instead of averages. Their argument, however, confounds the relationship between exceptional performers and statistical outliers. A statistical outlier is defined as an extremely unlikely data point on either side of a stochastic distribution. The exceptional performer may appear similar, but its appearance is not random—it is determined by the 'rational construction' of the firm. Hansen *et al.*'s (2004) study selected firms that had recently appointed CEOs for empirical calibration—a procedure that screens out all statistical outliers to begin with. Thus, it is similar to RBV in that it relies on exceptional performers.

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Table 1. Principal component analysis of financial indicators and the resulting resource configurations

Financial indicators	Resource configuration		
	Factor1: Relationship advantage	Factor2: Management ability	Factor3: Knowledge management
Accounts receivable turnover	**0.578**	−0.085	0.338
CGS/sales	**−0.677**	−0.204	−0.417
Inventory turnover	**0.595**	0.053	−0.033
Accounts payable turnover	**0.684**	0.008	0.043
R&D/sales	0.238	0.046	**0.859**
SG&A/sales	−0.063	−0.184	**0.812**
Depreciation/sales	0.034	**0.870**	0.014
Tax/sales	**0.568**	−0.229	−0.379
Fixed assets turnover	0.017	**−0.793**	0.101
Eigen value	2.36	1.56	1.45
Accumulated variance (%)	0.26	0.43	0.60

Bold numbers indicate a high correlation between the common factor and the corresponding financial indicator (greater than 0.5).

Unraveling sustainable competitive advantages

As discussed above, it might not be possible to directly observe a firm's sustainable competitive advantage or its efficient alignments responsible for the same. Certain effective configurations of observable traits, however, can be inferred from the firms' financial performance data. To begin with, principle component analysis (PCA)[9] was conducted on the financial indicators[10] to identify these configurations. After applying a varimax rotation to the eigenvectors and retaining those with eigenvalues greater than one, we obtained three principal components that together account for 60 percent of the total variance. Table 1 shows these three components or *factors* (represented as configurations of financial indicators) and the loadings associated with each variable. Significant loadings (0.55 and above) are printed in boldface.

In Factor 1, all significant financial indicators are related to *relationship management*. This factor includes customer relationship management (accounts receivable turnover), three variables related to supplier relationship management (accounts payable turnover, inventory turnover, and CGS/sales) and one variable associated with the government (tax to sales ratio). Thus, this factor illustrates the sustainable competitive advantage of firms that skillfully manage their upstream (suppliers), downstream (customers), and governmental relationships. There is also a negative correlation between CGS/sales and Factor 1 (−0.677), indicating that good relationship management can pay off with respect to a lower CGS. The semiconductor/IC industry has developed several partitions over the years, with firms dealing in intellectual property (NXP and IBM), integrated circuit (IC) design (Qualcomm and NVIDIA), wafer foundry (Taiwan Semiconductor Manufacturing Co. [TSMC]), and IC assembly (Advanced Semiconductor Engineering). The form of Factor 1 indicates that all these firms are highly interdependent—each has to ally with both upstream and downstream members of the industry.

Factor 2 consists of indicators related to a firm's *fixed asset managing capability*, including Dep./sales ratio and fixed assets turnover. The negative correlation between fixed assets turnover and Factor 2 (−0.793) indicates that firms exhibiting greater competence in assets management generate revenue at a lower unit historical cost. It is imperative in the semiconductor industry that firms fully utilize their fixed assets in a short period of time. The high correlation between Dep./sales and fixed asset management capability (0.870) reveals another unique feature of this capital- and

[9] The purpose of principal component analysis is to identify the most parsimonious groupings or configurations of variables that account for observable performance. It is based on the linear equation $\chi = \lambda\alpha + \varepsilon'\varepsilon$, where χ contains observable financial indicators, α is the 'latent structure' of the strategic configurations, and λ are the factor loadings connecting financial indicators and resource configurations. The bridge hypothesis $\varepsilon'\varepsilon$ is the 'causal ambiguity' projection, and encapsulates the maximum explainable variation in the relationship.

[10] Advertising expenditures are not included here due to data constraints.

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equipment-intensive industry: that effective asset management is associated with low asset depreciation. This result underlines the importance of 'light' asset operation in the semiconductor industry.

Factor 3 consists of indicators related to *knowledge management*, including R&D/sales and SG&A/sales. Both ratios measure a firm's effectiveness in resource deployment. The high correlations between Factor 3 and R&D/sales (0.859) and SG&A/sales (0.812) indicate that lower unit costs are associated with efficient management.

Principal component analysis thus confirms our proposition that the resource configurations and management capabilities of firms can be inferred from their observable financial indicators. We will examine the reliability and validity of this inference in the following section.

Segregating competitive advantage and competitive disadvantage

To infer sustainable competitive advantage, it is necessary to investigate sources of competitive advantage and the valuation of sustained superior performance on a deeper level. We follow Porter (1985), Hunt (2002), and Priem and Butler (2001b) in defining competitively advantaged firms as those whose financial performance is superior to the industry average. Companies with a high ROIC typically attract competition, so this ratio is taken as the appropriate indicator of financial performance. Furthermore, companies that have built up a sustained competitive advantage should generate a consistent or increasing ROIC over a long period of time. As Spanos and Lioukas (2001) have noted: 'The time period . . . is admittedly short (i.e., previous three years) to account for any business cycle effects or transient problems. It is important to note, however, that a longer time-frame (e.g., five instead of three years) could endanger the reliability of responses' (Spanos and Lioukas, 2001 : 923). Thus, only firms having a three-year average ROIC above the industrial level are considered to have observable superior performance.

Out of 147 firms, 138 provided information on all 11 of the financial indicators we require. Appendix 2 provides some descriptive statistics of the sample companies. The ROIC ratios of individual firms range from −43 percent to 45 percent, with an average of 4 percent. Their assets range from US$9 million to US$47,867 million (Intel). Table 2 ranks the top 15 semiconductor firms in terms of ROIC, and lists their resource-related financial ratios during 2003–2005.

The IC design houses Novatek Microelectronics (Taiwan), Mtekvision (Korea), and Memc Electronic Matrials (United States) command the highest ROICs in the industry. Two indicators confirm the existence of sustainable competitive advantage in the top two companies: (1) they have both high fixed assets turnover and low accounts payable turnover, indicating an ability to parlay their unique technologies into cost-effective design and manufacturing processes; and (2) their SG&A and R&D expenditures are low relative to sales, indicating effective knowledge management. Mtekvision also has a high accounts receivable turnover ratio (9.10), evidence of a strong relationship with its customers (manufacturers of mobile phones, smart phones, PDAs, digital cameras, MP3 players, and voice recorder products). In contrast, Memc (a global leader in the manufacture and sales of wafers and related intermediate products to the semiconductor and solar industries) has a low fixed assets turnover ratio (2.48). On the other hand, it has very effective knowledge management and strong customer relationships. It is noteworthy that all three high-return companies operate on a rather small scale in terms of total assets, compared to the industrial average.

Two global leaders, Intel and TSMC, command the highest Dep. to sales ratios. They also have relatively low fixed assets turnover ratios due to their 'heavy' asset investments. Among the top 15 firms, Intel, the personal computer central processing unit leader, commands the highest R&D/sales (0.14) and SG&A/Sales ratios (0.14). TSMC, the pure-play foundry business leader, has the highest Dep/sales ratio (0.278). Thus, neither company generated sustained competitive advantage from asset and/or knowledge management; competitive advantage instead derived from their management of supplier relationships. The CGS-to-sales ratio is very low in both firms, yielding high gross margins capable of subsidizing their high R&D and SG&A expenses. Furthermore, high inventory turnover compensates for low fixed asset turnover in both companies. The sustainable competitive advantages of these two companies, which have quite different configurations, are not based upon a single source, but rather an amalgamation of sources.

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Table 2. The top 15 semiconductor firms during 2003–2005, ranked by ROIC

Company	Area	ROIC	TA	ART	CGS/S	APT	INVT	R&D/S	SG&A/S	Dep/S	FAT	Tax/S
Novatek Microelectronics	Taiwan	0.45	426	4.19	0.70	6.08	11.60	0.05	0.04	0.005	31.08	0.000
Mtekvision	Korea	0.42	98	9.10	0.66	8.75	8.60	0.07	0.02	0.004	20.93	0.003
Memc Electronic Matrials	USA	0.38	962	7.91	0.63	9.00	8.14	0.04	0.07	0.044	2.48	0.002
Sitronix Technology	Taiwan	0.37	54	4.82	0.65	11.78	8.89	0.09	0.05	0.004	20.35	0.014
Melexis Nv	USA	0.31	151	4.91	0.52	29.82	5.64	0.14	0.07	0.074	4.20	0.030
Intel	USA	0.23	47,867	10.50	0.28	17.68	12.48	0.14	0.14	0.135	2.08	0.082
National Semiconductor	USA	0.22	2,432	11.92	0.36	21.16	10.85	0.17	0.14	0.093	3.14	0.045
Hynix Semicondutor	Korea	0.22	8,698	6.04	0.44	11.77	10.04	0.06	0.08	0.213	1.12	−0.025
On Semiconductor	USA	0.22	1,140	8.45	0.60	10.20	6.74	0.08	0.12	0.089	2.57	0.005
Xilinx Inc	USA	0.20	3,050	6.80	0.34	22.38	10.23	0.19	0.18	0.035	4.52	0.050
Samsung Techwin	Korea	0.20	1,645	7.32	0.80	13.77	8.98	0.03	0.07	0.041	3.66	−0.000
Taiwan Semiconductor Mfg Co.	Taiwan	0.19	14,354	7.93	0.29	27.51	16.10	0.05	0.05	0.278	1.01	0.007
Silicon Laboratories Inc	USA	0.19	492	7.61	0.41	9.73	13.28	0.19	0.14	0.042	11.91	0.061
Diodes Inc	USA	0.19	194	4.22	0.61	8.23	8.52	0.02	0.14	0.068	3.01	0.028
E2V Technologies Plc	UK	0.18	162	4.31	0.61	9.37	5.06	0.04	0.17	0.052	4.64	0.022
Industrial average		0.04	2,243	6.27	0.56	12.55	8.53	0.14	0.15	0.09	5.69	0.019

ROIC: return on invested capital; ART: accounts receivable turnover ratio; CGS: Cost of goods sold; S: annual sales; APT: accounts payable turnover ratio; INVT: inventory turnover ratio; SG&A: selling, general and administration expenditure; FAT: fixed assets turnover ratio; and TA: total assets in million US dollars.

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Table 3. Discriminant analysis on advantaged and disadvantaged firms

	Standardized canonical coefficients	F value	Prob > F
ART	−0.0517	1.08	0.3014
CGS/S	−0.2782	0.15	0.6958
APT	−0.1720	0.66	0.4184
INVT	0.1710	3.74	0.0552*
R&D/S	−0.2515	23.85	<0.0001***
SG&A/S	−0.2504	37.89	<0.0001***
Dep/S	−0.3525	2.01	0.1587
FAT	−0.1317	0.14	0.7136
Tax/S	0.2282	19.35	<0.0001***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Eigenvalue	Canonical correlation	Likelihood ratio	F value	Prob > F
1.1121	0.725628	0.47346	15.82	<0.0001

Classification results used for cross-validation[a]

Groups	Competitive advantage	Competitive disadvantage	Total
Competitive advantage	64	13	77
Competitive disadvantage	15	46	61

[a] Cross-validation is done by recalculating the discriminant function for all firms other than the validated firm.
[b] 88.4% ((70 + 52)/138) of firms are correctly classified.
[c] 79.7% ((64 + 46)/138) of the cross-validated firms remain correctly classified.

Discriminant function analysis[11] (DFA) is applied to identify the underlying resource configurations that best distinguish the 138 firms, all of which are classified as having either competitive advantage or competitive disadvantage by the three-year ROIC criterion mentioned above. DFA computes the posterior probability prob(θ/ψ, **Y**) (cross-validated hit ratio) that financial indicators are associated with the competitive advantage and competitive disadvantage groups, given group-specific density estimates prob(ψ/θ, **Y**)(the canonical coefficients in Table 3) and unconditional density estimates prob(ψ/**Y**) (the prior probability is set to 58% initially, since 80 of the 138 firms have three-year ROICs above the industry average). Table 3 presents the results of our two-group discriminant analysis. An examination of the group means shows immediately that ROIC discriminates the groups more effectively than any other indicator. In addition, SG&A/sales (S), R&D/S, and Tax/S all demonstrate significant ($p < 0.01$) power to separate the two groups. Table 3 also presents the classification accuracy of the discriminant function. Our results show that 90.9 percent of competitive-advantage firms and 85.3 percent of competitive-disadvantage firms are correctly classified, for an overall accuracy of 88.4 percent (>75%). Leave-one-out cross-validation correctly classifies 79.7 percent of firms (>58%). Evidently, financial resource bundles (Penrose, 1959; Rumelt, 1984) can be used to distinguish between competitive-advantage and competitive-disadvantage groups, given some knowledge of their configurations.

DISCUSSION

Much of past RBV research has focused on resource bundles, groups of indicators sharing

[11] Discriminant function analysis (DFA) is an empirical version of Bayes' theorem that transforms the prior probabilities of the advantaged and disadvantaged groups prob(θ) = prob(θ, $\sim\theta$) into posterior group memberships. The performance likelihood function (based on financial indicators) must be known beforehand. The 'hit ratio,' or Powell's (2003 : 287) merging of 'sense-making relations,' measures the accuracy of the prior and posterior membership transformations.

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common themes such as culture (Barney, 1986), organizational routines, management skills, and socially complex resources (Barney, 1991, 1997). Similarly, modern research on fit and organizational alignment (Porter, 1996; Siggelkow, 2001, 2002), including work based on the NK model (epistatic interactions among N organizational attributes in a K-dimensional fitness space) (Kauffman, 1993; Levinthal, 1997), really considers these bundles the *source* of competitive advantage. The problem is that resource and activity bundles are notoriously hard to dismantle, since they include complex linkages, complementarities (Milgrom and Roberts, 1990, 1995), and tacit dimensions (Nelson and Winter, 1982; Reed and DeFillippi, 1990). This is a particularly serious problem for variants of the RBV, such as the knowledge-based view (Kogut and Zander, 1992; Liebeskind, 1996) and the works on dynamic capabilities (Teece *et al*., 1997; Eisenhardt and Martin, 2000). Not only are the bundles hard to unpack in these models, but it becomes very difficult to test the prediction that such bundles provide a competitive advantage or affect long-run (or even short-run) performance.

There have been some efforts in this direction. Before the RBV made much headway, there was a stream of research connecting broad archetypes or configurations (Miles and Snow, 1984; Miller, 1986, 1996) to performance. Since Milgrom and Roberts (1990, 1995), there has also been some empirical work suggesting that complementarities do provide efficiency advantages (e.g., Ichniowski, Shaw, and Prennushi, 1997). Peteraf and Reed (2007) took this analysis to a higher level, examining how bundles of capabilities were managed and showing that proper management can lower firm costs, thereby creating value. Connecting bundles to competitive advantage and sustainable performance is a longstanding and important problem. Advancing the RBV, the dynamic RBV (Helfat and Peteraf, 2003), and research on dynamic capabilities (Teece *et al*., 1997) depends critically upon achieving this milestone. Similarly, advancing Porter's (1996) claim that 'fit' leads to sustainable competitive advantage depends on our ability to unfold the strategy-configuration-performance causal dependencies.

The resource configurations based on financial indicators introduced in this paper provide an effective way to value and predict the existence of competitive advantage within an industry. All the financial indicators of Figure 1 are related to value creation, either on the willingness-to-pay side or on the cost side (Hoopes *et al*., 2003). This approach has been shown to work well in several Harvard Business Cases and teaching notes (e.g., Gilson and Cott, 1997; Ghemawat, 2004; Ghemawat and Nueno, 2006; Rivkin and Porter, 1999). The DFA analysis (with its underlying Bayesian understanding) provides *prima facie* evidence that companies with a track record of sustainable profitability (not just a lucky year) are more likely to have a competitive advantage in terms of value. The PCA analysis reveals causal linkages among resource bundles, efficient alignments, and dynamic capabilities that indicate that competitive advantage causes superior performance. By combining these calibration tools, we can find out which potential routes to competitive advantage yield long-term payoffs in performance and profitability given a specific context, and which resource bundles really matter.

CONCLUSIONS

To resolve disputes over the resource-based tautology, Powell (2001) suggested adopting Bayesian probabilistic reasoning as a means of distinguishing sustained competitive advantage from sustained superior performance. This paper advances Powell's idea by proposing that particular resource configurations mediate between the two. Through a discussion of Bayes' theorem, we describe how empirical data on past financial performance in a population of firms can be used to generate the posterior probability of sustainable competitive advantage, given the prior probabilities of both competitive advantage and competitive disadvantage. The financial drivers of the du Pont identity are taken as a basis to derive relevant configurations of resource bundles.

Three configurations of 'resource bundles' were identified in an example drawn from the semiconductor industry: upstream and downstream relationship management, management of intellectual property, and fixed asset management. We conclude that superior financial performance arises from a firm's unique resource configuration and management capability. Since financial data is easy to access, this theoretical framework is very useful for investigating the competitive advantage proposition in a systematic and extensive manner.

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Taking the process a step further, we can bring other midrange theories such as strategic archetypes (Miles and Snow, 1978; Miller and Friesen, 1978; Hambrick, 1984), causal ambiguity (Lippman and Rumelt, 1982; Reed and DeFillippi, 1990), strategic equifinality (Payne, 2006), and contingency theory as conditional statements or auxiliary hypotheses to the competitive advantage and superior performance dyad. These possibilities certainly merit further investigation, and form a promising area for future research.

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APPENDIX 1: THE DU PONT IDENTITY, COMPETITIVE ADVANTAGE, AND FINANCIAL RATIOS

The du Pont identity is widely used as a strategy assessment tool to evaluate a company's capital efficiency and management capability (Firer, 1999; Grant, 1991, 2008). The return on invested capital (ROIC), an important measure of earnings efficiency, represents management's ability to advance and sustain shareholder value (Cao, Jiang, and Koller, 2006). The ROIC can be segregated to two parts: (1) how *efficiently* the resources are allocated and utilized (measured by NOPM, net operating profit margin), and (2) how *effectively* the resources are leveraged and managed (measured by capital turnover):

$$ROIC = \frac{NOPLAT}{IC} = \frac{NOPLAT}{S} \times \frac{S}{IC} = NOPM \times capital\ turnover \quad \text{(A1)}$$

where NOPLAT (net operating profit less adjusted taxes) = EBIT×(1-tax rate), and IC (invested capital) = (fixed assets + current assets) − non-interest-bearing liabilities. EBIT refers to earnings before interest and tax, and S to sales. The NOPM can be further decomposed into a function of selling price and unit cost:

$$NOPM = (p \times Q - c \times Q)/(p \times Q) = (p - c)/p = 1 - (c/p) \quad \text{(A2)}$$

where p = selling price, c = the firm's cost of producing the product, and Q = sales volume. If NOPM >0, the selling price is higher than the firm's production cost (p—c >0), so the firm benefits from higher producer surplus. That is, either the firm can produce the good at a lower cost for equivalent benefits (the cost-leading advantage), or consumers are willing to pay a higher price for some unique benefits (the differentiation advantage) (Porter, 1985). Additionally, if capital turnover, the second portion of Equation (A1), is greater than one, the invested resource bundles are efficaciously consolidated to stimulate revenue. The value of the competitive advantage is magnified by the effective use of the firm's infrastructure and tangible assets. For example, Dell's 'direct' business model brings it a higher price and a lower cost structure than its rivals. The competitiveness of Dell's cost advantage is revealed by its high inventory turnover rate, which results in a low cost-of-goods-sold and inventory cost (Rivkin and Porter, 1999). ZARA, another example, generates competitive advantage from an extremely quick response system. The high profit margin (p—c), the low working capital to sales ratio, and the high asset turnover contribute to its high return on equity (Ghemawat, 2004).

To summarize, if we define competitive advantage as the value created by the firm over its cost (Peteraf and Barney, 2003; Hoopes, Madsen, and Walker, 2003; Besanko *et al*., 2007: chap. 11), Equation (A1) provides a measurement of value creation from competitive advantage.

The components contained in the du Pont identity are related to value creation activities undertaken by the firm. To unpack the firm's complex operational activities, we further decompose NOPM and Capital Turnover (Koller, Goedhart, and Wessels, 2005) as:

$$ROIC = \frac{NOPLAT}{S} \times \frac{S}{IC} = \frac{(S - CGS - Adv - R\ \&\ D - Dep - SG\ \&\ A - tax)/S}{(FA + AR + Inv - AP + cash)/S}$$

where CGS = cost of goods sold; Adv = advertising expenses; $R\&D$ = expenditures on research and development; Dep = depreciation; $SG\&A$ = selling, general, and administration expenses; FA = fixed assets; AR = accounts receivable; Inv = inventory; and AP = accounts payable. The numerator consists of resource-employment expenditures to sales ratios while the denominator consists of tangible asset turnover ratios. These account ratios are classified into four groups, in accordance with their respective activities, in Figure 1.

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APPENDIX 2: DESCRIPTIVE STATISTICS OF THE SAMPLE COMPANIES

	Minimum	Maximum	Mean	Median	Std dev
ROIC	−0.4253	0.4546	0.0443	0.0610	0.1432
Accounts receivable turnover	1.2767	12.8320	6.2701	6.0654	2.2781
Accounts payable turnover	3.2559	36.6341	12.5521	11.0441	6.2438
Inventory turnover	1.7459	23.4770	8.5327	7.7816	4.1315
CGS/sales	0.2414	1.0108	0.5562	0.5614	0.1602
R&D/sales	0.0021	0.5894	0.1400	0.1111	0.1172
SG&A/sales	0.0202	0.4336	0.1453	0.1343	0.0812
Depreciation/sales	0.0036	0.4421	0.0933	0.0650	0.0824
Fixed assets turnover	0.6236	31.0814	5.6939	3.0188	6.3221
Total assets (US$ million)	9	47,867	2,243	589	5,043

Source: Compustat database (sample size = 138).

ROIC: return on invested capital $= \frac{NOPLAT}{Equity + interest\ bearing\ debt}$

Accounts receivable turnover $= \frac{sales}{accounts\ reveivable}$

Accounts payable turnover $= \frac{sales}{accounts\ payable}$

Inventory turnover $= \frac{sales}{inventory}$

Fixed assets turnover $= \frac{sales}{fixed\ assets}$

SG&A: selling, general and administration expenses

CGS: cost of goods sold

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