ANALOGICAL REASONING FOR DIAGNOSING STRATEGIC ISSUES IN DYNAMIC AND COMPLEX ENVIRONMENTS

KENT D. MILLER¹ and SHU-JOU LIN²*
¹ The Eli Broad Graduate School of Management, Department of Management, Michigan State University, East Lansing, Michigan, U.S.A.
² Graduate Institute of Global Business and Strategy, National Taiwan Normal University, Taipei, Taiwan

Organizations interpret their environments by categorizing strategic issues as either opportunities or threats. They make such categorizations as inferences drawn from analogies from past experience. The accuracy of issue interpretations turns on: (1) which analogy is used, (2) what are the environment’s properties, and (3) what is the timeframe? A computational model allows us to evaluate over time the accuracy of interpretations based on different forms of analogical reasoning in environments that differ in variation (unpredictability and dynamism) and complexity (dimensionality and ruggedness). This study elaborates a contingency approach to assessing analogical reasoning by organizations in which the form of analogical reasoning, environmental properties, and time all matter. Our findings indicate when particular forms of reasoning produce relatively more accurate inferences about opportunities and threats. Copyright © 2014 John Wiley & Sons, Ltd.

INTRODUCTION

Strategic managers face the ongoing challenge of interpreting a wide array of environmental signals and ascertaining their implications for their organization’s strategy and performance. Along with data from the environment, managers’ interpretive schema figure prominently in the diagnosis of strategic issues (Dutton, Fahey, and Narayanan, 1983). Managers often reduce complex situations down to simple interpretations such as whether the current environment presents a threat or an opportunity (Dutton and Jackson, 1987; Jackson and Dutton, 1988; Julian and Ofori-Dankwa, 2008). The importance of interpretations of strategic issues lies in their connection to decision making and organizational action (Dutton, Stumpf, and Wagner, 1990; Gilbert, 2006; Julian and Ofori-Dankwa, 2008).

Ascertaining the strategic implications of complex organizational environments often calls for reasoning by analogy (Dutton et al., 1983). Analogical reasoning draws upon a past experience in a similar, but not identical, situation to make inferences about the present situation (Holyoak, 2005; Holyoak and Thagard, 1995). The process of analogical reasoning involves elaborating and evaluating the mapping of a known source (a remembered experience) onto a partially-unknown target (a current situation). After identifying a suitable analogy, information about the source is transferred to the target as a plausible but fallible inference (Gentner and Markman, 1997). Analogical reasoning is relevant when a new situation requiring interpretation has both important similarities and dissimilarities relative to prior experiences. Real estate...
Analogical reasoning in decision making (Gregan-Paxton and Cote, 2000; Holyoak and Thagard, 1995). Another example comes from the use of financial reporting as an analogy supporting firms’ adoption of sustainability reporting (Etzion and Ferraro, 2010). Directly relevant to our topic is the observation from Gavetti, Levinthal, and Rivkin (2005) and Gavetti and Rivkin (2005, 2007) that strategists make use of analogical reasoning in novel environments. Research on analogical reasoning can enrich our understanding of how managers process environmental data to classify strategic issues.

Gavetti et al. (2005) contend that using analogical reasoning aids organizational adaptation in complex environments. They developed a computational model that identified some contingencies determining the effectiveness of analogical reasoning in novel situations. Our study extends their line of inquiry and responds to the call for research to identify the situational contingencies that affect the performance of analogical reasoning in strategic decision making (see Gary, Wood, and Pillinger, 2012). In particular, we ask: (1) which analogy is in use, (2) what is the nature of the environment, and (3) what is the relevant timeframe? We start from the premise that there are different ways to reason analogically and the efficacy of these different forms of reasoning when applied to strategic issues may depend upon features of the environment in which they are used. The timeframe matters because organizations need time to accumulate a repertoire of experiences from which to draw analogies. The set of possible analogies grows as an organization learns over time, and this may or may not improve decision making.

We advance this contingency view by using computational modeling to evaluate different kinds of analogical reasoning under different environmental conditions. We assume that learning and applying analogical reasoning occur together over time, thus we adopt a dynamic perspective toward evaluating how well analogical reasoning performs. Our model allows us to explore a wide variety of possible environments and various forms of reasoning, thereby identifying influences on the effectiveness of reasoning by analogy over time. We model an organization operating in a changing environment, not on a fixed landscape. Encompassing considerations raised by Wholey and Brittain (1989) and Levinthal (1997), our depiction of the environment includes variation (unpredictability and dynamism) and complexity (dimensionality and ruggedness). Computational modeling allows us to set up a full factorial experimental design to derive the implications over time of different forms of reasoning in environments that differ along various dimensions.

We evaluate the accuracy of two forms of analogical reasoning—best available match and satisficing match—in a wide array of environments. Analogical reasoning using the best available match draws inferences on the basis of the most similar past experience. Satisficing chooses an analogy that is deemed adequate to the situation, but not necessarily the best match (see Simon, 1956, 1976). We compare the accuracy of interpretations based on these two different approaches to analogical reasoning and using only exact matches from prior experience. We find, for example, that satisficing is advisable only in early periods in environments with low unpredictability or low frequency of change. Depending on the environment, organizational learning can have positive, neutral, or negative effects on the accuracy of satisficing reasoning over time. Using the best available match generally outperforms exact match reasoning, except when unpredictability and ruggedness are high.

This study advances understanding of the contingencies affecting the quality of strategic issue diagnoses. Evaluating empirically the accuracy of organizations’ diagnoses of strategic issues is problematic because such diagnoses are usually unobservable to outsiders and whether a situation is an opportunity or a threat can be difficult to ascertain ex post. Furthermore, natural experiments present incomplete designs with respect to the set of contingencies affecting the quality of issue diagnoses. Computational modeling bypasses these limitations, thereby allowing us to address an important topic that empiricists working on strategic issue diagnosis have not taken up. Overall, our analyses show the relevance of a contingency approach to assessing the accuracy of analogical reasoning for classifying strategic issues. The form of analogical reasoning, environmental properties, and time all matter. The accuracy of analogical reasoning about strategic issues depends upon complex interactions among environmental properties.
Managers face the ongoing challenge of interpreting the changing environments in which their organizations operate. According to Dutton et al. (1983), **strategic issue diagnosis** is a process whereby managers order and give meaning to a continuous stream of diverse and ambiguous data that characterize their organization’s situation. Whereas environmental scanning generates data, managerial interpretation gives meaning to data, thereby promoting learning and facilitating organizational action (Daft and Weick, 1984). Interpretation moves from myriad observations about aspects of the situation to an integrated, holistic understanding (Boland, Tenkasi, and Te’eni, 1994). Data from the current environment and organizational members’ past experiences enter into this interpretation process (Daft and Weick, 1984). Strategic issue diagnosis applies inferential reasoning to arrive at fallible hypotheses rather than definitive conclusions (Dutton et al., 1983). Such hypotheses about organizational situations guide action through decisions that exploit perceived opportunities when they arise in the environment (Eisenhardt and Sull, 2001). Hence, the accuracy of managers’ inferences carries implications for the strategic actions and performance of organizations. Managers’ biased interpretations of organizational environments, expressed as excessive optimism or pessimism about the organization’s prospects, can lead to inappropriate strategic actions (Martins and Kambil, 1999).

The interpretations that we consider here are simple categorizations of complex environments as favorable or unfavorable situations. Managers frequently use the labels “opportunity” and “threat” to distinguish these situations (Dutton and Jackson, 1987; Jackson and Dutton, 1988). Threatening circumstances present potential loss and reflect lack of organizational control, whereas opportunities afford potential gains that may be controllable (Jackson and Dutton, 1988; Thomas and McDaniel, 1990). Such categorizations affect how organizations process and respond to strategic issues (Chattopadhyay, Glick, and Huber, 2001; Dutton and Jackson, 1987). Prior studies indicate that interpreting an issue as an opportunity is likely to lead to a more proactive response than if the situation is considered threatening (Sharma, 2000; Thomas, Clark, and Gioia, 1993). Managers’ interpretations of organizational environments guide their strategic deployment of organizational capabilities and moves into new ventures (Cornelissen and Clarke, 2010; Eggers and Kaplan, 2013). Managers must detect and interpret environmental signals that, on the basis of prior experience, identify a threat before they can initiate remediating responses (Kiesler and Sproull, 1982).

Barr’s (1998) investigation of pharmaceutical firms’ interpretations of a regulatory change provides an in-depth look at the process of interest here. The environmental change featured in that study was an increase in the evidence of product efficacy required by the U.S. Food and Drug Administration. While the proposed legislation was being developed, pharmaceutical firms connected the unfolding legislative process with other experiences, such as prior government interventions or public relations problems. Such analogies to familiar past experiences guided their anticipation of eventual outcomes. Over time, as the nature of the emerging legislation became clearer, firms were able to ascertain more clearly its implications for the industry as a whole, and for their firm-specific performance. Managers’ interpretations of the issue, in turn, drove strategic changes involving R&D, marketing, foreign expansion, and diversification.

Prior research connects the diagnosis of strategic issues to various organizational characteristics, such as strategy and information processing structure and culture (Dutton and Ottensmeyer, 1987; Thomas and McDaniel, 1990), diversity of the top management team (Dutton and Duncan, 1987; Plambeck and Weber, 2009), resource dependencies (Milliken, 1990), as well as experience, inertia, and available resources (Denison et al., 1996). Studies report the relevance of information gathering and processing (Anderson and Nichols, 2007; Kuvaas, 2002) and past experience (Denison et al., 1996; Plambeck and Weber, 2010), but do not identify the specific hermeneutics (i.e., interpretive schemas) used by managers. Research on analogical reasoning helps fill this gap by clarifying how managers make use of environmental data to classify strategic issues.

The act of classifying environments suggests that an organization’s interpretive process follows some explicit or implicit schema. The characteristics of the current situation are compared with those of schematically-organized knowledge from past experience to arrive at categorizations of situations based on their degree of similarity (Jackson and Dutton, 1988). Judgments of similarity compare...
features and determine the extent to which they match (Tversky, 1977). The suitability of an analogy depends upon the extent to which its features map onto the target (Gentner, 1983; Holyoak and Thagard, 1989, 1995). Using an analogous situation, an inference can be made about the outcome of the presenting situation, and this inference guides current action. Understanding novel situations in the light of similar familiar situations is the basic structure of reasoning by analogy. Understanding of the current situation follows from comparative reasoning reflecting the general “as-structure” of interpretation.

However, the general claim that managers reason by analogy lacks precision; it offers insufficient detail about the nature of such reasoning. Analogical reasoning may take different forms (Weitzenfeld, 1984). Analogical reasoning in a choice situation involves specifying a consideration set (i.e., the set of possible analogies retrieved from memory for consideration), comparing analogies in this set to the target, selecting an analogy, and deriving inferences (Markman and Moreau, 2001). To advance a theory of analogical reasoning for diagnosing strategic issues, we need to specify how managers choose relevant experiences and reason from them to current decisions and actions (see Cornelissen and Clarke, 2010; Etzion and Ferraro, 2010; Foss and Lorenzen, 2009). Furthermore, we need to understand the conditions that determine when analogical reasoning—in its various forms—promotes organizational adaptation to complex environments. Prior research leaves unanswered whether we need a contingency perspective (i.e., different forms of analogical reasoning are superior for different environments) or whether some forms of analogical reasoning robustly produce accurate interpretations across different kinds of environments. Computational modeling provides a method for assessing the accuracy of different forms of analogical reasoning in different kinds of environments.

The process of analogical reasoning modeled by Gavetti et al. (2005) involved the following steps: (1) observe a subset of the current situation’s characteristics; (2) find a known analogy that is the best match for the observed dimensions of this situation; (3) choose the best performing general policy response based on average outcomes for the best matching situation; (4) randomly choose a set of detailed choices consistent with this general policy; and then (5) use incremental search to enhance performance. This characterization of analogical reasoning reflects some key implicit assumptions. Step 1 assumes a limited and comparable set of observable characteristics for the current and past situations. Step 2 requires extensive prior experience to build a broad portfolio of possible analogies. The learning process generating the set of possible analogies precedes application to analogical reasoning. Step 3 assumes knowledge of the performance implications of an extensive set of policy decisions for any given analogy, and optimization with respect to this set. Steps 4 and 5 are implications of the incomplete guidance provided by simplified representations of the environment. Reasoning by analogy is used just once to find a starting point for subsequent trial-and-error search on a fixed landscape.

The situation reflected in our model diverges from these assumptions. First, our focus is on categorizations of the environment as favorable or unfavorable (Dutton and Jackson, 1987; Jackson and Dutton, 1988), rather than choices among many possible multidimensional organizational strategies. The problems posed here and by Gavetti et al. (2005) are distinct but both are relevant to organizations. Complex strategies respond to the details of environments, but managers’ decisions about whether to deploy, postpone, or discard such strategies follow from holistic assessments of environmental favorability. Second, our modeled organization possesses no prior bank of experiences from which to draw analogies; rather, learning from experience and decision making through analogical reasoning occur together over time (Cornelissen and Clarke, 2010). Organizations often must draw conclusions from limited histories (March, Sproull, and Tamuz, 1991). We assume analogies emerge out of learning over time. Modeling the learning process from the beginning of a de novo organization distinguishes our approach from prior models of environmental interpretation (cf. Carley and Lin, 1997; Gavetti et al., 2005). Third, given our focus, we isolate analogical reasoning and do not augment it with other search and decision processes, which introduce confounding effects on the organization’s performance. Hence, analogical reasoning fully characterizes organizational decision making in our model. Fourth, we consider environments where change is ongoing, rather than one-time moves from one fixed landscape to another. Ongoing change allows the organization to build up its repertoire of experiences from which to draw
analogies and simultaneously presents the need for repeated application of analogical reasoning to interpret the environment over time.

Environmental variation is multidimensional. Based on a review of prior research on environmental instability, Wholey and Brittain (1989) concluded that environmental variation occurs along three dimensions: frequency, amplitude, and predictability. Frequency refers to the time between environmental changes. Amplitude indicates the extent of change or the distance between succeeding environmental states. Predictability is the degree to which a future state can be anticipated. The higher the number of possible states and the more equal their probabilities of occurring, the less predictable is the environment. Frequency and amplitude make up the rate of change (or dynamism), whereas predictability relates to how readily people can foresee the particular direction of change (McCarthy et al., 2010). These three dimensions of environmental variability are independent (Wholey and Brittain, 1989). As such, we can set up a series of experiments with our model that covers the range of possible combinations that make up distinct forms of environmental variation.

Our interest in characterizing the environment extends beyond its variation over time to its complexity. The complexity of an environment depends on the number of relevant industry and general environmental features and the extent of their interactivity in determining whether a situation presents an opportunity or threat for an organization. We refer to these features as an environment’s dimensionality and ruggedness, respectively. NK models feature both forms of complexity: N refers to the number of environmental elements and the contribution of any element depends on K other elements, so ruggedness increases with K (Kauffman, 1993; Levinthal, 1997). The concept “ruggedness” reflects interest going back to Emery and Trist (1965) in the causal texture of environments, i.e., the interdependencies among environmental components and their effects on organizations. Ruggedness refers to the extent to which interactions among environmental elements affect the resulting state (see Kauffman, 1993; Levinthal, 1997). For a smooth landscape, similar configurations of elements tend to cause the same state. By contrast, in a rugged environment, similar configurations of elements often produce different states. Such an environment is unstable and can easily tip from being favorable to unfavorable, or vice versa, due to minor perturbations of its components.

Our model combines complexity together with frequency, amplitude, and unpredictability of change to characterize a broad range of possible environments in which to test the efficacy of different forms of analogical reasoning.

MODEL SPECIFICATION

Environment

Each period in a model run represents the occurrence of a configuration of environmental elements that presents a strategic issue for organizational analysis.1 The environment consists of n elements representing industry forces and factors in the broader context that jointly determine whether the organization faces an opportunity or threat. Each environmental element takes one of two possible qualitative states in any period—represented by the values 1 or −1. Each of the 2^n possible configurations of the environmental elements determines an overall state that is either an opportunity (1) or a threat (−1). The set of possible 2^n configurations together with their resulting states make up a landscape.

As discussed above, environments can be characterized in terms of their variation (including unpredictability and dynamism) and complexity (consisting of dimensionality and ruggedness). Dynamism separates into two facets: the frequency and magnitude of changes. In all, there are five environmental characteristics incorporated into the model.

Dimensionality

The range and heterogeneity of environmental dimensions that are relevant to an organization make up important aspects of complexity (Child, 1972; Daft, Sormunen, and Parks, 1988; Miller, Ogilvie, and Glick, 2006). In our model, dimensionality is the number of environmental elements, n.

Unpredictability

An environment is predictable if it always produces the same state regardless of the configuration of its elements. By contrast, unpredictability

1 The passage of time should be understood in terms of the succession of strategic issue events, which may be separated by lulls of varying duration during which no strategic issue arises.
is highest when the two possible outcome states occur with equal probability. Let \( q \) be the probability of an opportunity state, so \((1 - q)\) is the probability of a threat state. When \( q \) equals 0.5, the landscape is most unpredictable, whereas it is completely predictable if \( q = 0 \) or 1 because the state never changes. In other words, unpredictability is a triangular function of \( q \) peaking at \( q = 0.5 \).

**Dynamism**

We model two facets of environmental dynamism: the frequency and magnitude of environmental change (see Kim and Rhee, 2009; Wholey and Britain, 1989). The *frequency* of environmental change \((f)\) is the inverse of the number of times that an issue recurs before an environmental change. If the environment presents the same issue repeatedly before switching to a new configuration then change occurs with low frequency.

When environmental change occurs, the probability of a state change (from 1 to \(-1\) or vice versa) for each element is \( p \). The higher \( p \), the greater is the expected magnitude of the environmental change.

**Ruggedness**

Our specification of environmental ruggedness follows a general polynomial function. This function is a sum of the values for the environmental variables and their cross products, each weighted by its assigned coefficient. The multiplicative (interaction) terms indicate interdependencies among the environmental elements that contribute to determining whether the overall environmental state is an opportunity or a threat. The general polynomial function is:

\[
P(n) = \sum_{i=1}^{n} \sum_{j=1}^{i} a_{j}^{(i)} X_{j}^{(i)}
\]

where \( X_{j}^{(i)} \) indicates the \( j \)th \( i \)-variable monomial term, \( a_{j}^{(i)} \) is its corresponding coefficient, and \( j(i) = \binom{n}{i} \). We assume that coefficients take values of either 1 or 0, thereby determining whether a monomial term is included or not in the polynomial equation. Landscape ruggedness generally increases with the number of cross-product coefficients (i.e., \( a_{j}^{(i)} \) for \( i \geq 2 \)) with a value of 1.

We assign states to environmental configurations based on the values generated by a polynomial function. We first rank the cases in the order of their function values. An opportunity state (value of 1) is assigned to a case when its functional value is ranked in top \( q \) proportion of all \((2^n)\) cases; otherwise it is classified as a threat (state of \(-1\)).

**Organizational reasoning and accuracy**

*Analogical reasoning* When confronting a strategic issue, the organization considers analogous cases from those stored in memory in order to posit an inference about the current state. The process of analogical reasoning consists of identifying possible analogies that make up a *consideration set*, evaluating the commonalities and alignable differences among analogies and the target, and drawing inferences about the target based on the analogies deemed suitable (Markman and Moreau, 2001). Figure 1 provides an overview of the modeled organizational reasoning process. In the example in Figure 1, the environment is a vector with \( n \) (=5) elements of either 1 or \(-1\), and experiences stored in memory are partitioned vectors consisting of the remembered \( n \) environmental elements and the associated state.

Identifying relevant analogies is based on judgments of similarity between prior experiences and the current situation (Gentner and Markman, 1997). Similarity is inversely related to the difference or distance in the two situations’ features (Goldstone and Son, 2005). Different subjective criteria for assessing similarity call for different functional forms (Gilboa and Schmeidler, 2001). We use Hamming \((H)\) distance to measure alignable differences between environments experienced in the past and

---

2 Because \( q \) is the probability of an opportunity state, it reflects the general level of munificence of the environment. Whereas unpredictability peaks at \( q = 0.5 \), munificence increases linearly with \( q \).

3 Using only the value of 1 for all nonzero coefficients does not limit the generality of our findings. Using values for nonzero coefficients drawn at random from a uniform distribution on the range \((0, 1)\) would produce the same results on average.

4 Ranks for environments that share the same polynomial function value are resolved by referring to a random order established at the beginning of a model run.
the current situation. Such an approach is consistent with prior research indicating the relevance of superficial similarities (i.e., one-to-one correspondence of attributes), rather than similarity of structural relations, in the retrieval of analogies from long-term memory (Gentner, Rattermann, and Forbus, 1993; Holyoak and Koh, 1987; Ross, 1989).

Reliance on corresponding attributes in the retrieval of analogies is particularly evident for repeated experiences within a domain (Ross, 1987) as is the case when an organization interprets repeatedly the environment in which it operates and draws analogies from its own past experiences.

Two plausible matching heuristics are using (1) the best available match or (2) a satisficing match. The former approach optimizes over a limited set of experiences, whereas the latter approach satisfices (Simon, 1956). When using the best available match heuristic, the organization considers the memorized pattern(s) having the minimum Hamming distance.

---

5 Hamming distance \((H)\) is the number of elements that must be changed to make one environmental configuration match another. In other words, Hamming distance is the number of nonidentical elements in a pairwise comparison of environments, which can range from 0 (all elements identical) to \(n\) (all elements different).
Analogical Reasoning in Dynamic and Complex Environments

(MIHD) from the current configuration of the environment. When applying the satisficing heuristic, the organization includes in its consideration set all cases with Hamming distance less than a threshold value (i.e., \( H \leq h \)). The maximum acceptable Hamming distance (MAHD), \( h \), is an integer between 1 and \( n \). If the cutoff is \( n \), then the organization deems all past cases to be relevant analogies.

If no experience fulfills the applied heuristic, the organization makes a random guess about the current state.\(^6\) If just one experience fulfills a heuristic, then the organization infers that the current state corresponds with the outcome of that prior experience. If more than one experience fulfills a heuristic, then the organization makes a probabilistic choice based on the frequency of each state among the cases in the consideration set.

**Exact match**

For comparison, we also examine exact match reasoning, which draws an inference about the state from a prior experience that corresponds exactly with the current environmental configuration \( (H = 0) \). An exact match is not, strictly speaking, an analogy because analogical reasoning requires that the source not be identical to the target (Holyoak, 2005).

**Accuracy**

Organizational performance is measured as its percentage of correct interpretations (i.e., inferences that correspond with the actual state). We report the accuracy of the organization’s interpretations over time averaged across runs for a given model.

**Experimental design and parameters**

Our model provides a rich set of possible environmental conditions for evaluating the accuracy of analogical reasoning. We chose two divergent values for each environmental parameter to set up our experimental design (see Law and Kelton, 2000: ch. 12). Table 1 lists the environmental parameters and the values chosen. For environmental dimensionality, we chose a low value, \( n = 5 \), that affords a wide range of levels of ruggedness. We briefly discuss the implications of higher environmental dimensionality \( (n \gg 5) \) at the end of the findings regarding interpretation accuracy, rather than present additional figures with these results.

Values of \( q \) equal to 0.1 and 0.5 correspond to low and maximum unpredictability. Environmental change occurs either once every 10 issues \( (f = 0.1) \) or every issue \( (f = 1) \). At \( p = 0.1 \), the environment experiences limited change. At values of \( p \) approaching 1, the environment tends to switch back and forth between two configurations. At \( p = 0.5 \), the environment configuration has maximum variability over time, so we use this as the high value for dynamism magnitude. The polynomial expressions with 5 and 30 terms produce low and maximum ruggedness.\(^7\) For satisficing reasoning, we chose the threshold value of \( h = 1 \) as the maximum acceptable Hamming distance (MAHD) for possible analogies.

We analyze the accuracy of the three forms of reasoning under each of 16 \( (=2^4) \) possible variants of the environment. Because the organization learns by accumulating experience, the accuracy of analogical reasoning changes over time. The graphs in the figures plot mean interpretation accuracy for each experiment over 500 strategic issues. The reported mean accuracy values are based on 1,500 runs of

---

\(^6\) In the initial period, an organization has no prior experience and simply makes a random guess regardless of its interpretation rule.

\(^7\) Our measure of ruggedness is the proportion of all possible environmental configuration pairs in a landscape with Hamming distance of one having opposite states. This novel measure indicates the uniqueness of configuration states when compared to those of all immediately adjacent \( (H = 1) \) configurations.
each model. Lower case letters (q, f, p, r) and upper case letters (Q, F, P, R) distinguish environments characterized by low and high levels of unpredictability, dynamism frequency, dynamism magnitude, and ruggedness, respectively.

**EVALUATION OF ANALOGICAL REASONING**

**Comparisons of interpretation accuracy**

Figure 2 plots interpretation accuracy for the three forms of reasoning in environments with high-frequency change (f = 1). Several key findings appear in these results. First, interpretation accuracy improves with experience for best available match and exact match reasoning. Eventually, cumulative learning causes the accuracy of these two forms of reasoning to reach 100 percent. However, the paths over time differ with the environmental characteristics. Organizations in environments characterized by incremental change (i.e., low p) have higher accuracy in early periods but slower learning processes over time than organizations in environments experiencing changes of greater magnitude (i.e., high p). The greater the magnitude of change, the more difficult is analogical reasoning, but learning opportunities are also greater. Second, reasoning according to the best available match generally outperforms exact match and satisficing match reasoning. The key exception occurs in highly-rugged environments, where exact match reasoning outperforms interpretations based on the best available match. When ruggedness is high, reasoning on the basis of a proximate, but less-than-exact, match often is not good enough to draw accurate inferences. Third, depending on the nature of the environment, experiential learning can have positive, neutral, or negative effects on the accuracy of satisficing reasoning over time. Considering the specific cases where learning causes improvement (QFPr, qFPr, qFPR), little effect (qFpr, qFpR), or deterioration (QFpr, QFpR, QFPR) of accuracy for satisficing match reasoning, no pattern appears at the level of main or two-way effects. Instead, these differing implications of learning reflect three-way interactions among unpredictability, dynamism magnitude, and ruggedness.

Low-frequency change causes volatility in interpretation accuracy over time. For reasoning according to best available match and exact match, environmental changes cause single-period drops in interpretation accuracy, but in subsequent periods of environmental stability accuracy goes to 100 percent due to learning from prior experience in the identical environment (so the best available match is an exact match). The result is generally high performance for these two forms of reasoning, with punctuating drops in interpretation accuracy whenever the environment shifts. Because of this pattern, plotted results for best available and exact match reasoning tend to overlap so Figures 3 and 4 separate them into two different columns—best available match on the left and satisficing match on the right. Figure 3 covers environments characterized by low-frequency change and low ruggedness. Figure 4 presents plots for low-frequency change and high ruggedness. For each environment, the left-hand and right-hand plots for satisficing match are identical and serve as a baseline for comparison with the other two forms of reasoning.

Figures 3 and 4 affirm some patterns already observed in Figure 2. First, average interpretation accuracy improves over time for both best available match and exact match reasoning irrespective of the environment. Second, best available match generally outperforms exact match reasoning irrespective of the environment. Second, best available match generally outperforms exact match reasoning. The key exception is when both unpredictability and ruggedness are high. In unpredictable and highly-rugged environments, analogical reasoning from proximate past experiences is prone to errors. Third, in environments with low-frequency change, learning over time generally diminishes interpretation accuracy for satisficing match reasoning. When environmental change occurs infrequently, early experiences provide exact matches from which to draw inferences about the state. As time passes, the organization draws from a growing set of possible analogies that satisfice yet are less accurate predictors of the environmental state than recent experiences.

Figures 3 and 4 also reveal that satisficing match reasoning results in much lower performance volatility than do the other two forms of reasoning in environments with low-frequency change. Furthermore, performance volatility from using satisficing reasoning diminishes with learning over time. The suboptimization associated with satisficing diminishes both volatility and performance relative to best match and exact match reasoning.

The worst performing decision rule differs depending on the time horizon and context. In early periods, the exact match rule is generally
Figure 2. (a–h) Interpretation accuracy in environments with high-frequency change. Correction added on 8 January 2015: each L should be R (uppercase) and each l should be r (lowercase).
Figure 3. (a–h) Interpretation accuracy in environments with low-frequency change and low ruggedness. Correction added on 8 January 2015: each L should be R (uppercase) and each l should be r (lowercase).
Figure 4. (a–h) Interpretation accuracy in environments with low-frequency change and high ruggedness. Correction added on 8 January 2015: each L should be R (uppercase) and each l should be r (lowercase).
the inferior approach in environments with low ruggedness. Following exact match reasoning, an inexperienced organization often resorts to random guessing because it has no memory that matches exactly its environment’s current configuration. An exact match is the optimal choice to guide decision making but it is not always an available choice. In such situations, either form of analogical reasoning would improve the organization’s ability to diagnose strategic issues arising in its environment. Exact match reasoning only dominates in early periods when both unpredictability and ruggedness are high. Satisficing can be a reasonable approach in early periods with low unpredictability or low frequency of change but it is always inferior to the other two forms of reasoning in the long run. The short-run potential and the long-run inferiority of satisficing reasoning are important implications of our analyses.

To limit the tables included, we presented results only for a relatively simple environment with \( n = 5 \) elements. Based on unreported supplemental analyses, we can offer a few conclusions about analogical reasoning in higher dimensional environments. In most cases, as environmental dimensionality (\( n \)) increases, the challenges associated with reasoning from analogies increase for an organization drawing only on its own limited experience. In a highly predictable environment (\( q \rightarrow 0 \) or \( q \rightarrow 1 \)), increasing dimensionality does not adversely affect the accuracy of inferences about the environment’s state drawn from past experience. Likewise, in a stable environment (\( f \rightarrow 0, \ p \rightarrow 0 \)), analogical reasoning works well. However, as the environment becomes unpredictable, unstable, and rugged, the accuracy of analogical reasoning from limited experience breaks down in high-dimension environments. Because the conditions that cause analogical reasoning to fail may characterize some (possibly, many) organizations’ environments, our supplemental findings highlight a practical concern about whether and how organizations can cope with such circumstances.

**Analysis of variance**

The analyses presented thus far compared the accuracy of predicted states using two different forms of analogical reasoning and the exact match rule in different environments. However, we may also be interested in posing a complementary question: which environmental characteristics—unpredictability (\( q \)), dynamism (\( f \)), magnitude (\( p \)), and ruggedness (\( r \))—account for the accuracy of each form of reasoning? Because interaction effects occur, the answer to this question is not directly evident from Figures 2–4. To address this question precisely, we applied multifactor analysis of variance to the data generated by our simulation runs. In these models, each of the four variables is dichotomized with 1 indicating the higher value and 0 otherwise. Therefore, the coefficients are easily interpreted as the incremental changes in the expected interpretation accuracy relative to the sum of the overall mean (\( \alpha \)) and the lower-order component terms. We estimated the following model:

\[
y = \alpha + \beta_1 q + \beta_2 f + \beta_3 p + \beta_4 r + \beta_5 qf + \beta_6 qp + \beta_7 qr + \beta_8 fp + \beta_9 fr + \beta_{10} pr + \beta_{11} qfp + \beta_{12} qpr + \beta_{13} qpr + \beta_{14} qarf + \beta_{15} qfpr + \epsilon,
\]

where \( y \) is the interpretation accuracy and \( \epsilon \) is the observation-specific error term.

Table 2 presents the multifactor analysis of variance results for the two forms of analogical reasoning and the exact match rule over the short run (periods 1–10), long run (periods 491–500), and entire run (periods 1–500). Each analysis is based on 24,000 observations because there were 1,500 runs for each of the 16 environmental contexts.

Some consistent patterns appear in Table 2. First, the intercepts (\( \alpha \)) are all close to 1, with values ranging from 0.899 to 0.997. When unpredictability, frequency, dynamism, and ruggedness are low, interpretations based on any of the three forms of reasoning are quite accurate. Apart from the intercept, most significant effects and all of the strong effects, defined as \(|\beta_k| > 0.1\) (\( k = 1, \ldots, 15 \)), are negative. Generally, the effects of unpredictability, frequency, dynamism, and ruggedness are detrimental to interpretation accuracy over the short, long, and entire runs.

Our results show that the effects of the environmental factors differ depending on the time horizon considered and form of reasoning used. For the three time horizons examined, environmental factors have the least predictive power (i.e., low adjusted \( R^2 \) as well as near zero coefficients) for

---

1. The analyses used the Stata (version 9) command `anova` with the `regression` option.
long-run accuracy, particularly when using best available match and exact match reasoning. As reported earlier, long-run accuracy associated with these two heuristics is nearly perfect regardless of the environmental characteristics. Contrastingly, when using satisficing match, environmental influences on interpretation accuracy continue in the long run, with strong environmental influences ($|\beta_{11}| > 0.1$) associated with unpredictability ($q$) and its interaction with ruggedness ($qr$). This pattern of lowest overall model fit (adjusted $R^2$) in the long run is an implication of organizational learning. As organizations accumulate diverse experiences, the accuracy of their interpretations depends less on the environmental characteristics. At the extreme, an organization has experienced and remembered all $2^n$ environmental configurations, and reasons from these. Hence, the time horizon figures prominently in whether the accuracy of analogical reasoning depends on the unpredictability, frequency, dynamism, and ruggedness of the environment.

For short-run accuracy, environmental characteristics account for about 70 percent of total variance for each form of reasoning, however, the strong influences differ across the reasoning approaches. When using analogical reasoning, the strong influencing factors ($|\beta_{11}| > 0.1$) are interactions involving subsets of all four variables ($rqf$, $fp$, and $qf$ for satisficing match; $rqf$ and $qfp$ for best available match). In contrast, the short-run accuracy of exact match reasoning depends most strongly on the effects of only dynamism frequency and magnitude ($fp$ and $f$). In early periods, an organization following exact match reasoning has not yet recorded enough experiences to interpret accurately frequently changing environments.

For satisficing match and best available match reasoning, environmental characteristics explain more than 90 percent of total variance in interpretation accuracy over the entire run. In contrast, the ANOVA model explains only 64 percent of variance when the organization follows exact match reasoning. Environmental ruggedness never significantly influences the interpretation accuracy for organizations following exact match reasoning because such organizations avoid reasoning from proximate experiences. Dynamism frequency ($f$) and magnitude ($p$) account for most of the explained variation for exact match firms for the entire run through their influence on experience accumulation and the relevance of past experiences for current inferences. Reasoning from exact matches...
benefits from rapid accumulation of diverse experiences in environments characterized by frequent and high-magnitude change.

It is noteworthy that not every coefficient is negative. For the models related to best match and satisficing analogical reasoning, all of the significant positive coefficients are associated with interactions involving dynamism frequency \( (f) \) and appear in the long-run and entire-run models. For satisficing, the overall effect of the frequency of change on accuracy is negative in the long run and entire run, despite the occurrence of some weak positive interaction effects. In contrast, for reasoning according to the best available match, the overall effect of frequency is unambiguously positive in the long run. Whereas frequent environmental changes pose a challenge, they also help build up organizational memory that improves the accuracy of inferences over time. In the long run, the benefits of diverse experiences outweigh the challenges. The positive long-run effect of frequent environmental changes holds for exact match reasoning as well.

**DISCUSSION**

Interpreting environments by reasoning analogically

Our study advances prior research on how organizations classify their contexts as favorable or unfavorable (e.g., Dutton and Jackson, 1987; Jackson and Dutton, 1988). Research on strategic issue diagnosis draws attention to the role that managers play in “how data and stimuli get interpreted and understood” in organizations (Dutton et al., 1983: 309) and suggests that managers arrive at interpretations by reasoning analogically (Jackson and Dutton, 1988). However, studies in this line of research rarely elaborate the reasoning process involved (e.g., Denison et al., 1996; Gilbert, 2006; Martins and Kambil, 1999; Sharma, 2000; Thomas and McDaniel, 1990). Although learning from experience is the basis for subsequent interpretations of organizational environments, how experience leads to interpretations is not explored in depth in research on diagnosing environmental opportunities and threats. For example, empirical studies show that prior relevant experiences increase the likelihood of interpreting an issue as an opportunity (Anderson and Nichols, 2007; Denison et al., 1996; Plambeck and Weber, 2010) but they do not fully specify the learning and reasoning process involved in arriving at this classification.

Our study draws from research on analogical reasoning to advance theoretical understanding of the process of environmental interpretation for strategic issue classification. By bringing analogy research to the study of environmental interpretation, we shed light on the nature of the learning and inferential reasoning involved. Details of the analogical reasoning process connect past experiences and organizational memory to inferences about a strategic issue that managers face in the current environment. We see further opportunities for theory building and testing at the intersection of analogical reasoning and strategic issue diagnosis research.

Prior research (e.g., Denison et al., 1996; Miller, 1993; Starbuck and Milliken, 1988) observes that accumulated experience in an issue domain shapes managers’ diagnoses. Without careful characterization of how prior experiences are processed and applied, theorized implications of experience for issue diagnosis could be superficial and vague. In response, we put forward a model that specifies explicitly the learning process and plausible decision heuristics associated with analogical reasoning in strategic issue diagnosis. Analyses using our model demonstrate which contingencies make the accumulation of experiences over time beneficial or detrimental to interpretation accuracy.

Overall, our study demonstrates the relevance of a contingency approach to assessing the implications of analogical reasoning by organizations in which the form of analogical reasoning, environmental properties, and time all matter. A contingency approach maintains that organizations may benefit from taking different approaches to reasoning and decision making depending on the context. Such a perspective poses the “meta-decision” problem of deciding how to decide (Grandori, 1984), which carries normative implications, but also may have relevance for predicting how organizations actually behave.

Five principal conclusions arise from our analyses of the three alternative forms of reasoning.

1. Interpretation accuracy improves over time for best available match and exact match reasoning, but often declines for satisficing reasoning. Old memories, which are best forgotten, often mislead a satisficing organization. In dynamic environments, organizations should either abandon satisficing in favor of the best available match.
form of analogical reasoning or they should promote unlearning of distant past experiences (see Martin de Holan and Phillips, 2004a, 2004b; Tsang and Zahra, 2008).

2. Environmental dynamism erodes performance in the short run, but enhances experiential learning, thereby improving the accuracy of analogical reasoning from the best available match over the long run. Consistent with this contention, Gary et al. (2012) found that exposure to source variation produced higher performance on an analogous task among participants in a laboratory experiment. New entrants into dynamic environments may invest heavily in learning but experience poor results in the short run, yet through their participation in a challenging environment they gain unique knowledge over time that enables them to cope with environmental dynamism.

3. Best available match generally outperforms exact match reasoning, except when unpredictability and ruggedness are high. This finding provides the general rationale and boundary condition for analogical reasoning by decision makers with limited experience relative to the diverse possibilities within their environment. Given limited experience, decision makings need to deploy the best of what they do know, rather than wait to acquire what they would ideally like to know.

4. In highly-rugged environments, satisficing can produce results that are worse than random guessing. Satisficing is advisable only in early periods in environments with low unpredictability or low frequency of change. Outside of stable or predictable contexts, we would expect—and advocate—that organizations abandon satisficing in favor of other forms of inferential reasoning.

5. Satisficing can reduce performance volatility (relative to using best available or exact match reasoning) when environmental change occurs infrequently, but lower risk comes at a cost to performance. In most environments, an organization would have to be extremely risk averse to accept the risk-return tradeoff involved in using satisficing reasoning over the long run.

Analyses of which environmental factors account for the variance in interpretation accuracy pointed to high-level (three-way and four-way) interactions among environmental unpredictability, frequency and magnitude of change, and ruggedness. Effects of the various environmental factors differ depending on the time horizon and form of reasoning used. These findings support the view that the accuracy of analogical reasoning is contingent upon complex interactions among environmental characteristics, and they strongly caution against broad generalizations about the validity of guidance drawn from analogies. Different environmental conditions call for different approaches to organizational learning (Gnyawali and Stewart, 2003). In general, unpredictability, dynamism, and ruggedness detrimentally affect the accuracy of analogical reasoning. These effects persist over time as long as the environment is sufficiently complex that the organization’s cumulative learning about possible environmental configurations remains nonexhaustive.

Strategic issue diagnosis can occur as a reflective and active process or as an unreflective and automatic process (Dutton, 1993). Prior research indicates that analogical reasoning often occurs with little conscious awareness on the part of decision makers (Gary et al., 2012; Schunn and Dunbar, 1996). The potential for improving strategic issue diagnosis as a process of analogical decision making turns on whether managers are capable of reflecting upon the details of their reasoning, and then evaluating those processes in light of the contingencies that characterize their decision contexts. Opportunities for improving analogical reasoning can be found in (1) more fully and accurately recording past experiences, (2) systematically searching experiences in memory, and (3) selecting analogies on the basis of criteria that suit the environment and level of organizational experience. To the extent that managers rely upon analogical reasoning to make strategic decisions that affect the overall direction and performance of organizations, making individual managers’ and collective management teams’ analogical reasoning processes more explicit and reflecting critically on these processes to find ways to improve them become compelling pursuits.

Our study carries various implications for researchers interested in strategic issue diagnosis. Overall, our study points out the need to consider the form of analogical reasoning, environmental properties, and learning timeframe, and their bearing on the accuracy of organizational diagnoses of strategic issues. Our framing encourages a shift in focus toward issue diagnosis quality,
a managerially-relevant yet under-researched outcome. Because environmental classifications trigger organizational responses to environmental stimuli (Chattopadhyay et al., 2001; Dutton and Duncan, 1987; Dutton and Jackson, 1987; Milliken, 1990), we can infer that organizational maladaptation could, at least partially, result from problematic issue diagnoses. Nevertheless, the evaluation of diagnosis quality has never been a significant topic in the strategic issue diagnosis literature. Albeit challenging, researchers should consider pursuing longitudinal research that examines organizational learning and reasoning processes over a prolonged observation window in order to evaluate the variables affecting issue diagnosis quality.

Computational modeling

Beginning with Levinthal’s (1997) study of organizational adaptation on a rugged landscape, application of Kauffman’s (1993) NK model to management issues has spread (see Ganco and Hoetker, 2009; Vidgen and Bull, 2011). NK models present static landscapes in which \(2^N\) configurations are available to an organization as possible choices at any point in time. The organization’s challenge is to find fitness-enhancing configurations through a process of searching and learning from performance feedback. The environment remains fixed and, although it determines the fitness outcomes for alternative organizational configurations, the organization never observes the environment.

We modeled a different problem—one involving an organization’s interpretations of an observable and changing environment. Our approach assumes that the environment is analyzable (Daft and Weick, 1984); in other words, an organization can access information about the many facets of its environment. The organizational problem is to categorize the current state as favorable or unfavorable on the basis of the observed environmental data. Hence, our model places the environment in the foreground, but removes the details of the organization’s adaptive response featured in prior NK models.

The organizational problem framed in this study resembles that found in the computational models of environmental interpretation developed by Carley (1992) and Carley and Lin (1997). Those studies modeled an organization that faces a series of multidimensional and varying situations that require simple classification decisions with only two or three possible inferential conclusions. Hence, the organization’s interpretations map a highly complex situation onto a simple dichotomous or trichotomous conclusion. Organizational members learn from feedback received in response to their prior decisions. In particular, they learn the true outcome of the situation, which remained unknown at the time of their decision. Organizational members relate remembered experiences to subsequent situations, thereby improving decision accuracy over time.

Gavetti et al. (2005) provide an important precedent for the use of computational modeling to understand the nature and implications of analogical reasoning in organizations. Our study extends their effort in three key ways. First, we acknowledge that there are various ways to draw analogies (Weitzenfeld, 1984). The form of analogical reasoning used in different organizational settings remains an open question that empirical researchers are just beginning to address (Kim, 2011). Our study considered two rules for identifying analogous cases—satisficing and best available match. These two specifications fit within a general understanding of analogical reasoning in choice situations as drawing potential analogies from memory and evaluating them on the basis of their similarities and alignable differences relative to the target to arrive at candidate inferences applied to the target (Gentner and Markman, 1997; Markman and Moreau, 2001). Our modeled decision process involves identifying a consideration set from organizational memory and then drawing an inference based upon the frequency of experienced states. Lovallo, Clarke, and Camerer (2012) argue that using multiple source cases together can improve the accuracy of managers’ analogical reasoning for strategic decisions.

Second, we specified various environmental properties that affect the accuracy of reasoning from analogies. These include variation (unpredictability, frequency of change, and magnitude of change) and complexity (dimensionality and ruggedness). This set of environmental properties combines the key aspects of environmental change (Kim and Rhee, 2009; Miller et al., 2006; Wholey and Brittain, 1989) with the emphases on dimensionality and ruggedness in NK modeling research (Kauffman, 1993; Levinthal, 1997). Gavetti et al. (2005) modeled analogical reasoning for one-time moves from one static environment to another. In contrast, we consider organizations in environments experiencing ongoing change. Combining variation and complexity reflects the distinctiveness of these
constructs and the need for both to characterize fully organizational environments (Miller et al., 2006).

Third, we assume that learning and analogical reasoning occur together over time. This assumption contrasts with that of some prior computational models (e.g., Carley and Lin, 1997; Gavetti et al., 2005) that separate into distinct phases (1) organizational learning through repeated experiences and (2) application of learning to subsequent experiences. Such a separation makes learning an off-line activity (Gavetti and Levinthal, 2000), rather than keeping learning and sensemaking together. Assuming an on-line view (i.e., learning through interpretation experiences) makes the accuracy of analogical reasoning depend upon the accumulation of experience in the organization’s memory over time (Cornelissen and Clarke, 2010).

Computational modeling facilitates theory development by permitting comprehensive and longitudinal experimental designs that are not feasible in an empirical setting (Burton, 2003; Davis, Eisenhardt, and Bingham, 2007). We specified an original computational model that allowed us to set up a full factorial experimental design for alternative landscapes. This design generated data to assess various forms of analogical reasoning over time across a broad range of environments. By requiring precise specification of alternative analogical reasoning processes and deriving their performance implications over time, computational modeling contributes to theory building in a way that complements empirical research on managers’ use of analogical reasoning in laboratory and field settings. Furthermore, computational modeling calls for careful operationalization of environmental constructs in a field in which verbal arguments are not always clear about the relevant environmental dimensions and their definitions (Miller et al., 2006).

We see various ways to extend our model in future research. Modelers could, for example, consider alternative assumptions regarding organizational memory and how organizations draw upon remembered past experiences when selecting analogies. The model presented here assumes that organizations remember all past experiences and draw equally upon those experiences irrespective of their age. Relative to what goes on in actual organizations, this may be an excessively rational form of learning and reasoning. We have not taken into account organizational forgetting or the possibility that organizations can exhibit biases in choosing among possible analogies. Rather than weighting all experiences equally, organizations may favor early cases (based on imprinting following founding) or recent cases (due to their salience). Analyses of such alternatives informed by research on organizational memory and decision making would extend further our explanation of the accuracy of analogical reasoning.

Organizations’ possible responses to dynamic and complex environments extend beyond what we have considered and modeled in this study. Organizations adapt to complex, unpredictable, and unstable environments by specializing in ways that limit their exposure to a subset of the environment’s demands. They both choose and enact environments that simplify the set of environmental factors to which they must attend. When possible, they seek to control critical environmental contingencies (Pfeffer and Salancik, 1978). Organizations foster intraorganizational specialization by creating differentiated divisions and roles that focus members’ attention on distinct aspects of their complex environment (Lawrence and Lorsch, 1967). Such specialization helps to rationalize the allocation of individuals’ limited attention (Ocasio, 1997; Simon, 1971, 1976) and information-processing capacity (Galbraith, 1977; March and Simon, 1958). Environmental interpretation is a social and political process, as well as a cognitive process (Dutton, 1997).

Following through with this richer conceptualization of organizations requires a shift from a single-agent model of analogical reasoning to a multiple-agent model in which analogical reasoning is decentralized. Whereas our study follows the single-agent approach of Gavetti et al. (2005) to model analogical reasoning, Carley (1992) and Carley and Lin (1997) set up the multiple-agent problem. In a multiple-agent model, individuals with distinct, limited focuses of attention use analogical reasoning to draw inferences about the overall environmental state from limited information, then they share their inferences with others to generate an organization-level conclusion. How agents allocate their attention across environmental elements and other agents holds important implications for the accuracy of organizations’ collective process of issue diagnosis. Furthermore, in a hierarchical organization, agents also actively exert upward influences through issue selling (e.g., Dutton and Ashford, 1993; Dutton et al., 1997, 2002) or downward influence through leader sensegiving.
(e.g., Gioia and Chittipeddi, 1991; Gioia and Thomas, 1996). Building on the current study, future research can address the multiple-agent problem using different specifications of analogical reasoning and our extended portrayal of the environment that includes variation and complexity. Such models should advance research on organizations as interpretation systems (Daft and Weick, 1984; Maitlis, 2005; Weick, 1995) by making explicit the social networks and decision processes involved, and their performance implications.

We see opportunities for further advances in understanding strategic issue diagnosis as analogical reasoning in organizations. Advances can come as computational modelers and empiricists work more closely together. Empirical researchers should seek access to organizations to identify how managers acquire and use analogies in actual practice. Such research can study individuals but also should seek to understand the social processes and environmental contingencies related to analogical reasoning in teams and organizations. Remaining to be explored are the critical connections between analogical reasoning, decision making, organizational action, and performance. Empirical research can ground computational modelers’ specifications. As illustrated in the present study, computational modeling can contribute to developing a process theory that explains the dynamics of learning and applying analogical reasoning in organizations over time.

ACKNOWLEDGMENTS

Our thanks go to Richard Bettis, Marta Geletkanycz, June-Young Kim, and Daniel Levinthal for helpful comments on earlier drafts.

REFERENCES


