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2010, Vol. 35, No. 4, 604–626.

# A MULTIDIMENSIONAL CONCEPTUALIZATION OF ENVIRONMENTAL VELOCITY

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**Environmental velocity has emerged as an important concept but remains theoretically underdeveloped, particularly with respect to its multidimensionality. In response, we develop a framework that examines the variations in velocity across multiple dimensions of the environment (homology) and the causal linkages between those velocities (coupling). We then propose four velocity regimes based on different patterns of homology and coupling and argue that the conditions of each regime have important implications for organizations.**

Environmental velocity[1] has become an important concept for characterizing the conditions of organizational environments. Bourgeois and Eisenhardt (1988) introduced this concept to the management literature in their study of strategic decision making in the microcomputer industry. They described this industry as a "high-velocity environment"—one characterized by "rapid and discontinuous change in demand, competitors, technology and/or regulation, such that information is often inaccurate, unavailable, or obsolete" (Bourgeois & Eisenhardt, 1988: 816). From the perspective that the environment is a source of information that managers use to maintain or modify their organizations (Aldrich, 1979, Scott, 1981), velocity has important implications for organizations. Studies have found, for example, that success in high-velocity industries is related to fast, formal strategic decision-making processes (Eisenhardt, 1989; Judge & Miller, 1991); high levels of team and process integration (Smith et al., 1994); rapid organizational adaptation and fast product innovation (Eisenhardt & Tabrizi, 1995); and the use of heuristic reasoning processes (Oliver & Roos, 2005). More generally, research on velocity has shown that it affects how managers interpret their environments (Nadkarni & Barr, 2008; Nadkarni & Narayanan, 2007a), further highlighting the effects of environmental dynamism on key organizational members (Dess & Beard, 1984).

A common feature of the treatment of environmental velocity in the literature has been the use of singular categorical descriptors to characterize industries—most typically as "low," "moderate," or "high" velocity (e.g., Bourgeois & Eisenhardt, 1988; Eisenhardt, 1989; Eisenhardt & Tabrizi, 1995; Judge & Miller, 1991; Nadkarni & Narayanan, 2007a,b). Although Bourgeois and Eisenhardt (1988) defined environmental velocity in terms of change (rate and direction) in multiple dimensions (demand, competitors, technology, and regulation), research on velocity has tended to overlook its multidimensionality, instead assuming that a single velocity can be determined by aggregating the paces of change across all the dimensions of an organization's environment. This assumption overlooks the fact that environmental velocity is a vector quantity jointly defined by two attributes (the rate and the direction of change) and that organizational environments are composed of multiple dimensions, each of which may be associated with a distinct rate and direction of change.

We are grateful to associate editor Mason Carpenter and three anonymous reviewers for their helpful and constructive comments. The development of this paper also benefited from comments from Joel Baum, Danny Breznitz, Sebastian Fixson, Mark Freel, Rick Iverson, Danny Miller, Dave Thomas, Andrew von Nordenflycht, Mark Wexler, Carsten Zimmermann, and seminar participants at Simon Fraser University and the 2008 INFORMS Organization Science Paper Development Workshop. We are also grateful to the Canadian Social Sciences and Humanities Research Council for funding that supported this research.

[1] To increase the paper's readability, we use the terms *environmental velocity* and *velocity* interchangeably.

In this paper we aim to advance understanding of environmental velocity by developing a theoretical framework that articulates its multidimensionality and by exploring the implications of this framework for understanding the organization-environment relationship. We argue that while there may be cases in which organizational environments can be accurately specified by a single descriptor (e.g., high velocity), a multidimensional conceptualization opens up a number of opportunities. First, it provides a basis for more fine-grained descriptions of the patterns of change that occur in organizational environments. An understanding of a firm's environmental velocity as composed of multiple, distinct rates and directions of change across multiple dimensions allows us to move beyond characterizations of industries as high or low velocity and the assumption that all dimensions change at similar rates and in similar directions (Bourgeois & Eisenhardt, 1988; Eisenhardt, 1989; Judge & Miller, 1991; Smith et al., 1994). Perhaps most important in this regard, a multidimensional conceptualization allows for an examination of the relationships among the dimensions of velocity, which we argue can have a profound impact on organizations.

Second, a multidimensional conceptualization of velocity offers a foundation for more consistent operationalizations of the construct, which would help improve the reliability and validity of research that employs it. Our review of the environmental velocity literature indicates a reliance on singular descriptors of velocity, which has led to inconsistent operationalizations of the construct. Thus, while it has sometimes been claimed that people can recognize a high-velocity environment when they see one (Judge & Miller, 1991), the different ways that the velocity of the *same* industry has been categorized by different researchers would seem to indicate otherwise. Such inconsistencies may be due to focusing on one or two particularly salient velocity dimensions or to combining data for multiple velocity dimensions without considering the aggregation errors that can occur if the dimensions do not perfectly covary.

Finally, by understanding that the environments of organizations have multiple, distinct velocities, it is possible to identify different patterns of environmental velocity whose conditions affect organizations in ways that go beyond the insights that have emerged from studies characterizing velocity as simply high or low. Specifically, we explain how the multidimensionality of velocity can affect the degree to which an organization's activities will be entrained and adjusted over time. We then highlight how these implications apply to two processes that have been central to prior research on velocity: strategic decision making and new product development.

Our exclusive focus on environmental velocity differs from prior research that has sought to characterize organizational environments in terms of a set of core properties—most commonly some variation of complexity, dynamism, and munificence (Aldrich, 1979; Dess & Beard, 1984; Scott, 1981). In pursuing this aim, we recognize the trade-offs among generalizability, accuracy, and simplicity (Blalock, 1982) inherent in examining one aspect of the environment in depth while bracketing other important environmental dimensions. Research focused on the general organizational environment has strived for "high levels of simplicity and generalizability, with a corresponding sacrifice of accuracy" (Dess & Rasheed, 1991: 703). This approach has been characterized as "collapsing" the heterogeneity of the environment into a more parsimonious set of properties (Keats & Hitt, 1988). In contrast, we focus on a single specific aspect of environmental dynamism—velocity—and explore in detail its dimensions, how the velocities of these dimensions vary and interact, and the consequences of those differences and interactions. Our approach follows other studies that have examined specific environmental constructs, such as uncertainty (Milliken, 1987) and munificence (Castrogiovanni, 1991). An important consequence of focusing on a single aspect of the environment is that any normative or predictive claims we make must be made with ceteris paribus restrictions placed on them. This, of course, complicates the application of such claims in research or practice but also allows a deeper examination of specific phenomena (Pietroski & Rey, 1995).

We present our arguments as follows. First, we review the concept of environmental velocity as it has been developed in management research, focusing on the opportunities that this work presents for developing a multidimensional conceptualization. Second, we present our framework by defining several fundamental dimensions of the organizational environment and defining the key aspects of velocity—the rate and direction of change—for each dimension. Third, we examine the potential relationships among velocity dimensions (such as products and technology) by introducing three concepts: (1) "velocity homology," which is the degree to which velocity dimensions have similar rates and directions of change at a point in time; (2) "velocity coupling," which is the degree to which the velocities of different dimensions affect one another over time; and (3) "velocity regimes," which represent patterns of velocity homology and velocity coupling. Fourth, we explore the implications of our framework for organization-environment relationships and for strategic decision making and new product development.

## ENVIRONMENTAL VELOCITY IN MANAGEMENT RESEARCH

In physics, velocity refers to the rate of displacement or movement of a body in a particular direction. Thus, it is a vector quantity jointly defined by two distinct attributes: the rate of change and the direction of change. The definition of high-velocity environments articulated by Bourgeois and Eisenhardt (1988) captured these two attributes, referring to rapid and discontinuous change in multiple dimensions of the environment, such as demand, competitors, technology, and regulation. The notion of high velocity provided an evocative way to characterize the fast-moving, high-technology industry that was the context of their studies, and it complemented a number of similar but conceptually distinct environmental constructs, including dynamism (Baum & Wally, 2003; Dess & Beard, 1984; Lawrence & Lorsch, 1967), turbulence (Emery & Trist, 1965; Terreberry, 1968), and hyperturbulence (McCann & Selsky, 1984). More recently, environmental velocity has been used in conjunction with or as a synonym for other related environmental constructs, such as "clockspeed" (i.e., the speed of change in an industry; Fine, 1998; Nadkarni & Narayanan, 2007a,b) and hypercompetition (Bogner & Barr, 2000; D'Aveni, 1994).

Table 1 lists some of the major studies in strategic management and organization theory in which the concept of environmental velocity plays a central role. For each study the table delineates the phenomenon of interest, the industry context, the level (high, moderate, or low) of velocity considered, and the measures employed (if any). Looking across these studies, we identify three themes that characterize much of the existing research in the area and provide the motivation for the theoretical framework that we develop.

First, existing studies have predominantly focused on high-velocity environments, with limited attention to other potential patterns of velocity. Consequently, we know relatively little, for instance, about the velocity-related challenges faced by firms operating in low-velocity environments, where the slow pace of change may be associated with protracted development lead times, long decision horizons, and relatively infrequent feedback. Also, and more generally, the focus on high-velocity environments may be a significant factor in the treatment of velocity in terms of singular categorical descriptors; the term *high-velocity environment* itself seems to imply that multiple dimensions of the environment (e.g., products, markets, technology) combine nonproblematically to produce a single, cumulative, high level of velocity. While this may be true in some cases, it is not clear that it applies broadly across firms and industries.

Second, high-velocity environments are often presented as synonymous with high-technology industries, perhaps because Bourgeois and Eisenhardt's initial study focused on the early microcomputer industry. Industries have been categorized as high velocity simply because they are technology intensive (Smith et al., 1994) or are built around an evolving scientific base (Eisenhardt & Tabrizi, 1995), regardless of whether *other* environmental dimensions exhibit low or modest rates of change or relatively continuous directions. Judge and Miller (1991), for instance, identified the biotechnology industry as high velocity, despite its relatively long product development lead times and product life cycles (both ten to twenty years).

Finally, existing research tends to lack an explicit measurement model or justification for the categorization of specific organizational contexts or industries. Instead, researchers declare that they are studying high-velocity environments and reiterate Bourgeois and Eisenhardt's (1988) original definition without significant explanation or direct evidence (the studies by Judge and Miller [1991] and Nadkarni and Barr

**TABLE 1**
**Environmental Velocity in Management Research**

| Example Studies | Management/Organization Phenomena | Level of Velocity (Industry Context) | Conceptualization of Velocity | Velocity Measures Used |
|---|---|---|---|---|
| Bourgeois & Eisenhardt (1988) | Pace and style of strategic decision making | High (microcomputer industry) | Uniform change in the rate and direction of demand, competition, technology, and regulation | Illustrative statistics and examples |
| Eisenhardt & Bourgeois (1988) | Politics of strategic decision making | High (microcomputer industry) | As per Bourgeois & Eisenhardt (1988) | Illustrative statistics and examples |
| Eisenhardt (1989) | Rapid strategic decision making | High (microcomputer industry) | As per Bourgeois & Eisenhardt (1988) | Illustrative statistics and examples |
| Judge & Miller (1991) | Antecedents and outcomes of decision speed | High (biotechnology), medium (hospital), and low (textile) | Aggregation of industry growth and perceived pace of technological, regulatory, and competitive change | Industry data and survey data from firms |
| Smith et al. (1994) | The effect of team demography and team process | High (informational, electrical, biomedical, environmental) | Rate of change in product, demand, and competition | Illustrative statistics |
| Eisenhardt & Tabrizi (1995) | Rapid organizational adaptation and fast product innovation | High (computer) | As per Bourgeois & Eisenhardt (1988) | Illustrative statistics and examples |
| Brown & Eisenhardt (1997) | Continuous organization change | High (computer) | As per Bourgeois & Eisenhardt (1988) | Illustrative statistics and examples |
| Stepanovich & Uhrig (1999) | Strategic decision-making practices | High (health care) | Rate of change in demand, competition, technology, and regulations | An illustrative example |
| Bogner & Barr (2000) | Cognitive and sensemaking abilities | High (IT) | A form of hypercompetition | None |
| Oliver & Roos (2005) | Team-based decision making | High (toys and IT tools) | Rate of change and the time available to make decisions | None |
| Brauer & Schmidt (2006) | Temporal development of a firm's strategy implementation | High and low (industries not specified) | A form of dynamism and volatility | Industry market returns data |
| Davis & Shirato (2007) | A firm's propensity to launch World Trade Organization actions | High (computer), medium (auto), and low (steel) | The number of product lines and the rate of product turnover | R&D expenditure/ total revenue |
| Nadkarni & Narayanan (2007a) | How cognitive construction by firms drives industry velocity | High (computers, toys) and low (aircraft, steel) | Rate of change (clockspeed) for product, process, and organizational dimensions | Industry clockspeeds |
| Nadkarni & Narayanan (2007b) | Relationship between strategic schemas and strategic flexibility | High (computers, toys) and low (aircraft, steel) | The rate of industry change (clockspeed) | Industry clockspeeds |
| Nadkarni & Barr (2008) | How velocity affects managerial cognition, which in turn affects the relationship between industry context and strategic action | High (semiconductor, cosmetic) and low (aircraft, petrochemical) | As per Bourgeois & Eisenhardt (1988) | A review of existing literature and matching using industry attributes |
| Davis, Eisenhardt, & Bingham (2009) | The performance and structural implications of velocity | High and low (conceptual simulation model) | The speed or rate at which new opportunities emerge in the environment | A Poisson distribution of new opportunities |

[2008] representing notable exceptions). This variation in the extent to which velocity has been operationalized has resulted in some counterintuitive and inconsistent categorizations of industry velocity. Studies of health care, for instance, have labeled those environments as both high velocity (Stepanovich & Uhrig, 1999) and moderate velocity (Judge & Miller, 1991). Furthermore, our understanding of velocity and its effects across industry contexts has largely focused on only one attribute of velocity—the rate of change—since prior research has tended to use measures associated with the clockspeed of an industry (e.g., Nadkarni & Narayanan, 2007a; Oliver & Roos, 2005; Smith et al., 1994) or has equated velocity with the speed at which new opportunities emerge (Davis, Eisenhardt, & Bingham, 2009).

Looking across these themes, we see that research on environmental velocity has provided interesting and influential insights, particularly into the nature of organizational processes operating in fast-changing, high-technology industries. We suggest, however, that the construct itself requires a more fine-grained examination, since existing research tends to assume that it can be adequately represented by an aggregation of the rates of change across different environmental dimensions or by a focus on change in only one dimension of the environment to the exclusion of others. In contrast, we believe that a multidimensional conceptualization of velocity would provide a stronger foundation for clarifying and operationalizing its characteristics and for better understanding its diversity and impacts on organizations.

## ENVIRONMENTAL VELOCITY AS A MULTIDIMENSIONAL CONCEPT

The core understanding of environmental velocity that we propose is that organizational environments are composed of multiple dimensions, each of which is associated with its own rate and direction of change. This simple notion, we argue, has profound effects on how we understand and research velocity and on the organizational reactions to velocity we expect and prescribe. In this section we begin to construct our theoretical framework, first by defining the basic concepts of rate of change and direction of change as they apply to the organizational environment in general, and then by describing how these basic concepts apply to some primary dimensions of the organizational environment.

### The Rate and Direction of Change

Environmental velocity is a vector quantity defined by the rate and direction of change exhibited by one or more dimensions of the organizational environment over a specified period. The rate of change is the amount of change in a dimension of the environment over a specified period of time, synonymous with such concepts as pace, speed, clock rate, or frequency of change. The direction of change, while often mentioned in studies citing Bourgeois and Eisenhardt's (1988) definition, has attracted relatively little attention beyond that. One possible reason for this is the relative difficulty of describing the direction of environmental change. Whereas the velocity of a physical object can be described simply as moving eastward at 50 km/hr, similarly straightforward descriptions of the direction of change of an organizational environment are not so obvious. This is particularly the case when we consider the direction of change across different industry dimensions, such as products, technology, and regulation, the direction of each of which could be described in numerous distinct ways.

In order to describe the direction of change in a way that allows comparison across industry dimensions, we follow Bourgeois and Eisenhardt (1988), who suggest that the direction of change varies in terms of its degree of continuity-discontinuity. They argue that continuous change represents an extension of past development (e.g., continuously faster computer technology), whereas discontinuous change represents a shift in direction (the move from film to digital photography, or the shifts that occur in fashion industries). Discontinuities, therefore, can be represented by inflection points in the trajectories that describe change in a dimension over time (e.g., technology price-performance curves or demand curves for specific products).

To more fully articulate a continuum of continuous-discontinuous change, we draw on Wholey and Brittain's (1989) three-part conceptualization of environmental variation, arguing that the direction of change is discontinuous to the extent that shifts in the trajectory of change are more recurrent, with greater amplitude and with greater unpredictability over a period of time. This approach helps us distinguish between relatively regular, predictable (e.g., seasonal) variations in environmental velocity and irregular types of change that are more difficult to predict and, consequently, more challenging in terms of organizational responses (Milliken, 1987). We suggest that such variations in the continuity-discontinuity of a velocity dimension's trajectory allow for the use of structural equation modeling (Kline, 2004) and difference scores (Edwards, 1994) to produce growth models that measure transitions in change over time (Bliese, Chan, & Ployhart, 2007; Singer & Willett, 2003).

Furthermore, to operationalize the rate and direction of change of each velocity dimension, we suggest that the measures will require scale uniformity to allow the relative differences between the dimensions to be compared and correlated (Downey, Hellriegel, & Slocum, 1975; Milliken, 1987). To achieve this, we suggest that the rate and direction of change will be some form of scalar measure (e.g., change/time). Therefore, even though what is changing will vary for each of the dimensions, their relative rates and directions of change can be determined and compared by using the same period of time for the different dimensions (i.e., new products *per year* and changes in product direction *per year*).

## Dimensions of Environmental Velocity

The second way in which we break down the concept of environmental velocity is in terms of the dimensions of the organizational environment that are changing. While the dimensions of the environment that are salient for any particular study will vary according to the specifics of the research project, there are several that have been widely used in prior research on organizational environments. We use the four dimensions suggested by Bourgeois and Eisenhardt (1988)—demand, competitors, technology, and regulation—and to this list we add a fifth dimension—products. We do this because prior research on environmental velocity has tended to merge the technology and product dimensions, and we argue that they often have dissimilar rates and directions of change, which makes separating them important for our purposes. Archibugi and Pianta (1996) point to the importance of this distinction when they argue that product changes need not be technical but can also include changes in the aesthetic, branding, or pricing features of a product. Our discussion of environmental dimensions is not meant to be exhaustive; rather, it is meant to highlight the heterogeneity of environmental dimensions that motivates our development of a multidimensional conceptualization of velocity.

**Technological velocity.** Technological velocity is the rate and direction of change in the production processes and component technologies that underlie a specific industrial context, such as float glass technology in glass manufacturing, genetic engineering in the biotechnology industry, and rolling mills in metals processing. See Table 2 for a summary of the definitions for each of the velocity dimensions on which we focus.

The rate of technological change is the amount of change in those technologies over a specific time period, including the creation of new technologies, the refinement of existing technologies, and the recombination of component technologies. The rate of technological change varies dramatically across industries. Drawing on patents as an indicator of the rate of technological change, one can argue, for instance, that the electronics industry exhibits a more rapid rate of technological change than does the oil industry. In 2006, rankings for the number of patents granted in the United States showed that the top five positions were held by electronics companies, whereas the oil industry firms Shell and Exxon occupied positions 126 and 139, respectively (IFI, 2008). Although some technological change is either not patentable or not patented for strategic reasons, the rate of patenting can nevertheless provide a useful indication of the technological rate of change since it is a relatively direct and publicly available indicator of the proprietary technological

**TABLE 2**
**Environmental Velocity: Dimension Definitions and Example Measures**

| Definition/Example Measures | Technological | Product | Demand | Regulatory | Competitive |
|---|---|---|---|---|---|
| Velocity dimension definition | The rate and direction of change in the production processes and component technologies that underlie a specific industrial context | The rate and direction of change in new product introductions and product enhancements | The rate and direction of change in the willingness and ability of the market to pay for goods and services | The rate and direction of change in laws and regulations that affect an industry | The rate and direction of change in the structure of competition within an industry |
| Example measures of the rate of change in the dimension | The number of new patents and copyrights granted in a given period | The number of new products introduced in a given period (i.e., product clockspeed) | The change in industry sales in a given period | The number of new and amended laws and/or regulations introduced in a given period | The change in industry population size and density (i.e., number and size of firms) in a given period |
| Example measures of the direction of change in the dimension | The changes in the direction of the relationship between the price and technical performance of technology in a given period | The change in the nature of product features as perceived by the market in a given period | The change in the trend (e.g., growth versus decline) and nature (e.g., personal versus impersonal) of demand in a given period | The change in the nature and scope of the control provided by new laws and regulations in a given period | The change in industry growth trends (e.g., growth versus decline) in a given period |

outputs of an industry (Archibugi & Pianta, 1996; Griliches, 1990).

The direction of technological change refers to the trajectories along which technological advancements take place (Abernathy & Clark, 1985; Dosi, 1982; Tushman & Anderson, 1986). Distinguishing between continuous and discontinuous directions of technological change is most easily understood in terms of performance/price curves. Continuous technological change involves a series of improvements that enhance the performance of the technology (e.g., advances in photographic film technology focused on improving contrast quality, light sensitivity, and speed). Such changes move a technology smoothly along a performance/price curve, usually at a decreasing rate, thus creating a concave downward performance/price curve. In contrast, discontinuous technological change involves "architectural" (Henderson & Clark, 1990) or "radical" innovations that "dramatically advance an industry's price vs. performance frontier" (Anderson & Tushman, 1990: 604). These innovations temporarily alter the shape of the performance/price curve such that it becomes concave upward until the immediate benefits of the innovation are exhausted.

**Product velocity.** This dimension is the rate and direction of new product introductions and product enhancements. We define products as any combination of ideas, services, and goods offered to the market (Kotler, 1984). The rate of change in products can vary tremendously across industries and across market segments within an industry. In terms of the former, Fine (1998) and Nadkarni and Narayanan (2007a,b) show that the movie, toy, and athletic footwear industries have relatively high rates of product change (new products launched every three to six months), whereas the aircraft, petrochemical, and paper industries have low rates of product change (new products launched every ten to twenty years).

The direction of change for products can be described as continuous when new product introductions represent improvements on previously important product attributes, and discontinuous when the new products introduce fundamentally new attributes for consumer choice. Adner and Levinthal's (2001) study of the personal computer industry between 1974 and 1998 provides an example of relatively continuous product change, with only two major inflection points with respect to price (in 1981 and 1988) and no major inflection points with respect to performance. In contrast, fashion products, such as clothing, music, and travel, all change frequently through the creation of new products and the transformation and repackaging of existing ones. Such variations in product change across industries are associated with differences in the complexity, risk, and impact of the product change.

While velocity research has often lumped together product and technological velocities, our definitions of their rates and directions of change illustrate the importance of distinguishing between them. Over the past several decades, for example, the underlying materials and production processes in the automobile industry have changed more rapidly and discontinuously than have the end products themselves. In contrast, textile production technologies have changed more slowly and continuously than the fashion products they are used to create.

**Demand velocity.** Demand velocity is the rate and direction of change of the willingness and ability of the market to pay for goods or services, including changes in the number and types of transactions and market segments. The rate of change in demand varies tremendously across industries, with some experiencing rapid growth or decline and others facing steady growth for years. Such variance is influenced by a wide range of factors, including changes in taste, new rival products, substitutes, complements, changes in relative prices, business cycle fluctuations, and switching costs. Empirical research has used summary industry sales figures as an indicator of the rate of change in demand (e.g., Bourgeois & Eisenhardt, 1988).

The direction of change for demand is continuous when there is a steady progression of increasing or decreasing sales to a consistent set of consumers. Conversely, change in the direction of demand is discontinuous when there are frequent, significant, unpredictable shifts in the growth, decline, or steady state of demand, or a radical change in the segments that compose the overall market. For example, demand velocity in the U.S. restaurant industry from 1970 to 1995 was relatively continuous, with sales gains made nearly every year during that period (Harrington, 2001). In contrast, the demand for commodities, such as copper and gold, can be highly volatile owing to a wide range of macroeconomic influences, exemplifying the case of a discontinuous demand velocity. Similarly, the Nintendo Corporation created discontinuous change in the demographics of demand since its Wii games console appealed to nontraditional market segments, such as families, women, and older people.

**Regulatory velocity.** We define regulatory velocity as the rate and direction of change in the regulations and/or laws that directly affect the firm or industry under consideration. This includes government action (e.g., changes in laws, regulations, and polices) and industry self-regulation (e.g., voluntary standards and codes). It is a dimension that can open or close markets, present organizations with compliance costs, and necessitate strategic shifts in practices. The rate of regulatory change is a function of the creation of new laws or regulations, or changes to existing laws or regulations, in a time period. It can vary greatly across industrial, national, and historical contexts, and it often depends on other factors, such as technology (e.g., regulations for stem cell research), business scandals (e.g., the Enron scandal), health and safety issues (e.g., mad cow disease), and demographic shifts (e.g., an increase in the retired population).

The direction of change in regulation is continuous to the degree that new regulations resemble the old in scope, form, or substantive areas of concern, and it is discontinuous to the degree that they address new issues, focus on different kinds of behaviors, or employ new principles. For example, the U.S. airline industry from 1938 to 1975 experienced changes in regulations that were relatively continuous, in that the Civil Aeronautics Board (CAB) restricted prices, flight frequency, and flight capacity (Vietor, 1990). Then, in 1975, the direction of regulatory change changed as the CAB began experimenting with limited deregulation, and in 1978 the industry was completely deregulated and the CAB abolished.

**Competitive velocity.** Competitive velocity is the rate and direction of change in the structural determinants of industry profitability (Barney, 1986; Porter, 1980). Its rate of change is, in part, a function of the entrance and exit of industry rivals (Hannan & Carroll, 1992), as well as the speed with which firms respond to competitors' strategic moves or other shifts in the environment (Bowman & Gatignon, 1995). Such measures describe the overall pace at which the competitive conditions that define an industry are changing—a factor that has been shown to influence firm performance across a wide range of industries, including the automotive (Hannan, Carroll, Dundon, & Torres, 1995), computer (Henderson, 1999), and insurance (Ranger-Moore, 1997) industries.

The direction of change in competitive structure involves continuity-discontinuity with respect to the value chain in an industry (Jacobides & Winter, 2005), the nature of rivals (Porter, 1980; Schumpeter, 1950), or changes in market contestability (Hatten & Hatten, 1987). Change in competitive structure is continuous to the degree that these characteristics remain constant and stable over time. Conversely, the change in direction in competitive structure is discontinuous to the degree that industry value chains are in flux (Jacobides, 2005) and existing bases of competition are challenged by firms introducing new products, pioneering new markets or sources of supply, or implementing new means of production (Schumpeter, 1950).

## RELATIONSHIPS AMONG VELOCITY DIMENSIONS: VELOCITY HOMOLOGY, VELOCITY COUPLING, AND VELOCITY REGIMES

An important benefit of a multidimensional conceptualization of environmental velocity is the potential it provides to examine the differences and relationships among the velocities of different dimensions. To that end, we introduce three concepts: (1) velocity homology—the relative similarity among the rates and directions of change of different dimensions; (2) velocity coupling—the degree to which the velocities of different dimensions are causally connected; and (3) velocity regimes—the different patterns of environmental velocity that emerge from variations in velocity homology and velocity coupling.

### Velocity Homology

The term *homology* was coined by the paleontologist Richard Owen (1843) to explain the morphological similarities among organisms. It has been used by management scholars to describe the degree to which two phenomena are similar

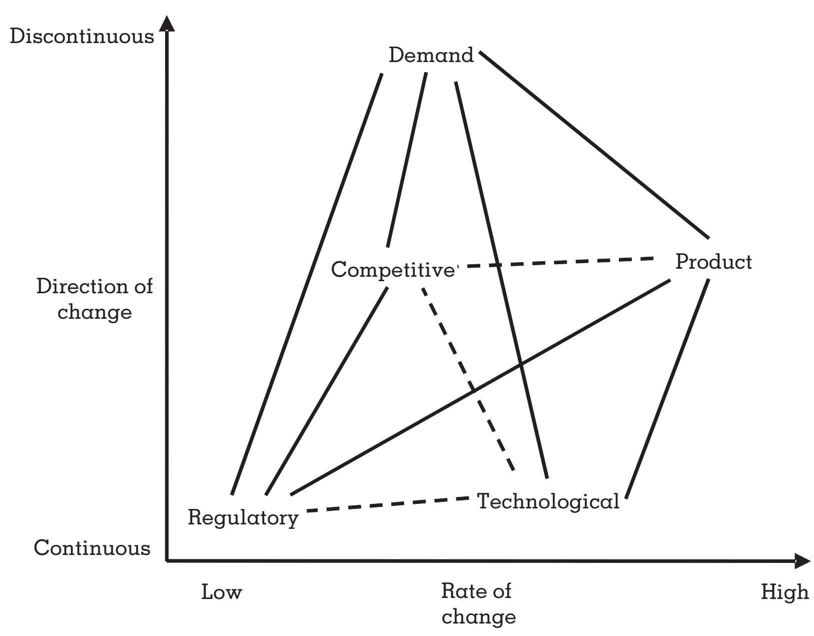
(Chen, Bliese, & Mathieu, 2005; Glick, 1985; Hanlon, 2004) and is consistent with the homogeneity-heterogeneity aspect of environmental complexity (Aldrich, 1979; Dess & Beard, 1984). In our framework, velocity homology is the degree to which the rates and directions of change of different dimensions are similar to each other over a period of time. Thus, "high homology" describes a condition in which the velocities of different dimensions in a given environment exhibit relatively similar rates and directions of change, whereas "low homology" describes relatively dissimilar rates and directions of change.

To help explain velocity homology, we present a map of the velocities of different dimensions, with the rate of change and the direction of change on each axis (see Figure 1). With this image of velocity (based on the fashion apparel industry example we present in the following sections), homology is represented by the closeness of the points. Thus, low homology (as is the case in Figure 1) is represented by relatively spread out points, and high homology would be represented by relatively tightly clustered points. To operationalize this concept of homology, we suggest using distance measures and methods, such as cluster analysis (Ketchen & Shook, 1996), factor analysis (Segars & Grover, 1993), and multidimensional scaling (Cox & Cox, 2001), all of which are considered suitable for assessing interdimension similarity in construct composition (Harrison & Klein, 2007; Law, Wong, & Mobley, 1998).

An assumption of a highly homologous set of velocities typified much of the early work on high-velocity environments, in which industries such as microcomputers were characterized by "rapid and discontinuous change" across multiple dimensions (Bourgeois & Eisenhardt, 1988: 816). An assumption of high homology carried over to subsequent studies, with limited consideration of the degree to which homology might vary across firms and industries. Most studies seem to have aggregated the velocities of different dimensions, regardless of the variance among these dimensions, thereby assuming similarity (i.e., high homology in our terms) among the velocities of different environmental dimensions. Consequently, we know relatively little about the conditions and effects of low-homology environments, where the velocity properties of a firm's multiple environmental dimensions are highly dissimilar.

To illustrate and clarify the concept of homology, we present the example of the apparel in-

**FIGURE 1**
**Fashion Apparel Industry Example**




Key: The solid lines indicate tight coupling and the dashed lines loose coupling.

dustry and focus on the industry segment involved in the design and supply of seasonal fashion apparel. This includes brands sold primarily through own-brand stores (e.g., Gap, Zara, and American Apparel) and brands sold through a mixture of own-brand stores and independent stores (e.g., Armani, Benetton, and Levi's). We chose this industry because academic studies and business reports suggest that from 1985 through 2005 the velocities of different dimensions in this industry spanned a diverse range of rates and directions of change (Djelic & Ainamo, 1999; *The Economist*, 2005; Jacobides & Billinger, 2006; Taplin & Winterton, 1995).

Beginning with the product dimension, this segment of fashion retailing is associated with a relatively high rate of change and a moderately discontinuous direction. This is illustrated by the operations of Zara, one of Europe's leading fashion brands. Zara launches some 11,000 new products annually, most of which are completely new products as perceived by the customer and typically take only five weeks from design to retail store (*The Economist*, 2005). Even casual fashion houses, such as Sweden's Hennes & Mauritz (H&M) and the American chain Gap, roll out between 2,000 and 4,000 products each year. Moreover, the rate of change in products has increased, with the emergence of "fast fashion" as a dominant strategy for mass market designers/retailers (Doeringer & Crean, 2006). We argue that the direction of product change is moderately discontinuous, because although these firms launch many new products, they represent a mix of new items and extensions of existing products. This view is consistent with studies of the rate and direction of change in women's formal wear (Lowe & Lowe, 1990).

The technologies that underpin the fashion industry have been changing rapidly over the past twenty years (cf. Richardson, 1996) but at a relatively slower rate than changes in fashion products. Although manufacturing technology in the apparel industry has remained stable for nearly a century (Audet & Safadi, 2004), there have been advances in the manufacture of textiles, as well as in communication and information technologies, that have facilitated the move to quick response (Forza & Vinelli, 1997) and fast fashion (Doeringer & Crean, 2006) strategies in fashion design and retailing. The direction of these changes has been relatively continuous over the past twenty or so years—toward greater automation and efficiency in textile manufacturing, more rapid response to customer demands, and more efficient communication and coordination in fashion design and retailing (Doeringer & Crean, 2006; *The Economist*, 2005).

In contrast to product and technological velocities, regulatory change in this industry has, for the past two decades, occurred relatively slowly and continuously. The regulation that affects this industry most significantly is directed at the manufacture of clothing and the protection of consumer rights, both of which have changed slowly over that period. With respect to the manufacture of garments, the Multi Fibre Arrangement (MFA) was introduced in 1974 as a short-term measure to govern world trade in textiles and garments, imposing quotas on the amount developing countries could export to developed countries (Spinanger, 1999). This regulation underwent only minor modifications until it expired in 2005 (Audet & Safadi, 2004). National-level regulation tends to focus on labor and employment standards. In response to the shift of clothing manufacturing from developed to emerging economies, the governments of Western nations have been reluctant to further regulate (and potentially stifle) clothing manufacturing, much of which occurs as home-based work (Ng, 2007).

Change in demand for fashion apparel has, for the past twenty years, occurred moderately slowly, with a high degree of discontinuity. Researchers argue that the fashion industry is characterized by low to moderate levels of positive sales growth each year (Nueno & Quelch, 1998), with occasional major demographic and lifestyle shifts and changes in customer preferences (Danneels, 2003; Siggelkow, 2001). Although the direction of change in demand for fashion has oscillated between relative stability and discontinuity over the last 150 years (Djelic & Ainamo, 1999), the past 20-year period has been associated with customers becoming more demanding, arbitrary, and heterogeneous (Djelic & Ainamo, 1999; *The Economist*, 2005).

The competitive velocity of the fashion industry has long fascinated observers. In recent years it has altered as increased cost pressures have led firms to engage in rapid-fire attempts to source the lowest-cost materials and to move labor-intensive aspects of the value chain to countries with lower costs. The industry has also experienced constant shifts in the major centers of production (Dosi, Freeman, & Fabiani, 1994). By way of example, U.S. employment levels in this sector in 2002 were a third of what they were in the early 1980s (Doeringer & Crean, 2006). The intersection of cost pressures and the increasing rate of change in consumer preference and demand has led to significant shifts in firms' strategies, particularly speeding up the supply chain (Richardson, 1996) and altering organizational structures and boundaries (Djelic & Ainamo 1999; Jacobides & Billinger, 2006; Siggelkow, 2001). Such conditions characterize change that is both moderately rapid and continuous in nature.

The fashion industry points to two important issues with respect to understanding homology among environmental velocity dimensions. First, it highlights that the organizational environment is composed of a number of distinct dimensions, each of which is defined by its own rate and direction of change—or velocity. Second, we see that there are significant differences in the rates and directions of change (low homology) across the five dimensions that we have considered. This makes the idea of describing the industry as having a single velocity, whether based on an "average" across dimensions or on the velocity of whichever dimension might be considered most important, misleading both to researchers attempting to understand the industry and to managers needing to make strategic decisions.

### Velocity Coupling

A second important aspect of the relationship between velocity dimensions is the degree to which and the ways in which they interact over time. We examine these interactions through the concept of coupling. This is the degree to which elements of a system, including product components (Baldwin & Clark, 1997; Sanchez & Mahoney, 1996), individuals (DiTomaso, 2001), organizational subunits (Meyer & Rowan, 1977; Weick, 1976, 1982), and organizations (Afuah, 2001; Brusoni, Prencipe, & Pavitt, 2001), are causally linked to each other (Orton & Weick, 1990; Weick, 1976). In our framework velocity coupling is the degree to which the velocities of different dimensions in an organizational environment are causally connected—the degree to which a change in the velocity of one dimension causes a change in the velocity of another.

Weick (1976) defined loosely coupled systems as those in which the properties of constitutive elements are relatively independent, whereas the properties of elements in tightly coupled systems are strongly mutually dependent. Weick (1982) further argued that loose coupling involves causal effects that are relatively periodic, occasional, and negligible, whereas tight coupling involves relatively continuous, constant, and significant causal effects. Thus, we describe the velocities of different dimensions of a firm's environment as loosely coupled when changes in the velocity of one dimension (e.g., technology velocity) have relatively little immediate, direct impact on the velocities of other dimensions (e.g., product velocity), and we describe them as tightly coupled when the relationship between the velocities of different dimensions involve significant immediate, direct causal effects. To determine the degree of coupling between velocity dimensions, we suggest using structural equation modeling (Kline, 2004), which is recommended for operationalizing covariance between construct variables (Law et al., 1998).

Although coupling and homology both describe the relationships among velocity dimensions, they are separate, distinguishable aspects of those relationships. The velocities of different dimensions can have high levels of interdependence (coupling), regardless of whether they exhibit similar rates and directions of change (homology). Homology is a first-order property of velocity, describing the similarity among velocities over a period of time. In contrast, coupling is a second-order property, describing the degree to which changes in the velocity of a dimension affect the velocity of another dimension over the same specified period of time. The distinction between homology and coupling is observable in the biotechnology industry, which experiences high rates and discontinuous directions of technological change but relatively slow, continuous regulatory and product velocities (Zollo, Reuer, & Singh, 2002). While these dimensions have very different velocities (low homology), there is evidence to suggest that they are relatively tightly coupled. This is illustrated by the impacts of the 2001 U.S. regulation on stem cell research, which restricted research to twenty-one stem cell lines (a family of constantly dividing cells) and, in turn, limited the rate and direction of U.S. stem cell research activity (i.e., technological velocity) relative to other countries. In 2009 this regulation was overturned, permitting research on up to 1,000 new stem cell lines, allowing "U.S. human embryonic stem-cell research to thrive at last" (Hayden, 2009: 130).

We again draw on the fashion apparel industry to illustrate the idea of coupling among velocity dimensions. Beginning with products, changes in the velocity of this dimension have been attributed to increases in the adoption of new communications, design, and manufacturing technologies, suggesting a relatively tight coupling between product and technological velocity dimensions. Perhaps most significant, changes in the direction of technology have improved the ability of fashion apparel firms to gather market feedback and, thus, to develop new product offerings at a faster rate (Jacobides & Billinger, 2006; Kraut, Steinfield, Chan, Butler, & Hoag, 1999; Richardson, 1996). Similarly, the velocity of demand has been tightly coupled to product velocity over the past two decades: industry observers argue that the perceived new arbitrariness of customer demand has forced fashion organizations to frequently engage in large-scale market explorations (Cammet, 2006; Jacobides & Billinger, 2006). In contrast, there is little evidence of a strong relationship between product velocity and competitive velocity. Product velocity appears to be primarily driven by changes in market demand and the product innovation programs of existing organizations exploiting those changes, as opposed to a flow of new entrants (Cammet, 2006).

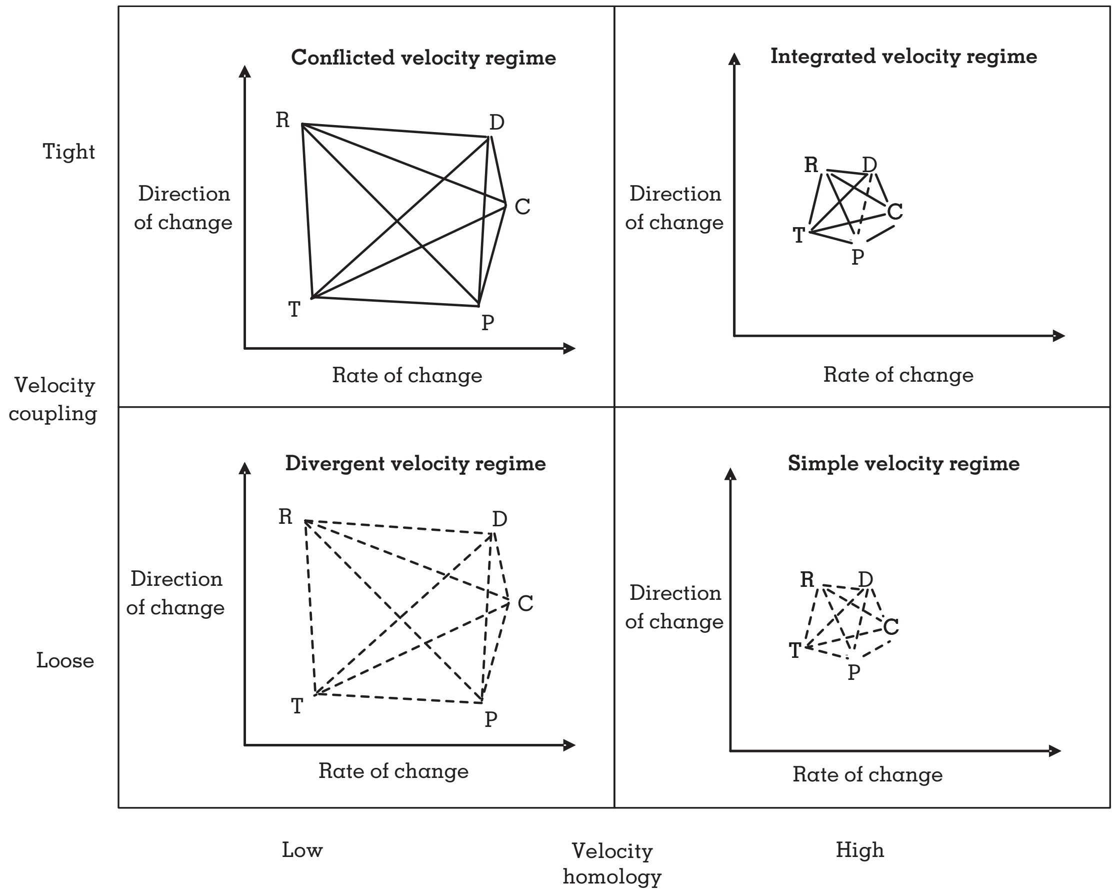
In terms of the velocity of regulation in this industry, there is evidence that it is tightly coupled to the velocities of competition, demand, and products, with changes in international trade regulations (Spinanger, 1999) and domestic labor standards (Ng, 2007) leading to increasing imports from developing economies, both creating and satisfying the demand for cheaper fashion products. Similarly, the velocities of competition and demand appear to be tightly coupled, with firms in this industry attempting to predict and adapt to what Siggelkow (2001) calls "fit-destroying changes" that can significantly alter their competitive positions. There is also tight coupling between the velocity of technology and the velocity of demand. For example, in their study of the U.S. fashion apparel industry in the 1980s, Abernathy, Dunlop, Hammond, and Weil (1999) explain how changes in demand led to "lean retailing," which, in turn, required firms to drastically alter their information and production technologies to enable new working practices. In contrast, there is little evidence to suggest that changes in the velocity of technology for the fashion industry will affect or are affected by changes in the velocities of competition or regulation.

In this illustrative example (see Figure 1), we argue that seven of ten possible dyadic connections among velocity dimensions are relatively tightly coupled (designated by solid lines) such that changes in the velocity of one dimension will affect the velocity of another. We have argued that the three other connections are loosely coupled, as indicated by the dotted lines. Thus, although not all of the velocity dimensions of the fashion industry exhibit strong causal connections to each other, we suggest that this industry can be described as a relatively tightly coupled environment. Any assignment of such a category is somewhat arbitrary without a formal measurement of coupling, so for now we follow work on modular (loosely coupled) and integrated (tightly coupled) organizational forms that suggests that when at least 50 percent of the system elements are tightly coupled to each other, the system can be considered tightly coupled (Schilling & Steensma, 2001).

## Velocity Regimes

We propose the concept of a velocity regime as a way to describe the pattern of velocity homology and velocity coupling within an organizational environment. Although both these characteristics of velocity vary continuously, we focus on combinations of high or low homology and tight or loose coupling to more clearly illustrate how they vary and the effects of these variations. The result is a typology (see Figure 2) with four distinct velocity regimes that represent ideal types, rather than an exhaustive taxonomy of velocity conditions. To illustrate and visualize the degrees of homology and coupling that characterize each regime, we have embedded a variation of Figure 1 into each cell of Figure 2. Like Figure 1, these embedded figures present illustrative sets of velocities, the rela-

**FIGURE 2**
**Environmental Velocity Regimes**




Key: T = technological velocity, R = regulatory velocity, D = demand velocity, C = competitive velocity, and P = product velocity. The solid lines indicate tight coupling and the dashed lines loose coupling.

tive positions of which indicate their rates and directions of change for different dimensions.

The first velocity regime in our typology occurs when environmental dimensions are highly homologous and loosely coupled to each other. We call this the "simple velocity regime" because it has similar rates and directions of change across all dimensions. Thus, regardless of whether these dimensions are all changing slowly and continuously or rapidly and discontinuously, we argue that it is the relative uniformity of the change in strategic information that makes the environment relatively analyzable (Daft & Weick, 1984). Furthermore, because the velocities of the multiple dimensions are loosely coupled, they are free to vary independently so that changes in the velocity of one dimension are unlikely to affect the velocities of other dimensions.

An example of a simple velocity regime is the U.K. tableware industry from the mid 1950s to the late 1970s. During this period, this industry was exposed to changes in regulations, demand, product, technology, and competition that were all relatively slow and continuous in nature (Imrie, 1989; Rowley, 1992). At the same time, this industry had relatively loose coupling among velocity dimensions. For example, when change did occur in the velocity of the product dimension during the 1970s, due to an increase in the rate at which product variety and customization changed, the only other velocity dimension to be affected was technology, whereby changes in the flexibility of production machinery altered at a similar rate (Carroll, Cooke, Hassard, & Marchington, 2002; Day, Burnett, Forrester, & Hassard, 2000). This combination of high homology and loosely coupled dimension velocities created an environment that analysts and scholars described as being uniformly stable, consistent, and regular in nature (Imrie, 1989).

The second environmental velocity regime in our typology occurs when the velocities of different dimensions are highly homologous and tightly coupled. This creates what we call an "integrated velocity regime." This regime is integrated in two senses: the velocity attributes of each dimension (i.e., rates and directions of change) are very similar, and the velocities of the dimensions are highly interdependent on each other for a period of time. The tight coupling differentiates this regime from the simple regime, presenting managers with the complex task of monitoring and responding to causally connected changes in a velocity. This is what Aldrich (1979: 77) calls the "everything's related syndrome," where a change in the velocity of one dimension reverberates throughout the velocities of other dimensions. Together, these conditions create an environment that is best understood as having, at least for a time, a single overarching velocity. Moreover, if all the dimensions are changing rapidly and discontinuously, this situation will be exemplified by the "high-velocity" industries that have dominated research on environmental velocity.

Consequently, an example of an integrated velocity regime is the global computer industry from approximately 1982 to 1995. During this period, which is known as the third era of the industry, the microprocessor and personal computer were invented (Malerba, Nelson, Orsenigo, & Winter, 1999), and most of the environmental dimensions were changing rapidly and in a discontinuous direction. Firms were frequently entering and exiting the industry, as well as forming and breaking alliances with each other (Bresnahan & Malerba, 1999; Langlois, 1990). Technological substitution in hardware and software was a frequent occurrence, resulting in regular product innovations (Bourgeois & Eisenhardt, 1988; Brown & Eisenhardt, 1997). While Eisenhardt and colleagues clearly argued that such conditions equated to multiple velocities undergoing similar "rapid and discontinuous change," we suggest there was also a significant level of interdependence among the velocities of these dimensions. For example, studies have explained how the velocity of competition affected the rate at which new technologies and products were developed, which, in turn, affected the rate at which new market segments were created (Bresnahan & Malerba, 1999; Langlois, 1990). This coupling among dimensions also brought about the wholesale change in the velocities that occurred around 1995 as the industry began its fourth era—the age of the network (Malerba et al., 1999).

The third velocity regime, which we call the "divergent velocity regime," has a set of dissimilar and loosely coupled velocities, so firms face diverse and possibly contradictory environmental conditions. This potentially makes the environment more difficult to analyze, because some dimensions change slowly and continuously—generating modest amounts of information—while other dimensions change rapidly and discontinuously—producing large quantities of information that quickly becomes inaccurate or obsolete. This set of dissimilar velocities presents diverse temporal demands on the information processing and sensemaking abilities of managers. The relatively loose coupling among these dissimilar velocities, however, somewhat lessens the challenge of monitoring and responding to environmental conditions, because changes in the velocities of different dimensions are relatively independent, limiting the potential for rapid, widespread change in the flows of strategic information.

An example industry of this regime would be the U.S. flat glass manufacturing industry from 1955 to 1975. During this period, the environmental dimensions for this industry had very different and unconnected velocities. The technology—float glass production methods—that was developed to produce flat glass was adopted relatively quickly during this period compared to other process technology innovations (Teece, 2000). It was also a discontinuous change that revolutionized how flat glass was made, with productivity gains approaching 300 percent as the need for grinding the glass was eliminated (Anderson & Tushman, 1990). This led to significant price/performance improvements so that float glass products replaced existing flat glass products in a relatively rapid and continuous fashion, rising from 30 million square feet per year of glass in 1960 to 1,730 million square feet per year of glass in 1973 (Bethke, 1973). Because this change in demand was generated by existing producers for existing automotive and construction customers, the pace and direction of competitive change remained relatively slow and continuous in nature. The only significant regulatory event for this industry was that the U.S. Tariff Commission and Treasury more frequently cited foreign producers for dumping flat glass on the U.S. market at prices lower than those in their own markets (Bethke, 1973). This link between the rate of government action and the increase in production capacity from the new technology appears to be the only major interdependency between the different velocities of the dimensions for this industry during this period.

The final velocity regime we propose is composed of dimensions whose velocities are relatively dissimilar and tightly coupled. We call this the "conflicted velocity regime," since organizations operating with such a regime will experience diverse and potentially contradictory velocities that are also highly interdependent. As in the case of the divergent regime, the low level of homology among velocity dimensions in the conflicted velocity regime leads to conditions that are, as a whole, inconsistent and relatively unanalyzable. However, the tight coupling among these heterogeneous velocities increases the difficulty associated with tracking, understanding, and responding to changes in the conditions of this regime, because the causal variation makes the environment relatively unstable over time. Although neglected in the velocity literature, we believe that this kind of velocity regime may be quite common. Our example of the fashion industry since the mid 1980s illustrates the dynamics associated with the conflicted velocity regime. We argued that the rates and direction of change in this industry span a diverse range. We further argued that this industry's environmental dimensions are relatively tightly coupled. Such conditions define an environment with a set of dimensions that are not only changing dissimilarly but are also highly interdependent.

## ORGANIZATIONAL AND STRATEGIC IMPLICATIONS

The importance of environmental velocity is due to the impacts it has on key organizational and strategic processes. Thus, in this section we examine how a multidimensional conceptualization of environmental velocity would affect our understanding of these impacts. We explore the implications of velocity homology and velocity coupling in terms of their general impacts on organizing and on the processes of strategic decision making and new product development.

### Implications of Velocity Homology

We argue that the notion of velocity homology significantly affects how we need to think about the relationship between an organization and the temporal characteristics of its environment. The dominant notion that has emerged over the past two decades in the velocity literature, and more broadly in research on time and organizations, has been the importance of organizations operating "in time" with their environments and in synchrony across their subunits and activities. This is the view of research on organizational "entrainment" (Ancona & Chong, 1996; McGrath, Kelly, & Machatka, 1984; Pérez-Nordtvedt, Payne, Short, & Kedia, 2008), which argues that "functional groups not only must be [internally] entrained with each other for the organization to work, there must also be external entrainment, at both the subsystem and system levels, to ensure adaptation to the environment" (Ancona & Chong, 1996: 19). The impact of external entrainment on performance is echoed in research on high-velocity industries, which argues that organizational performance in such environments is associated with rapid decision making (Eisenhardt, 1989) and fast new product development (Eisenhardt & Tabrizi, 1995; Schoonhoven, Eisenhardt, & Lyman, 1990). In their discussion of "timepacing," Eisenhardt and Brown (1998) provide examples of the importance of external entrainment, including the household goods manufacturer that timed its product launch cycles to key retailers' shelf planning cycles and, thus, was able to win more shelf space.

Our multidimensional conceptualization of velocity suggests that temporal alignment between an organization's operations and its environment is critically important but that variations in homology create significant limits to the synchronization of activities within firms (internal entrainment). If the velocities associated with different environmental dimensions are similar, as in our high-homology regimes (simple and integrated), then it is appropriate to entrain the pace and direction of all organizational activities to this uniform environmental velocity. This will be a relatively simple situation to manage. However, if the dimension velocities differ significantly, as in our low-homology regimes (conflicted and divergent), then the situation will be more difficult to manage. This is because the task of entraining organizational activities with dissimilar dimension velocities will lead to heterogeneous sets of paces and directions of activities within firms. Such differences create challenges for firms, including potential incoherence among subunits and activities, fragmented internal information flows, and the breakdown of issue capture and analysis across intraorganizational boundaries. Furthermore, managers who understand that changes in velocity homology conditions can be both endogenous and exogenous in nature will have not only the option of reactively entraining their organizations to their environment but also the option of trying to alter the speed and direction of change in specific environmental dimensions to suit their organization. Firms might, for example, lobby to influence the rate at and direction in which legislators develop laws and regulations (i.e., shape what is regulated/deregulated in an industry and the pace at which regulatory reform occurs), or undertake marketing activities to influence changes in demand.

A central theme of research on environmental velocity has been its effect on strategic decision making—those "infrequent decisions made by the top leaders of an organization that critically affect organizational health and survival" (Eisenhardt & Zbaracki, 1992: 17). Following our general argument regarding the impact of velocity homology, we argue that variations in homology reward strategic decision-making activities that are individually entrained with the velocity of their relevant environmental dimension. Thus, more effective strategic decision making in high-homology regimes (simple and integrated) will involve a set of activities with similar paces and directions. Such internal consistency will provide benefits in terms of greater efficiency and lowered task conflict (Gherardi & Strati, 1988). In contrast, strategic decision making in low-homology regimes (conflicted and divergent) will be more effective when the pace and direction of strategic decision-making activities are dissimilar, because they are tailored to their relevant but distinct dimension velocities.

A second key strategic process that illustrates the implications of velocity homology is new product development—the set of activities that transforms ideas, needs, and opportunities into new marketable products (Cooper, 1990). Previous research has shown the value of rapid new product development in high-velocity industries (Eisenhardt & Tabrizi, 1995) but leaves open the question of how this might change if we incorporated a multidimensional conception of environmental velocity. Although new product development processes may seem to be primarily linked to the product dimension of the organizational environment, they cut across a wide range of organizational functions, including research, development, design, manufacturing, legal, marketing, and sales. Consequently, each of these different new product development activities collects, interprets, and applies relevant information from different dimensions of the organization's environment. Thus, the contribution of each function to new product development is likely to be more effective when that function is entrained with the environmental dimension for which it is more directly responsible. The ability of marketing, for instance, to effectively contribute to the development of new products depends on its being entrained with the velocity of demand. This means that different new product development functions may need to operate at different speeds and in different directions in order to ensure process-environment entrainment. Again, this can potentially create significant organizational challenges in terms of coordination and integration across the stages of the new product development process.

### Implications of Velocity Coupling

We argue that the notion of velocity coupling significantly affects how we think about the stability of velocity conditions and impacts how organizations coordinate changes in the pace and direction of their internal activities. Previous research has tended to treat environmental velocity not only as a unidimensional concept but as a relatively stable feature of organizational environments. In contrast, we argue that variations in velocity coupling will lead to important differences in the stability of the velocity conditions of environments. For firms operating in tightly coupled environments, a change in the velocity of any one dimension (e.g., technology) will have a broad impact on the velocity conditions of the regime, through its effects on the velocities of the other dimensions to which it is coupled (e.g., products, demand, competition). This suggests that regimes with tight velocity coupling (integrated and conflicted) will have relatively unstable velocity conditions. This argument follows research on coupling in both organizational environments and organizations that has shown that tight coupling among elements of a system increases the instability of that system (Aldrich, 1979; Dess & Beard, 1984; Terreberry, 1968). An important facet of this instability is the rhythms through which it occurs. The impacts of changes in the velocity of one dimension on the velocities of other dimensions are unlikely to occur instantaneously but, rather, over time, as the social and technological mechanisms that connect the dimensions are sequentially triggered and exert their impact.

We argue that the environmental instability and sequencing of changes associated with tight coupling provide an advantage to certain firms over others. In particular, tightly coupled regimes (integrated and conflicted) will reward firms that employ mechanisms that sensitize them to velocity changes and allow them to rapidly and effectively shift the paces of their internal operations. Typical mechanisms could include strategic scanning systems that managers use to monitor and respond to changes in their environments (Aguilar, 1967; Daft & Weick, 1984) and "interactive control systems" (Simons, 1994) to promote external reflection and internal communication and action. These mechanisms are analogous to other traditional organizational integration (Lawrence & Lorsch, 1967) and boundary-spanning (Galbraith, 1973) mechanisms, but with a focus on coordinating change in the pace and direction of organizational activities to match temporal instability in the environment.

Moreover, sequenced changes in velocities provide an advantage to firms that recognize these causal connections and are consequently able to anticipate sequences of velocity changes. For example, increases in human genetic engineering technology in the late 1990s led geneticists and government agencies to call for more regulation to control the development and application of this technology. Those firms that anticipated the connection between technological velocity and regulatory velocity proactively planned and shifted the velocities of their research advocacy units to better link with the activities of patient advocacy groups. These changes helped the industry to garner the public support necessary to overturn regulations (Campbell, 2009).

Achieving this sequenced change in the pace and direction of organizational activities would involve the use of time-based mechanisms. These include scheduling and project deadlines, information technologies that align organizational activities, and resource allocation rules that specify the time to be spent on decision tasks (McGrath, 1991).

As with velocity homology, changes in velocity coupling may stem from external conditions, or it may be that managers are able to increase or decrease the causal connections among velocity dimensions in order to create strategic advantage for their firms. One strategy to affect velocity coupling is to alter the degree of modularity in products (Baldwin & Clark, 1997; Sanchez & Mahoney, 1996), technologies (Yayavaram & Ahuja, 2008), organizations (Meyer & Rowan, 1977; Weick, 1976, 1982), or interorganizational networks and supply chains (Afuah, 2001; Brusoni et al., 2001). Such changes can affect the overall coupling among environmental dimensions, particularly if they establish new competitive standards. Furthermore, such changes can be hard to attain and therefore difficult to imitate, thus creating a competitive advantage. Shimano, for example, became the dominant supplier of bicycle drive train components (shifters, chains, derailleurs, etc.) by developing high-performing, tightly coupled component systems that changed the nature of the new product development and production functions for their customers, as well as the nature of end-user demand. Shimano's strategy altered the pace and direction of multiple velocity dimensions for the bicycle industry and has been credited with helping Shimano gain almost 90 percent of the drive train market for mountain bicycles (Fixson & Park, 2008).

The effects of velocity coupling on how organizations coordinate their activities can also be illustrated by considering strategic decision making and new product development processes. For strategic decision making, coordination is an issue of social cognition within top management teams (Forbes & Milliken, 1999), which we argue is significantly affected by the "temporal orientation" of a team. A temporal orientation is a cognitive concept that describes how individuals and teams conceive of time—as "monochronic," a unified phenomenon that motivates attention to individual events in serial fashion, or as "polychronic," a heterogeneous phenomenon that necessitates simultaneous attention to multiple events (Ancona, Okhuysen, & Perlow, 2001; Bluedorn & Denhardt, 1988; Hall, 1959). We argue that strategic decision making in tightly coupled regimes would benefit from a polychronic orientation on the part of top management teams so that team members share a view of time as malleable and unstructured. This would help them to simultaneously coordinate strategic decision-making velocities and to pay continuous partial attention to a broad set of issues (Stone, 2007). In contrast, in loosely coupled regimes the benefits of multitasking, monitoring, and simultaneously adjusting to the velocities of different dimensions are lower. Such situations, we argue, reward a monochronic temporal orientation that leads senior management teams to engage in strategic decision making in a relatively independent manner, focusing on one issue at a time.

For new product development processes, the impact of velocity coupling rests on the ability of firms to recognize and predict the conditions under which a new product will be launched. The instability associated with tightly coupled regimes (integrated and conflicted) influences the effectiveness of different process control frameworks that help ensure that the right type of product innovation is launched at the right time (McCarthy, Tsinopoulos, Allen, & Rose-Anderssen, 2006). "Linear" new product development frameworks conceive of the process as a series of relatively discrete, sequential stages, with team members at each stage making decisions (go forward, kill the project, put the project on hold, etc.) about the progress and outputs of the process (McCarthy et al., 2006). These frameworks include the waterfall model (Royce, 1970) and the stage-gate method (Cooper, 1990), which assume and impose structures or "scaffolds" that restrict the amount of iterative feedback. We argue that such linear frameworks are best suited to new product development processes that operate in loosely coupled velocity regimes in which the activities within the new product development process are relatively discrete, with changes in their paces and directions having limited impacts on each other.

In contrast, "recursive" new product development frameworks conceive of the process as a system of interconnected, overlapping activities that generate iterative and nonlinear behaviors over time (McCarthy et al., 2006). These include Kline and Rosenberg's (1986) chain-linked model and Eisenhardt and Tabrizi's (1995) experiential model, both of which, we argue, are suited to tightly coupled velocity regimes because they facilitate improvisation and flexibility. These capabilities help managers of the process to focus on and accommodate both the greater instability and more turbulent information flows associated with these velocity regimes.

## CONCLUSION

In the paper's introduction we suggested that a multidimensional conceptualization of environmental velocity presented three important opportunities to advance research in the area. First, we argued that it would allow a more fine-grained examination of environmental velocity so as to better understand the diversity of this construct across different organizational contexts. In our discussions of several industries, including fashion, tableware, computers, and flat glass, we have shown that characterizing these environments simply as high or low velocity overlooks the fact that environmental velocity is composed of multiple dimensions, each with a distinct velocity.

Second, we argued that a multidimensional approach to velocity could lead to more reliable and, thus, more valid empirical research by offering a basis for more consistent operationalizations of velocity. Consequently, with our framework we have urged researchers to consider both the rate *and* direction of change for multiple pertinent dimensions of the organizational environment. This reveals homology and coupling relationships among the velocity dimensions, which describe the different velocity regimes we propose. These concepts provide a basis to better specify environmental velocity and use appropriate operationalizations to measure its diversity. This, in turn, helps avoid inappropriate aggregations and inconsistent uses of the velocity construct.

Third, we suggested that a multidimensional conceptualization of environmental velocity and the conditions of our proposed velocity regimes could provide insights into organizational and strategic processes beyond what has been possible with a unidimensional concept. To this end, we have explored some general implications for organizations that follow from velocity homology and velocity coupling, along with more specific implications for two key processes: strategic decision making and new product development. We have explained how variations in velocity homology influence the degree to which a firm's activities or subunits will be synchronized (internal entrainment) as they seek to operate in time with their respective dimensions of the environment (external entrainment). We have also described how variations in velocity coupling affect the need for organizations to recognize the stability of their velocity regime and anticipate sequences of changes in the velocities of their environmental dimensions.

In summary, the challenges of high-velocity environments have captured the attention of managers and scholars. However, the multidimensional nature of the velocity construct and its effects have not been explored. Our work builds on contingency approaches to organization-environment relations and work on time and organizations. To these traditions it offers a more nuanced understanding of one aspect of change in organizational environments, and it urges researchers to examine both the complexity and diversity of the construct and its effects on organizations.

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