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THE COEVOLUTION OF TECHNOLOGIES AND CATEGORIES DURING INDUSTRY EMERGENCE

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Scholars have long studied technology evolution. More recently, organizational theorists have begun to explore the role of categories and their associated labels in industry dynamics. Yet little is known about how technological designs and categories coevolve. We build on these two bodies of literature to develop an integrative model of how industries emerge and evolve. We propose that the evolution of both technological designs and categories follows a similar pattern, characterized by an early period of divergence followed by a period of convergence, and we identify the mechanisms that account for this coevolutionary process. We add to the literature on technological evolution by explicating the mechanisms through which designs evolve and identifying how different stakeholders' categorical understandings shape design competition. Our model also augments the categorization literature by detailing categorical evolution as a contested process of category creation and selection, which, in turn, is influenced by the designs that the categories are trying to group. Our model creates a much needed bridge between two bodies of literature that, while addressing similar topics, have evolved largely separately.

Scholars across disciplines have long studied the technological dynamics of industry evolution (Abernathy & Utterback, 1978; Gort & Klepper, 1982; Hannan & Freeman, 1989). An industry—commonly defined as comprising competing technological designs (and corresponding producers) seen as direct substitutes (Schumpeter, 1934)—emerges from a technological or market discontinuity that triggers the creation of multiple new technological designs (Anderson & Tushman, 1990; Schumpeter, 1934). The extant literature conceptualizes technological designs as consisting of two elements: (1) a set of components and (2) an architecture that defines "the way in which the components . . . are linked together" (Henderson & Clark, 1990: 10). Producers' introduction of multiple technological designs following a discontinuity marks a period of divergence in the industry. This period is followed by a mature stage where selection among competing designs often culminates in convergence among producers on one dominant design—"a single architecture that establishes dominance [within an industry]" (Anderson & Tushman, 1990: 13; see also Abernathy & Utterback, 1978).

While the dynamics of technological designs are relatively well understood, scholars have paid relatively less attention to the sociocognitive aspects of this process. In one of the few early integrative attempts, Clark (1985: 244) proposed that technological "design hierarchies" had to be analyzed together with the "formation of consumer concepts" to obtain a full picture of how industries evolve. More recently, scholars have begun to look at industry emergence through sociocognitive lenses, proposing several constructs to capture the sociocognitive dimension of industry emergence. These include field frames (Lounsbury, Ventresca, & Hirsch, 2003), technological frames (Gurses & Ozcan, in press; Kaplan & Tripsas, 2008; Orlikowski & Gash, 1994), and schemas (Bingham & Kahl, 2013). However, the *coevolution* of technological designs and sociocognitive constructs has received less attention (Kaplan & Tripsas, 2008). The specific mechanisms

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through which this coevolution occurs remain unidentified, and an understanding of how sociocognitive constructs "emerge and fall out of use" and of "what they come to mean" (Kennedy & Fiss, 2013: 1) is still missing. Despite the inherent dual-causality challenges that studying coevolution necessarily entails (Archer, 1995; Justesen, 2008; Wooldridge, 2013), a more comprehensive understanding of the mutual influence between the technological designs and the sociocognitive dimensions of industry emergence is important lest researchers face the risk of either technological or social overdeterminism (Barley, 1986).

In examining the coevolution of technological designs and sociocognitive constructs, we focus on the process that unfolds following a technological or market discontinuity that creates opportunities for "the introduction of a new good . . . [and] the opening of a new market" (Schumpeter, 1934: 65-66). The period following a discontinuity is characterized by high uncertainty that leads to a wave of firm entry and design experimentation (Abernathy & Utterback, 1978; Anderson & Tushman, 1990) and an associated process of sensemaking about the industry and its designs (Rosa, Porac, Runser-Spanjol, & Saxon, 1999; see also Weick, 1979).

In studying the sensemaking process following a technological or market discontinuity, we focus on categories and their associated labels as the sociocognitive constructs of interest. We refer to categories as socially constructed partitions that group together objects perceived to be similar (Bowker & Star, 2000). Categories generally

> have two basic properties: (1) constituent members, whose inclusion is defined by rules or boundaries pertaining to a common type of product or service, and (2) a concept, label, or identity that reflects the commonalities that link together the members of the category (Navis & Glynn, 2010: 440).

Our theory builds on recent research emphasizing categorization as one of the fundamental social processes that shape the dynamics of industries (Durand & Vergne, in press; Hsu, 2006; Hsu & Grodal, 2015; Jones, Maoret, Massa, & Svejenova, 2012; Kennedy & Fiss, 2013; Navis & Glynn, 2010; Pontikes, 2012a; Suarez, Grodal, & Gotsopoulos, 2015). Several studies have explored the link between categories and firm performance (e.g., Zuckerman, 1999, 2000), while others have studied how categories evolve over time (Kennedy, 2008; Khaire & Wadhwani, 2010; Rosa et al., 1999). Importantly, categories and their associated labels are not merely abstract sociocognitive constructs but are also basic elements of written and oral communication (Murphy, 2002). Tracking their formation and usage enables us to capture the enormous variation and subtle distinctions in meaning that characterize industry emergence (Bingham & Kahl, 2013). Indeed, by studying categorical dynamics, we can explain how a multitude of different stakeholders debate, contest, and make sense of an emerging industry (Durand & Paolella, 2013; Ozcan & Santos, in press), as well as influence the emergence and evolution of technological designs (Rosa et al., 1999).

This article extends the existing literature to provide a more complete picture of how an industry emerges and evolves. First, we suggest that the evolution of technological designs and categories follows similar patterns of initial divergence and subsequent convergence. Second, we consider technological designs and categories simultaneously as integral parts of industry emergence, and we identify the mechanisms that shape the coevolution of technological designs and sociocognitive constructs. Third, we extend the well-established literature on technology evolution by offering a model that details how technological design recombination and design competition are influenced by the categories and associated labels that stakeholders use to make sense of the emerging industry. Fourth, we augment the more recent theories of category evolution by explicitly theorizing how multiple stakeholders create new category labels through linguistic recombination and then select some over others. In particular, we suggest that categories and their associated labels do not emerge in isolation but, instead, are continually shaped by changes in the technological designs they are trying to group.

In constructing our arguments, we separately explore and theorize about the dynamics of technological and categorical evolution before bringing them together into an integrative model. In the following sections, therefore, we detail the evolutionary mechanisms associated with each of the following four processes: technological evolution, categorical evolution, technological evolution's influence on categorical evolution, and categorical evolution's influence on technological evolution.

Although the mechanisms we outline below are active throughout the evolution of an industry, for the sake of clarity we associate each one with the particular industry period in which it is most prominent. Figure 1 provides an overview of our integrative model of the coevolution of technologies and categories during industry emergence. Mechanisms already described in the existing literature are italicized, whereas the new mechanisms that we propose are in regular font. Table 1 provides a more complete summary and definitions of the mechanisms behind each process. We further elaborate on each of these mechanisms in the following sections.

MECHANISMS OF TECHNOLOGICAL EVOLUTION

Scholars of technological evolution generally agree that the emergence of new industries is triggered by a technological or market discontinuity (Schumpeter, 1934). Such a discontinuity stimulates the creation of a plethora of new designs and ushers in a period of divergence and technological variation (Utterback & Abernathy, 1975). The period of divergence often culminates in the emergence of a dominant design—that is, the introduction of a technological design that will eventually dominate the industry (Abernathy & Utterback, 1978). The emergence of a dominant design begins a period of design convergence, during which many early producers fail, thus increasing concentration within the industry. Fewer and fewer designs remain in use, while the focus shifts to operations and process R&D (Klepper, 1997, 2002), thereby fundamentally altering the nature of the competition and signaling the onset of the dynamics that will lead to the industry's maturity (Agarwal & Bayus, 2002; Teece, 1986).

In prior literature scholars typically have not detailed the specific mechanisms underlying technological design evolution (see Davis & Marquis, 2005, and Hedström & Swedberg, 1996). A careful reading, however, suggests three key mechanisms: *design recombination* is primarily responsible for the creation of new technological

FIGURE 1
The Coevolution of Technologies and Categories During Industry Emergence

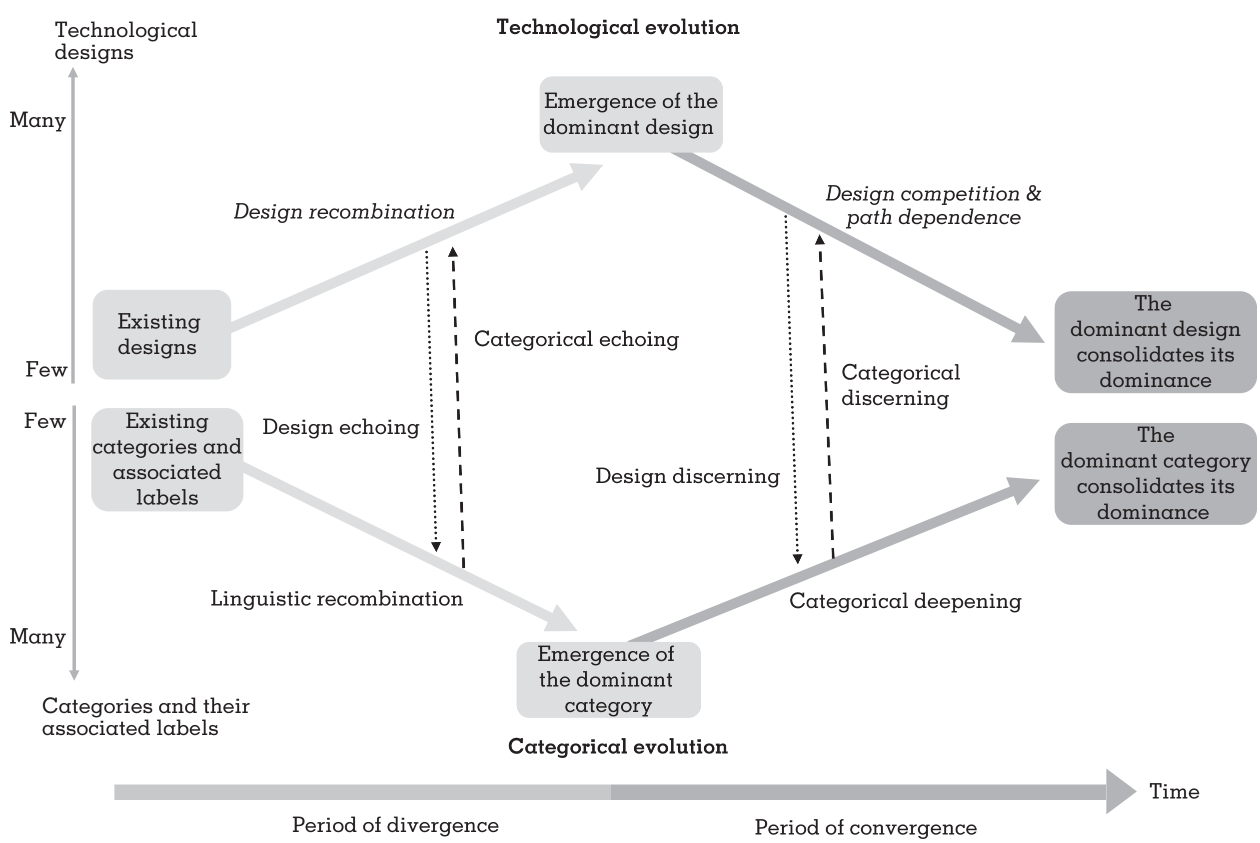

TABLE 1
Mechanisms of Technological and Categorical Coevolution

Process	Mechanism	Definition
Technological evolution	Design recombination	Design recombination is the creative synthesis of two or more previously separate designs that results in the creation of a new design to address an existing or potential need.
	Path dependence	Path dependence is the mechanism through which the cumulative effects of prior technological design choices increasingly determine and constrain subsequent design recombinations.
	Design competition	Design competition is the mechanism by which producers and users make design investment choices about which designs to retain and which to abandon.
Categorical evolution	Linguistic recombination	Linguistic recombination is stakeholders' creative reformulation and/or synthesis of one or more preexisting words or phonemes that results in the creation of a new category label.
	Categorical deepening	Categorical deepening is the mechanism by which the network of semantic connections of a particular category becomes denser.
Technological evolution's influence on categorical evolution	Design echoing	Design echoing is the mechanism through which technological designs influence the choice of words and phonemes that are used in linguistic recombinations.
	Design discerning	Design discerning is the mechanism through which technological designs influence categorical deepening and selection.
Categorical evolution's influence on technological evolution	Categorical echoing	Categorical echoing is the mechanism through which categories and their associated labels potentiate the recombination that leads to new technological designs.
	Categorical discerning	Categorical discerning is the mechanism through which categories constrain technological design recombinations and intensify design selection by dictating which characteristics a design needs to possess and which traits it cannot possess in order to claim membership in a particular category.

designs (divergence), whereas *design competition* and *path dependence* contribute to the reduction in the number of designs (convergence). Acting together, these mechanisms fuel a complex process through which design variations emerge and initially increase in number, after which some are selected and retained while others are abandoned (Anderson & Tushman, 1990).

The Period of Technological Divergence: Design Recombination

While there may be instances where designs are created totally anew, in the vast majority of cases new industries emerge from innovations that come about through the discontinuous recombination of preexisting technological designs (Abernathy & Utterback, 1978; Anderson & Tushman, 1990; Schumpeter, 1934). Design recombination is the creative synthesis of two or more previously separate designs that results in the creation of a new design to address an existing or potential need (Hargadon, 2003). Mechanical typewriters, for instance, were created

> as a synthesis of many existing elements. Clockwork suggested the idea of the escapement (to move the carriage one letter at a time). A telegraph sender provided parts for the first model for keys and arms. A sewing machine pedal was used for returning the carriage. The piano contributed the concept of the free and swinging arms and hammers for imprinting the letters (Utterback & Suarez, 1993: 9).

In a similar fashion, automobiles combined carriages, previously propelled by horses, with the internal combustion engine (Rao, 1994), and the biotechnology field was created by applying chemical knowledge to biological phenomena (Plein, 1991).

Early industries are characterized by significant diversity in attempted design recombinations, since it is unclear which design is best suited to address still-evolving user needs. Producers introduce designs that reflect their understandings of the emerging industry and are often influenced by their prior experience or capabilities (Benner & Tripsas, 2012). Depending on the aspects of the new product they deem salient, producers might use different components or combine similar components in different ways, leading to different design architectures. In the early CT scanner industry, for example, producers variably prioritized aspects such as resolution, speed, and safety, thereby creating multiple and often incompatible technological designs (Yoxen, 1987).

New designs are proposed and introduced not only by producers but also by users (Riggs & von Hippel, 1994). Users often have a better firsthand understanding of their needs and might actively seek a solution in the form of a new design (Autio, Dahlander, & Frederiksen, 2013). In some industries, such as scientific instruments, users account for 77 percent of the new designs (von Hippel, 1988).

The aforementioned first commercial typewriter was, for example, designed by a newspaper publisher (i.e., a "user"), Christopher L. Scholes, who was originally interested in designing a machine that he could use to put numbers on book pages (Linoff, 2000). After a couple of design iterations, Scholes sold his design to the Remington Company. Remington's entry to the nascent market was followed by Caligraph, Hammond, and dozens of other companies that introduced different technological designs and added new functionalities. The Remington #2 machine, for instance, improved on Scholes' machine by adding a "shift" key for uppercase letters, whereas Caligraph chose to have a "full keyboard"—separate keys for lowercase and uppercase letters (Utterback, 1994).

Thus, the varying understandings and different backgrounds of the relevant stakeholders (producers and users) often lead them to introduce a plethora of different technological designs. These designs might differ markedly from one another in form and function, or even in the specific user needs they address, but still coexist temporarily in the emerging industry.

The Period of Technological Convergence: The Abandonment of Designs

The initial period of design divergence is generally followed by a period of design convergence. The transition between the two periods is marked by the emergence of the dominant design—that is, the one design that will eventually achieve dominance in the industry. Although the literature on industry evolution (Utterback, 1994; Anderson & Tushman, 1990) acknowledges that social factors play a role in the process that leads to the abandonment of some designs in favor of others, the eventual dominance of one design within an industry has largely been seen as driven by technological considerations. Abernathy and Utterback, for instance, described the dominant design as a synthesis of previous designs, a "new product synthesized from individual technological innovations introduced independently in prior products" (1978: 8). More recent research on technology evolution has elaborated on this idea but has still largely maintained a focus on the characteristics of technological designs in order to understand how one of them becomes dominant. For instance, Murmann and Frenken see the emergence of a dominant design as a "nested hierarchy of design spaces" (2006: 931) and base their understanding of dominant designs on an analysis of the "technological characteristics" (components) and "product attributes" that are associated with different design architectures (2006: 941). Taken as a whole, this literature points to two main mechanisms that facilitate the process of convergence toward a dominant design: path dependence and design competition.

Path dependence. The evolution of technological designs follows a "hierarchy of design" (Clark, 1985: 24), in which prior design choices constrain the paths that further technological evolution can follow and limit subsequent design recombinations (Sahal, 1985). Path dependence, thus, is the mechanism through which the cumulative effects of prior technological design choices increasingly determine and constrain subsequent design recombinations.

Path dependence works in parallel with design recombination. Prior design choices lock producers into a given design hierarchy that allows subsequent design recombinations to develop only within the trajectory defined by earlier ones. This dynamic increasingly restricts design recombinations (Murmann & Frenken, 2006; Vergne & Durand, 2010) and leads to a situation of "quasi-irreversibility of the investment" (David, 1985: 336). This is clearly exemplified by Clark's description of the evolution of design recombinations for the automobile engine:

> The central functional problem in the evolution of the engine was the choice of fuel and the principle of energy transformation. In the very early days of the industry it was not clear whether steam or electricity or gasoline would dominate . . . By 1902, however, the dominance of the gasoline engine was largely established. Once the core concept became internal combustion based on gasoline, the technical agenda was set for a variety of

> subsidiary problems and choices. Starting and firing the engine, sizes and configuration of cylinders, placement of valves and camshafts, and so forth . . . But such things would have had no place on the agenda established by the electric car (1985: 243).

The impact of path dependence on technology design recombination implies that, over time, convergence occurs at increasingly lower levels of the design hierarchy. During the divergence period, markedly different design architectures might coexist in the market, and initial design recombinations show great variation. However, after a specific trajectory of technological design evolution has been chosen, subsequent design recombinations involve increasingly peripheral components (e.g., the number of cylinders in the internal combustion engine; Murmann & Frenken, 2006). Recombinations that attempt to go "up the design hierarchy" (Clark, 1985) to use previously abandoned design trajectories are no longer available (e.g., automobiles with electric or steam engines). Therefore, radically new designs are seldom introduced once the industry is deep into a particular technological trajectory, since straying away from the chosen evolutionary path becomes increasingly difficult.

Path dependence thus shapes the trajectory of technological evolution: while early decisions concern core choices of appropriate components and architectures, the resolution of such core issues allows producers and other stakeholders to shift their attention to the selection and improvement of more peripheral issues. As the technology gradually matures, the cumulative effect of choices made at each earlier stage of its development shapes which new design recombinations are feasible. In the automobile industry, for example, once the internal combustion engine dominated other technological design choices, subsequent design recombinations for the decades to come conformed to the design architecture and the constraints set by this particular choice. Continuous investment in the internal combustion engine's technological design led to significant improvements in its performance, which were also accompanied by large investments in production capacity and complementary infrastructure (Kirsch, 2000). Indeed, recent attempts to return to an electric automobile design have been hindered by the fact that undoing all those years of technical decisions is both complex and costly.

Design competition. Design competition is the mechanism by which producers and users make design investment choices about which designs to retain and which to abandon (Abernathy & Utterback, 1978). This process of selection among alternative designs has long been viewed as the primary mechanism of convergence through which a dominant design emerges and becomes widely adopted in an industry (Anderson & Tushman, 1990; Argyres, Bigelow, & Nickerson, 2015).

Early in the evolution of an industry, preferences are mutable because producers and consumers are confused by the variety of available technological choices and design elements. A process of iterative interaction among producers and users thus determines which designs they invest in, with the result that a specific set of design elements gains favor and becomes dominant. Contests or other forms of direct comparison of competing design are common in early industries, as producers compete to have their designs adopted and users and industry commentators struggle to evaluate the different offerings. Utterback, for example, detailed such dynamics in the early typewriter industry:

> In 1888, the company's [Remington's] sales agency put up a $1,000 challenge to Caligraph and the handful of other competitors, proposing a public contest with impartial referees to determine which machine was the fastest. Caligraph did not shrink from this challenge, but sent its typing champion with the double-keyboard machine to take on Remington in a highly publicized event in Cincinnati in July 1888. Caligraph was soundly thrashed (1994: 10).

Similarly, contests in the early automobile industry promoted speed and reliability as the most salient characteristics of the new product and the bases of comparison among competing designs, largely overlooking alternative attributes, such as comfort or fuel efficiency (Rao, 1994).

As some design elements are retained and others are abandoned, product design in the industry begins to converge on a common product architecture (Murmann & Frenken, 2006). While this process does not preclude the introduction of still-novel designs, better defined consumer preferences diminish producers' incentives and ability to do so (Clark, 1985). For instance, in describing the retention of central product design characteristics in the mechanical typewriter industry, such as the single QWERTY keyboard, visible type, the tab feature, the shift key, and the carriage cylinder, Utterback noted that

> any firm that wanted to offer a keyboard with an innovative arrangement of letters, or that wanted a circular type wheel (like the old Burt design), did so at its peril; it might capture some small niche . . . but it could abandon any hopes of being a mainstream producer with those sorts of designs (1994: 25).

MECHANISMS OF CATEGORICAL EVOLUTION

Even though the primary focus of the literature on technology evolution has been on the evolution of technological designs per se, some authors have also highlighted the impact of sociocognitive dynamics on technological design evolution. Clark (1985), for example, noted the influence of consumers' conceptual frameworks on the introduction and evolution of technological designs. Kaplan and Tripsas (2008) theorized that technological frames (Gash & Orlikowski, 1991; Orlikowski & Gash, 1994) influence firms' production decisions. Several technology scholars have emphasized the role of institutional stakeholders in the success or failure of different designs (Garud & Kumaraswamy, 1993; Garud & Rappa, 1994; Tushman & Rosenkopf, 1992).

A growing body of literature on categorization has provided new impetus and powerful theoretical tools for the study of the sociocognitive factors influencing industry evolution (Jones et al., 2012; Kennedy, 2008; Navis & Glynn, 2010; Pontikes, 2012a; Rosa et al., 1999). As noted earlier, categories are socially constructed partitions that divide the social space into groupings of objects perceived to be similar (Bowker & Star, 2000). The first step in the evolution of a category can be considered the creation of an associated category label (Pontikes, 2012b), as stakeholders try to make sense of an emerging (or envisioned) industry. Over time, however, categories create boundaries and develop rules that determine which items can be considered as belonging within each particular category and which ones cannot.

While research has shown the importance of categorization processes in the evolution of new industries (Rosa et al., 1999; Weber, Heinze, & DeSoucey, 2008), most previous studies have focused primarily on the one category that became successful (Etzion & Ferraro, 2010; Jones et al., 2012; Kennedy, 2008; Navis & Glynn, 2010; Weber et al., 2008) and not paid much attention to the process of category creation and contestation. This approach, while sound and effective to reconstruct the key events during the evolution of a focal category, tends to neglect other categories that never gained prominence (Kennedy & Fiss, 2013). However, paying attention to these less successful contestants in the battle for categorical dominance is important if we are to construct a full picture of how industries emerge.

Below we detail the mechanisms involved in the evolution of categories and their associated labels. We posit that the process of categorical evolution resembles technological design evolution in that it is also characterized by a period of divergence followed by a period of convergence. We propose that the main mechanism that contributes to the creation of new categories is *linguistic recombination*. Conversely, *categorical deepening* drives categorical convergence and selection.

The Period of Categorical Divergence: Linguistic Recombination

Early in the development of industries, stakeholders invent category labels in an attempt to communicate and exchange information about novel technological designs (Pontikes, 2012b; Vygotsky, 1986). Successful category labels facilitate information exchange among stakeholders by conveying both the novelty of the category and its relationship to preexisting ones. When producers and other industry participants create new category labels, they have to resolve the paradox of making the labels simultaneously (1) distinctive enough to convey the novelty of the underlying product and attract the attention of stakeholders and (2) familiar enough to be easily comprehensible (Bingham & Kahl, 2013). While the literature on categorization has highlighted the importance of category labels for the emergence of meaningful categories (Hannan, Polos, & Carroll, 2007; Navis & Glynn, 2010; Pontikes, 2012a), the mechanisms through which stakeholders produce new category labels (i.e., the first step in the emergence of categories) remain rather unclear (Kennedy & Fiss, 2013; Kennedy, Lo, & Lounsbury, 2010). Research in linguistics suggests that most new category labels emerge through linguistic recombination (Bybee, 1985; Farnetani, Torsello, & Cosi, 1988; Giegerich, 2004. We define linguistic recombination as stakeholders' creative reformulation and/or synthesis of one or more preexisting words or phonemes that results in the creation of a new category label. Linguistic recombination is typically done through either compounding or derivation.

Compounding is the most common type of linguistic recombination. A compound is "the simple concatenation of any two or more nouns [or other words] functioning as a third nominal" (Downing, 1977: 810). Because compounds recombine existing words or phonemes, they allow stakeholders to build links to existing categories when introducing or discussing a new design, which, in turn, invokes familiarity (Lieber, 1983; Wry, Lounsbury, & Jennings, 2014). At the same time, compounding allows for new and unique recombinations. Compounds, thus, are a way for stakeholders to create category labels that convey novelty and familiarity simultaneously, and they evoke nuanced combinations of meanings that would be difficult to achieve through labels that are created anew (Berger, Bradlow, Braunstein, & Zhang, 2012). Indeed, category labels that do not reference any existing categories, such as the label "nylon," tend to be rare (Navis & Glynn, 2010).

Derivation is another way in which stakeholders create new linguistic recombinations. A derivation is the novel use or transformation of an existing word, most often by changing an existing word into a different grammatical form, such as from a verb to a noun (Bybee, 1985). For example, the category label "computers" is derived from the verb "to compute," "fertilizers" from "to fertilize," and "lubricants" from "to lubricate." Compared to compounds that simply invoke familiarity of established product classes, derivations tend to stress the activity for which the new product is to be used.

Linguistic recombinations have informational advantages over category labels that are created anew: even when stakeholders know very little about the new design to which a label refers, the meaning that the label inherits through reference to existing categories suggests how it should be understood and positioned vis-à-vis existing designs (Kennedy et al., 2010). The category label "smartphone," for example, first used by Ericsson in 1997 to introduce its Penelope GS88 device, borrows meaning from the familiar "phone" category to signal that the device can be used to communicate with other people across distance (i.e., it can be used as a phone) but adds the word "smart" to indicate features that make the device more sophisticated and useful than earlier designs. In another example, the label "scanner" borrows meaning from the verb "to scan" to evoke a device that is designed to examine an object systematically. By creating associations to preexisting, familiar categories, and by highlighting similarities and differences, linguistic recombinations immediately capture stakeholders' attention and enhance information exchange. As a result, producers that introduce new designs in an emerging industry often use compounds and derivations to communicate the salient characteristics of their products.

The creation of the first category labels through linguistic recombination often occurs even before the launch of the first product, when initial R&D efforts are undertaken (Agarwal & Bayus, 2002) or when industry commentators, such as journalists, technology forecasters, or even fiction writers, first begin to anticipate a product's emergence. For instance, Gatland and Jefferis's 1979 book *The World of the Future: Future Cities* created the label "wrist-phones" for a design that today would be referred as to a "smartwatch." The creation of a category label facilitates acquiring and retaining knowledge about a category and the objects that it groups together (Lupyan, Rakison, & McClelland, 2007). When stakeholders use the same category label to refer to a set of designs, they signal that they consider the designs to belong to the same category (Navis & Glynn, 2010; Yamauchi & Markman, 1998) and to have a relatively high degree of similarity. In contrast, designs that are assigned different category labels are perceived to be more different from each other (Vygotsky, 1986).

After the launch of the first commercial product, producers become the main creators of category labels, which they use to position their designs in the market (Pontikes, 2012b). Producers coin new category labels through linguistic recombination to communicate the defining characteristics of their designs to customers and industry commentators, but also to differentiate their products from those of competitors (Granqvist, Grodal, & Woolley, 2013; Ocasio, 2011). Nokia, for instance, generated the compound "game deck" in 2004 to describe and categorize N-Gage, one of its early smartphones, as a means to emphasize the advanced gaming capabilities of the new device. As producers introduce new designs and/or attempt to differentiate their products from competitors', and as more producers enter the emerging industry, the number of category labels that they coin increases rapidly.

During this period of divergence, technological designs are poorly understood and their categorization is open to debate and contestation among stakeholders. Producers create new category labels through compounding and derivations to suggest how their products should be categorized, but the categories associated with these labels have no clear meanings yet. Other stakeholders, such as users and industry commentators, might adopt the category labels that producers propose, but they might also coin new ones in their efforts to make sense of and facilitate communication around the new class of designs (Kahl, 2007). For instance, the category label "typewriter" came from an industry commentator, a journalist in an 1867 article (*Scientific American*, 1867).

The Period of Categorical Convergence: Categorical Deepening

When a label is first introduced, the category it references has shallow meaning, limited to the meaning evoked by the words or phonemes used to create the label. Labels created anew (e.g., "nylon") have no inherent meaning; in contrast, labels created through compounding (e.g., "videocassette recorder") or derivation (e.g., "browsers," derived from the verb "to browse") evoke specific understandings through the meaning they inherit from existing categories. In industries that are in the initial stages of emergence, the introduction of many disparate and still shallow category labels creates confusion among stakeholders about the meaning of their associated categories. Different category labels may be used to refer to the same technological designs, or the same label may be used to refer to dissimilar designs (Pontikes, 2012b). This stifles understanding and hinders communication among stakeholders.

To resolve these problems, stakeholders engage in a process of iterative sensemaking, debating and discussing the meaning of the different proposed categories and their associated labels. The increasing use of a category label (e.g., through comentioning it in press releases, newspaper articles, and reviews) expands the semantic links between the referenced category and other categories, which helps better define the label's meaning (Peirce, 1958; Steyvers & Tenenbaum, 2005; Vygotsky, 1986). As this process continues, the focal category gradually assumes meaning, being perceived as similar (proximate) to or different (distant) from other categories. In the early computer industry, for example, the meaning of the category "computer" was deepened over time by creating semantic links to categories such as "brain," "machine," "clerk," "punch card," "policy," and "tabulator" (Bingham & Kahl, 2013). Such semantic links, especially when they stress distinctions, also help categories form boundaries that determine which designs can legitimately claim membership to them and which designs will be excluded (Hannan et al., 2007). As categories mature, they generally become stricter and define a narrower range of variation for the designs claiming membership. We use the term categorical deepening to describe the mechanism by which the network of semantic connections of a particular category becomes denser and categorical boundaries emerge. Through categorical deepening, categories that were initially shallow acquire meaning and develop more clearly defined boundaries.

Producers, through their press releases, often create initial semantic links when they announce and describe a new product design. However, industry commentators such as journalists and analysts can have a disproportionate role in creating and reinforcing semantic connections because they tend to occupy positions that offer them the opportunity to disseminate their opinions to a wide audience. These commentators customarily compare different designs and often act as gatekeepers who control the flow of information and arbitrate competing categorical claims or inconsistent semantic links.

An illustrative example of semantic linking comes from the robotics industry. Czech playwright and journalist (i.e., an industry commentator) Karel Capek coined the category label "robot" in the 1920s, which he derived from the Czech word "robota," meaning "forced labor" or "slave." In addition to these inherited meanings, in his writings Capek associated the newly created label with categories such as "humanoid," "autonomous," "biology," and "physiology." Starting in the 1960s, robot producers, through their product releases and advertisements, created other associations, such as "arm" and "house cleaning." Simultaneously, industry commentators writing about robotic designs created links to categories such as "computers," "electronics," and "precision tasks," while the connections to "biology" and "physiology" began to fade. This process of categorical deepening has led to the modern category of a robot, which is widely understood and agreed upon as a multipurpose machine having advanced artificial intelligence used to address different tasks (Hockstein, Gourin, Faust, & Terris, 2007).

Categorical deepening aids stakeholders in comparing categories and deciding which ones are better suited to describe the designs that proliferate in the industry. The categories and associated labels best suited for this task gain traction as more stakeholders use them to talk about new designs. In particular, categories that become deeper and more meaningful are likely to be preferred by stakeholders because they transfer information about the new designs more effectively (Clark & Wilkes-Biggs, 1986). In contrast, categories that fail to deepen will lose favor and gradually disappear, causing the number of categories in use to decrease. The initial period of categorical divergence, thus, is generally followed by a period of categorical convergence during which increasingly fewer categories remain in use (Suarez et al., 2015).

The selection process that leads to the reduction of categories and their associated labels is not without contestation. Stakeholders might disagree about which category should be retained; producers of competing designs, in particular, might fight to keep the categories they sponsor alive. Indeed, different categories incarnate different understandings and visions about the emerging industry (Kennedy & Fiss, 2013). The disappearance of a category requires some producers to reposition their designs in one of the remaining categories, which could imply costly design changes for the product to fit the new category. More important, it also implies heightened competition: the fact that consumers perceive product designs positioned within the same category as more similar limits producers' ability to differentiate their products (Hsu & Hannan, 2005; Zerubavel, 1997).

Industry commentators and users are likely to be more influential than producers in driving the process of categorical selection. Unlike producers, who have an incentive to promote the particular categories in which they position their designs, commentators and users are generally less invested in any particular category. For them, the primary purpose of categories is to help them make sense of the evolving industry and to reduce uncertainty regarding the traits of competing products. Fewer and more meaningful categories are thus preferable, since they ease understanding and comparison of competing designs by setting clear boundaries for the set of designs to be considered (Zuckerman, 1999). This iterative process of contestation and reduction in the number of categories and their associated labels often culminates in the emergence of a dominant category, "the conceptual schema that most stakeholders adhere to when referring to products that address similar needs and compete for the same market space" (Suarez et al., 2015: 439-440).

The early stages of the smartphone industry, for example, were characterized by a plethora of competing labels and categories. Early category labels such as "camera phone" and "PDA phone" incarnated very different understandings of the emerging industry: camera phones evoked entertainment and capturing memories through pictures, whereas PDA phones evoked work and responsibilities. As competing categories deepened, stakeholders gradually became able to assess their relative merits. Over time, the "smartphone" category outcompeted other categories, because stakeholders began to perceive it as better fit for describing the new design's multiple functions. This happened through semantic connections between "smartphone" and categories such as "memories," "friends," "connectivity," "texting," and "apps" that turned out to be important dimensions of how the emerging product design in the industry was used. Even companies such as Apple and BlackBerry that had initially resisted the use of the "smartphone" category label eventually had to accept its dominance.

THE INFLUENCE OF TECHNOLOGICAL EVOLUTION ON CATEGORICAL EVOLUTION

In the preceding sections we detailed the mechanisms of technological and categorical evolution, examining them independently. However, technological designs and categories do not develop in a vacuum; rather, they directly influence each other's evolution. In the following sections we detail the mechanisms through which technological evolution shapes categorical evolution, and vice versa. We begin with the influence of technological evolution on categories and their associated labels, proposing that it occurs through two main mechanisms: *design echoing* and *design discerning*.

Design Echoing

In the section on categorical evolution we described how most new category labels are created through linguistic recombinations, but we did not discuss how stakeholders choose the words or phonemes to be combined or reformed. This choice, however, is not random; instead, linguistic recombinations tend to reflect the technological designs that their creators are attempting to describe and categorize. We define design echoing as the mechanism through which technological designs influence the choice of words and phonemes that are used in linguistic recombinations.

During industry emergence, stakeholders create category labels to make sense of the new designs. Because understanding of the new designs is poor, referencing their defining elements (e.g., components or architectural features) helps stakeholders to better grasp these designs' functions and to position them with respect to preexisting technological designs. At the early stages of the automobile industry, for example,

> there was no semantic agreement on what a car was—other than the fact that it was not drawn by a horse. Commentators variously referred to it as a . . . "motorcycle," "locomobile," "electric runabout," "electric buggy," "horseless carriage," "automobile," and "quadricycle" (Rao, 2008: 19).

This plethora of category labels created through linguistic recombination directly referenced aspects of the new vehicle's main design characteristic—the fact that it was self-propelled, fast, and had four wheels. Similarly, category labels such as "electric car" or "tumble dryer" make direct reference to the corresponding technological designs.

It follows that, generally, the more heterogeneous the technological designs introduced to the new industry, the larger the number of category labels coined to echo these designs will be. For instance, since its inception in the 1920s, the credit card industry has seen only a few designs, reflected in an equally limited number of category labels.[1] The early precursor of the credit card, developed in the 1920s, was a 2½ x 1¼ inch metal plate embossed with the customer's name so that a paper copy could be created at the point of purchase and used for in-store credit. This design was referred to by the category label "Charga-Plate." The second design came with the creation of the Diners Club, which sprang from founder Frank McNamara's experience of not having cash to settle the bill for a dinner. His design entailed providing members with credit through a card that could be used in restaurants and with other merchants instead of cash, along with a set of participating merchants committed to accepting this new form of payment. McNamara called the new product the "credit identification card," reflecting its key characteristics. The third design came with the introduction of revolving credit, first offered by Bank of America and quickly followed by many others. The category label used for this enhanced product was "credit card," a label that has prevailed to this date.

In contrast, stakeholders in industries with many technological designs tend to introduce a large number of category labels as they attempt to categorize the designs into meaningful groups. The smartphone industry, for example, where designs are introduced in rapid succession, has been characterized by an equally vast array of category labels. Similarly, the automobile industry generated a plethora of labels (Rao, 1994). For the software industry, Pontikes (2012a) counted 456 labels in total. Yet the correspondence between technological designs and category labels might not always be one to one. In some cases an early category label can gain considerable traction from the start of the industry and quickly become dominant, even if it is assigned to disparate designs.

Importantly, judgments regarding the similarity between designs rest with the stakeholders. Even if two designs differ on some metrics and/or are considered as materially different by the producers, other stakeholders might still apply the same category label to them, if they are unable to understand the differences or see them as inconsequential. Moreover, stakeholders differ in how they use design echoing. Producers have a deep understanding of their own technological designs, their components, and architectural features; as a result, the category labels they coin tend to be more technical. For instance, in the early 1970s Radio Corporation of America (RCA) developed a new electronic display technology that RCA labeled "liquid crystal display" (LCD), directly mirroring the underlying technological design. In contrast, users and industry commentators are more removed from the specifics of the different technological designs and, therefore, less likely to stress those features when creating

[1] Note that service industries also have designs much in the sense of physical industries. In particular, a service design is composed of component elements, the role and interaction of which are defined and governed by an overall architecture (Baum, Korn, & Kotha, 1995).

labels, focusing instead on the defining characteristics of the design's appearance or suggested use. For instance, the category label "mountain bike" was created by a biking aficionado in California, evoking the context in which the new bike was used, instead of the particular technological characteristics (e.g., fat tires) of its design. Similarly, the category label "browser" makes no reference to the underlying technology but, rather, alludes to the new product's use. Thus, we offer the following proposition.

> *Proposition 1: The greater the number of technological designs in an industry, the larger the number of category labels.*

Design Discerning

In the section on categorical evolution we noted how initially shallow categories deepen and become meaningful as stakeholders use the associated category labels and create semantic links to other categories. However, we offered limited insight into the bases of the categorical deepening process and its impact on categorical selection. To a considerable extent this process is influenced by the characteristics of the technological designs that stakeholders attempt to classify. We define design discerning as the mechanism through which technological designs influence categorical deepening and selection.

Over time, increasing familiarity and experience help stakeholders develop more accurate perceptions of categories, their usefulness, and the commonalities or differences between them. As experience with the products accumulates, stakeholders increasingly base their comparisons between categories on the characteristics of the architecture, components, and resulting uses of the designs they are trying to categorize. Stakeholders gradually become better able to discern design features that are important from those that are peripheral and, thus, also better able to discern which categories better capture relevant differences among designs. Categories that classify designs based on salient design differences are likely to gain further traction and to solidify. In contrast, categories that are too broad, inconsistent, or capture only secondary differences will lose traction. As this process takes place, the meaning of the remaining categories deepens and their boundaries become clearer, which, in turn, speeds up the abandonment of categories perceived as superfluous.

At the same time, categorical selection is further accelerated by the ongoing selection taking place among different designs. Because design competition and path dependence cause many designs to be abandoned, the categories and labels associated with the abandoned designs are also likely to be abandoned.

Users and industry commentators play the most significant role in design discerning, being the stakeholders who primarily use and experience the competing designs, and they determine the salience of the different technological design characteristics as bases of categorization (Clark, 1985; Kahl, 2007). Moreover, the success or failure of any design and any category ultimately depends on the endorsement of consumers who purchase the product. In contrast, producers' investment in and detailed understanding of their own particular designs can make them stick to categories that other stakeholders do not deem meaningful. This is particularly true given producers' incentives to overemphasize their products' unique traits in order to set them apart from competing alternatives. As a result, firms might fail to observe important commonalities across designs and, hence, continue to support categories that others gradually abandon.

For example, early designs of what today are known as "electronic spreadsheets" (software products for financial and other types of calculations) were referred to using category labels ranging from "business computer language" (BCL) to "financial planning and control systems." The original designs were understood as new programming languages or routines to perform specific tasks, and the category labels used to reference them echoed these defining elements of the early designs. As users and other stakeholders gained experience with these software products, they realized that they could be used for many different purposes and resembled accountants' and financial analysts' paper spreadsheets. This realization was reflected in the introduction of the compound category label "electronic spreadsheet," first used to describe Visicalc, software developed by users of financial information that subsequently launched on an Apple machine in 1979. The "electronic spreadsheet" category label more directly reflected the design characteristics and product use within this emerging industry, quickly leading to the abandonment of competing labels and their associated categories.

Therefore, we propose that design discerning affects the deepening of meaning and selection of categories.

Proposition 2: The greater the stakeholders' perceptions of commonality between technological designs, the larger the number of categories that are abandoned.

Proposition 3: The greater the stakeholders' perceptions of inconsistency between the linguistic components of a category label and the technological characteristics of the design it references, the more likely the category will be abandoned.

THE INFLUENCE OF CATEGORICAL EVOLUTION ON TECHNOLOGICAL EVOLUTION

Theories of technological evolution often rely disproportionately on design characteristics in explaining the evolution of products in an industry (Garud & Kumaraswamy, 2010). In reality, however, the process of technological evolution has strong sociocognitive underpinnings (Garud, Jain, & Kumaraswamy, 2002; Shane, 2000). Categories in particular, as embodiments of different perceptions of an underlying technology and its envisioned use, can play a significant role in influencing design decisions and, thus, in influencing the evolution of technological designs. As Dosi and Nelson recently stated:

> Whenever efforts at inventing and designing are oriented in most cases by relatively strong professional understanding, part of the relevant variation, and the selection, which is involved in the evolution of technologies occurs in the human mind, in thinking and analysis, in discussion and argument, in exploration and testing of models, as contrasted with being out there in practice (2013: 4).

We identify two mechanisms through which categorical evolution shapes the process of technological design evolution: *categorical echoing* and *categorical discerning.*

Categorical Echoing

The extensive literature on the role of recombinations in the evolution of technological designs has focused primarily on which design features producers select and modify (Abernathy & Utterback, 1978; Utterback & Suarez, 1993). Technological recombination, however, does not occur in a vacuum. While technological capabilities determine which recombinations are feasible, producers' choice of the ones that will actually be pursued in specific designs depends on their perceptions about different recombinations' relevance and desirability (Clark, 1985). Such perceptions, in turn, are socially constructed and expressed in categories and their associated labels. Categories and their associated labels, thus, not only are influenced by the designs that they describe but also influence designs' evolution. While initial designs often give rise to early labels and categories, these new categories and labels and others already in existence begin to inspire subsequent designs. We define categorical echoing as the mechanism through which categories and their associated labels potentiate the recombination that leads to new technological designs.

Categories and their associated labels constitute the lenses through which producers understand an evolving industry (Moreau, Markman, & Lehmann, 2001; Rosa et al., 1999). Which designs are pursued depends not only on the designs' technical feasibility but also on how prominently they figure in producers' cognitive repertoires (Clemens & Cook, 1999). At the early stages of an industry in particular, novel category labels can create expectations about the form and function of future designs, significantly influencing these designs' development. This process might be initiated before the first commercial product is introduced, and it continues with the introduction of new category labels. Because most new category labels are created through linguistic recombination, even when they are novel, they are still infused with the meaning they inherited from their component categories. Early category labels can spur recombinations that producers would otherwise not have considered (Garud & Rappa, 1994). Even when a certain recombination is currently not technologically feasible, category labels can direct technological search in its direction and influence which features will eventually be integrated into a technological design. In their study of the "eBook" industry, for example, Seidel and O'Mahony (2014: 12-13) describe how the category label "eBook" exerted a strong influence on the kinds of recombinations pursued. Although new, the compounded "eBook" category label evoked meaning from the existing categories "e[lectronic]" and "book," which shaped the engineers' choices about what the new design should look like:

> Someone had a long discussion about why we would need a calculator in . . . [the eBook]. At the end, . . . [the project manager] would go, "But it's a book!" . . . If books did not have calculators, to be consistent with that metaphor, neither should the eBook. In another instance, the question of whether to allow a list of contacts on the eBook was addressed differently. The executive manager explained that "someone can have a little black book of names . . . [which] is a book also. So it fits the paradigm" (Seidel & O'Mahony, 2014: 702-703).

Categorical echoing was also at play in the evolution of what today is known as "cloud computing." Centralized hosting of software applications started in the early 1960s in IBM's Watson Research Center. In 1961, at a talk at MIT, renowned computer scientist John McCarthy referred to the nascent industry as "utility computing." This category label embodied a vision of computing services provided as a utility, much like electricity and water. McCarthy's new compound category label triggered the imagination of many computer scientists and entrepreneurs (users and producers), who developed systems that fulfilled this understanding of the emerging industry. In doing so they created category labels that more closely evoked the expanded possibilities of centralized computing, including "application service providers" (ASPs) and "software as a service" (SaaS).

The multitude of category labels that stakeholders create in early industries functions not only to attract the attention of stakeholders and transfer information about the underlying products but also to ultimately shape technological design evolution by prompting new technological recombinations. Because different category labels correspond to different perceptions of and visions for the industry, they often also spur different designs. Competing labels tend to stress different features or functionalities of the product they refer to and also suggest different paths of further evolution. Thus, the more labels stakeholders coin, the more room for design variation producers will enjoy. Therefore, we propose the following.

> *Proposition 4: A greater number of category labels will inspire more technological recombinations, which, in turn, will result in a greater number of technological designs.*

Categorical Discerning

While the multiplicity of early and often shallow categories might spark technological design recombinations, later and more meaningful categories that are characterized by more stringent rules of membership directly dictate the traits that category members must have or cannot have (Hannan et al., 2007; Pontikes, 2012a). Such meaningful categories help stakeholders distinguish between designs that belong to a category and designs that do not. Producers who wish to position their designs in a focal category thus need to conform to the category's rules of membership, or they risk being overlooked by customers and suffering a performance penalty (Zuckerman, 1999). We define categorical discerning as the mechanism through which categories constrain technological design recombinations and intensify design selection by dictating which characteristics a design must possess and which ones it cannot possess in order to claim membership in a particular category (Vygotsky, 1986; Yamauchi & Markman, 1998).

The evolution of the bicycle industry vividly demonstrates the dynamics of categorical discerning. During the period of divergence, a multitude of new designs and category labels were created. Bicycle designs ranged from propulsion by the rider's feet on the ground to incorporation of chains and pedals to varying numbers and sizes of wheels. A correspondingly large number of category labels were created to refer to these designs, including "velocipede," "ordinary," "facilie," "dicycle," and "bicyclette," each of which was associated with a different perception of the industry and its products. Early category labels, like "velocipede," tended to stress speed, emphasizing that the early bicycle was primarily used for racing. However, the different potential functions for the bicycle were hotly contested among producers, users, and industry commentators. In particular, some stakeholders began to argue that bikes should primarily be used as transportation vehicles. This vision instigated design changes, such as the replacement of wood tires with rubber tires to enable rides on ordinary bumpy streets and not just on designated racing tracks. At the time, the degree to which biking was morally appropriate for women was also highly contested. Early designs that had a huge front wheel were indeed very difficult to mount and ride, particularly for women who wore long skirts. The deepening of meaning to focus on transportation and include women's riding shaped the creation of a "safety bicycle" design. This bike design had two equal-size wheels, with the saddle positioned between them, and used pedals and a chain for forward propulsion. It soon became the dominant design for the industry, gaining widespread acceptance (Bijker, 1995).

As an industry evolves, categories become both fewer and deeper, and as categorical understandings solidify, categorical rules of membership become stricter. Producers need to adapt their designs to these categories for their products to succeed. Categorical discerning thus reinforces the effects of technological competition and path dependence. Indeed, designs are constrained not only by path dependence imposed by earlier technological choices (Clark, 1985) but also by solidified understandings of the product's form and function. Moreover, as designs increasingly claim membership in the few remaining categories, consumers begin to perceive the designs as more similar (Zerubavel, 1997) and to directly compare their features (Hsu & Hannan, 2005). This further intensifies competition among the designs that users increasingly perceive as close substitutes, making it harder for producers to distinguish their offerings from competitors (Vygotsky, 1986; Zerubavel, 1997) and to pursue differentiation strategies (Porter, 1985). This speeds up the process of design selection, culminating in one design achieving dominance within the industry. Therefore, we propose the following.

> *Proposition 5: The deeper the meaning of competing categories, the larger the number of technological designs that are abandoned.*

> *Proposition 6: The number of technological designs claiming membership in a given category is positively associated with the abandonment of technological designs.*

DISCUSSION

We set out in this article to integrate theories of technological evolution with theories of categorization in order to generate a more nuanced understanding of industry emergence. In particular, leveraging the rich literature on categories and their associated labels (Bybee, 1985; Giegerich, 2004; Kennedy, 2008; Navis & Glynn, 2010; Rosa et al., 1999), we have detailed the mechanisms that drive their coevolution with technological designs. Our theoretical model and proposed mechanisms are summarized in Figure 1.

The mechanisms through which technological design and categorical evolution occur unfold horizontally on the lower and the upper parts of Figure 1. Our model shows that there are important similarities between the two processes. Both technological design and categorical evolution first undergo a period of divergence: the number of technological designs and category labels increases, fueled by design recombination and linguistic recombination, respectively. The initial period of divergence is generally followed by a period of convergence: the number of both technological designs and categories with their associated labels decreases significantly, fueled respectively by design competition and path dependence, and by categorical deepening. The period of convergence is rife with debate and struggles for supremacy as producers try to win the battle not only over which design becomes dominant but also over which category becomes the evolving industry's cognitive referent.

As Figure 1 makes apparent, designs (upper part of the figure), as well as categories and their associated labels (lower part of the figure), do not evolve independently but, instead, directly influence each other. These coevolutionary processes are present during both the early period of divergence and the later period of convergence. During the period of divergence, categorical echoing shapes technological recombinations, because the perceptions associated with category labels and their associated categories stimulate the technological designs pursued by producers. At the same time, design echoing influences the creation of new category labels (and corresponding categories), because linguistic recombinations often directly reflect the technological designs that they reference.

The transition from the period of divergence to that of convergence is marked by the emergence of two important markers: the dominant design (Utterback & Suarez, 1993) and the dominant category (Suarez et al., 2015). Although no design or category has achieved dominance at this point, the creation of the design and category that will eventually dominate the industry is generally seen as signaling the beginning of convergence in the industry. During the period of convergence, technological designs influence the evolution of categories and their associated labels through design discerning. As the differences and similarities between technological designs begin to be better understood, users and commentators can better judge the fit of and possible inconsistencies between categories, their associated labels, and the designs they claim to reference. Thus, technological design evolution during convergence catalyzes categorical deepening and selection.

Likewise, categories influence the further evolution of technological designs through categorical discerning. Those technological designs that better fit the emerging categorical rules of membership are more positively received by users and industry commentators and enjoy an advantage over competing designs. Furthermore, as categorical selection proceeds, producers increasingly position their designs within fewer categories. This fuels competition among technological designs, because being perceived as members of the same category makes it increasingly difficult for producers to differentiate their offerings. Categorical discerning thus further reinforces design competition and path dependence.

Finally, as depicted in the figure, the coevolution between technological designs and categories and their associated labels generally culminates in the establishment of one dominant technological design and one dominant category. Below we elaborate on the implications of our model.

Contributions to the Literature on Industry Evolution

Our theory extends the literature on industry evolution (Anderson & Tushman, 1990; Utterback & Abernathy, 1975) by identifying some important but overlooked dynamics. While our work is consistent with the well-established notion of variation-selection-retention (see Zollo & Winter, 2002), we extend this literature by detailing how the existence of a multitude of different categories and associated labels influences the evolution of technological designs by creating expectations regarding specific design features. Similarly, we suggest that convergence on a dominant design is driven not only by design competition and path dependence (Clark, 1985) but also by rules of categorical membership that dictate, sometimes with considerable precision, the characteristics a design must possess in order to be compatible with a specific category.

The incorporation of categorical dynamics into theories of industry evolution allows us to depart from a linear and deterministic view of how technologies evolve. As categories and their associated labels incarnate understandings and evoke visions of the industry, they reflect both the past (e.g., by evoking meanings associated with preexisting industries through the new compound category labels) and possible avenues for the future. Technological evolution thus reflects stakeholders' recursive reflections between these different temporal dimensions (see Emirbayer & Mische, 1998). Importantly, core meanings associated with a category might emerge long before the related industry and might significantly influence how the industry develops. Our framework therefore lends further support to recent studies emphasizing temporal dynamics as constantly changing, negotiated, and collectively constructed based on participants understandings of the past and the future (Kaplan & Orlikowski, 2013).

One of the most important implications of our work for theories of industry evolution is that categories can change the dynamics of competition within an industry. For instance, users consider any two designs as more distant when perceiving them as belonging to different categories rather than the same category and, thus, tend not to compare them directly (Zerubavel, 1997). This, in turn, can buffer competition and allow producers to pursue differentiation strategies (Porter, 1985). The existing literature has noted that the emergence of the dominant design initiates a period of fierce competition (Utterback, 1994), resulting in an industry shakeout (Klepper, 1997). However, scholars have viewed this increase in competition leading to a shakeout as resulting from increased organizational density (Hannan & Freeman, 1989), increased product standardization (Abernathy & Utterback, 1978), firms' increased investment in process R&D (Klepper, 1997), or the presence of network effects in the so-called standards wars (Shapiro & Varian, 1999). Our model suggests that increases in competition might also derive from the decrease in the number of categories within an evolving industry that occurs during the period of convergence. As producers are forced to position their designs within the fewer remaining categories, users and commentators perceive them as increasingly similar and, thus, are prompted to directly compare design features and see designs as closer substitutes.

Integrating theories of categorical evolution into the literature of industry evolution also highlights that a struggle for dominance takes place not only among designs but also in the category domain. This insight adds to a small but growing body of literature (Granqvist et al., 2013; Santos & Eisenhardt, 2009; Suarez et al., 2015) suggesting that firms need to strategically manage their categorical affiliations much in the same way they manage their design choices in navigating the competitive dynamics of an emerging industry. To secure a competitive advantage in an emerging industry, firms may need to monitor or even actively shape users' and commentators' categorical understandings.

Our model also adds to the literature on industry evolution by emphasizing the importance of the dynamics taking place prior to the launch of the first design in an industry (i.e., during the precommercialization phase). We have long known that the R&D process, which shapes design creation, begins long before the first products are introduced in an industry (Schumpeter, 1934), yet very little research has been conducted on the effects of such precommercialization activities on industry evolution. In one of the few exceptions, Rosenbloom and Cusumano (1987) suggested that firms engaging in R&D early during the precommercialization phase are more likely to eventually dominate the industry. Our model highlights the creation of category labels that influence technological search as another important dynamic of the precommercialization phase. As we have noted, producers, commentators, and users sometimes create labels and articulate impactful visions for future designs. The eventual dominance of firms that engage early in the precommercialization phase might be attributable not only to advantages derived from their head start in R&D (Rosenbloom & Cusumano, 1987) but also to their ability to influence the formation of early categories and labels, as well as their corresponding ability to shape understandings and visions of the emerging industry. This insight is important for firm strategy since it suggests that, prior to product launches, firms might need to monitor more closely the early categorical dynamics and pay attention to or even try to influence the expectations that are forming around the emerging industry. In future research, scholars studying industry evolution might have to take such dynamics into account and begin data collection even before the first product is introduced.

Last, our theoretical framework has interesting implications for the still unresolved question of how industry boundaries are formed. Surprisingly, although the formation of industry boundaries constitutes a crucial aspect of industry emergence (Santos & Eisenhardt, 2009) and an important practical issue for research on industry dynamics in general, existing theories of industry evolution have not paid much attention to defining what an "industry" is. For instance, Anderson and Tushman (1990: 606) used "standard industry boundaries" in their study, as defined by the four-digit Standard Industrial Classification (SIC) codes, which are created by grouping firms into industries according to similarities in the processes used to produce goods or services (Economic Classification Policy Committee, 1994). The idea of "similarity" used in SIC codes is related to the insight from economics that an industry consists of producers of products that are good substitutes for each other, as evidenced by high cross-elasticity of demand. However, both economists and scholars of industry evolution have rarely focused on how stakeholders come to perceive products as similar and belonging to the same industry. Tellingly, in one of the classic textbooks in industrial economics, Nobel Prize winner Jean Tirole states, in the preface:

> For the purpose of the present book, this empirical difficulty of defining a market will be ignored. It will be assumed that the market is well defined, and that it involves either a homogeneous good or a group of differentiated products that are fairly good substitutes (1988: 13).

The theoretical framework we have developed opens this black box of industry boundaries. Product categorization is initially based on the membership claims producers make regarding their designs as they create new labels or use existing ones. As other stakeholders become more familiar with the industry, they might dispute producers' claims and recategorize products based on those design features they deem salient. Over time, as categories become meaningful, and particularly after a dominant category emerges, increasingly strict rules of membership draw the boundaries that help stakeholders determine which product designs do or do not belong to the industry. Industry boundaries and the notion of substitutability, thus, are not fully objective but, rather, socially constructed. Indeed, categories not only set rules that differentiate members from nonmembers but also emphasize the homogeneity of their members (Zerubavel, 1997). Simply bearing the same label and belonging to the same category stresses the similarities between objects (Hannan et al., 2007) and can make them appear to be closer substitutes than they actually are.

Contributions to the Literature on Categories

We contribute to the literature on categorical dynamics (Hannan et al., 2007; Navis & Glynn, 2010; Pontikes, 2012a; Zuckerman, 1999) by explicating linguistic elements and detailing their importance during the divergence and convergence periods of industry evolution. In so doing, we begin to address the call by Kennedy and Fiss (2013) to study the process through which categories emerge and fall out of use. Prior studies have either focused on the role of categories in industry dynamics by studying their cross-sectional effects (Hsu, 2006; Zuckerman, 1999, 2000) or focused primarily on the processes through which a single focal category is legitimized (Jones et al., 2012; Navis & Glynn, 2010; Weber et al., 2008). An emphasis on the success of a single category, however, overlooks the fact that the creation, evolution, and dominance of one particular category are intrinsically related to the creation, evolution, and most often demise of competing categories. Our work suggests that a more complete understanding of the categorical dynamics during industry emergence requires that we study both those categories that persist and those that fail.

In particular, our approach allows us to delve deeper into the origins of categories and the factors that make some category labels more successful than others. While scholars have recently begun to explore the role of category labels in industry dynamics (Hsu & Grodal, 2015; Navis & Glynn, 2010; Pontikes, 2012a), most of their research has focused on the performance implications of claiming multiple labels simultaneously (Hsu, 2006; Hsu, Hannan, & Kocak, 2009) or has examined the impact of ambiguous labels on performance (Pontikes, 2012a; Ruef & Patterson, 2009). Borrowing concepts from linguistics, we extend this recent research stream to theorize about the origins of categories and their associated labels, the process though which categories become meaningful, and the process through which some categories and labels are selected over alternative ones.

In prior literature, even when noting the existence of different kinds of stakeholders, scholars (Hsu, 2006; Hsu et al., 2009; Zuckerman, 1999), generally have not paid much attention to stakeholders' often conflicting interests and priorities in coining labels, debating and contesting the meaning of the associated categories, and eventually converging on the use of a dominant category. In this article we differentiate among three types of stakeholders (producers, users, and industry commentators) and highlight the multifaceted roles they play during industry emergence, sometimes in surprising ways. For example, industry commentators not only function as evaluators of categorical claims but also actively engage in category creation. Similarly, users are not only passive receivers of categories but, as in the case of designs (Riggs & von Hippel, 1994; von Hippel, 1988), also their creators, often challenging producers' understandings of the new industry or their classification of designs. Moreover, we argue that stakeholders differ in their motives for creating a new category label and associated category or using an existing category. For users and industry commentators, the main purpose of categories is to make sense of an emerging industry. In contrast, producers often choose a categorical affiliation with the aim of differentiating their designs from competitors' or becoming the cognitive referents of the emerging industry (Santos & Eisenhardt, 2009). Categorical creation, deepening, and eventual selection are, thus, iterative, contested processes though which shared and agreed upon categorical understandings eventually arise. Our theorization on the role of various stakeholders thus adds much needed elements of dynamism and contestation to existing categorization literature.

Industry Context and the Boundary Conditions of Our Model

As we noted at the outset of this article, our theory and arguments apply primarily to new industries that are created through technological or market discontinuities (Schumpeter, 1934) that give rise to a period of design experimentation and sensemaking (Abernathy & Utterback, 1978; Anderson & Tushman, 1990; Kaplan & Tripsas, 2008; see also Weick, 1979). In other contexts, even though the main tenets of our model are likely to still apply, the dynamics that we describe may unfold somewhat differently and boundary conditions might apply.

For instance, extensions of existing industries generated by incremental recombination or subsegmentation might not be followed by the same degree of experimentation and sensemaking. Because such incremental recombinations are easier to understand, fewer new category labels will be generated, less contestation will occur, and categorical and design convergence will happen more quickly.

An important avenue for future research is to determine the conditions under which categorical dynamics precede or follow design dynamics. As mentioned earlier, sometimes category labels are created during the precommercialization phase. This is more likely to be the case for industries with complex products that involve multiple innovations and large investments, and often require a long time between the initial conception of the industry and the actual creation of the first design. This was, for example, the case for robots (Hockstein et al., 2007), nanotechnology (Kennedy et al., 2010), and artificial intelligence (Crevier, 1994), where the introduction of the first commercial product came decades after writers or scientists had conceived the idea of each respective industry. In contrast, for simpler recombinations the creation of the first category label is likely to coincide with the introduction of the first product using the novel design as the producer attempts to describe the product to other stakeholders.

In this article we have argued that the transition from the period of divergence to the period of convergence is marked by the emergence of a dominant design and a dominant category. For simplicity, in Figure 1 we depict the transition as roughly co-occurring for technological designs and categories. While this is not necessarily always the case, the two points of transition are unlikely to be very far apart, given that technological designs and categories coevolve. In fact, in most industries convergence on a dominant category is likely to occur somewhat earlier than convergence on a dominant design, because convergence on a common understanding about the industry is most often both a prerequisite and a catalyst for convergence on design. Convergence on the dominant category is likely to increase the pace of design selection as users begin to compare and contrast in more detail designs that they now consider close substitutes.

In our theory we also suggest that categorical convergence is accompanied by categorical deepening, which sharpens categorical boundaries. This, however, might not always be the case. Indeed, if a focal category builds semantic connections to disparate categories that are hard to reconcile, its boundaries might remain blurred. While such fuzzy categories generally hamper sensemaking (Hannan et al., 2007), they might be well suited for industries where technological change is so fast as to render stricter categories quickly obsolete (Pontikes, 2012b). However, fuzzy categories are likely to exert a weaker influence than more firmly bound categories on the evolution of technological designs. Future research is required to compare the relative influence that categories exert on technological design evolution in contexts that differ regarding the sharpness of categorical boundaries, possibly relating both to the speed of technological change.

Finally, a model like ours that details the coevolution of technological designs with categories and their associated labels inevitably creates both theoretical issues (Archer, 1995) and methodological challenges (Wooldridge, 2013), given that the complex relationships we study imply dual causality. While underlining the bidirectional nature of the influence between designs and categories is a first step in properly understanding the complex dynamics of industry emergence, future empirical research can help us further explicate the effects of designs on categories, and vice versa. Theoretically, this involves further specifying how different boundary conditions affect the influence of our theorized mechanisms and their timing (Archer, 1995). Empirically, it implies tackling issues of reverse causality and identification, for which several modern econometrics techniques can be used, ranging from Granger causality models on panel data (Engle & Granger, 1987; Habibullah & Eng, 2006) to simultaneous equation models with instrumental variables (Wooldridge, 2013).

Our theorizing and propositions open many avenues for future empirical research. Existing literature has already shown that data can be collected on technological design characteristics (e.g., Christensen, Suarez, & Utterback, 1999). Less empirical research has followed the evolution of categories and their associated labels. However, a few recent studies suggest how these can be tracked over time for empirical analysis (Granqvist et al., 2013; Pontikes, 2012a). Category labels can be extracted from public sources, such as product press releases, product reviews, analyst reports, newspaper and magazine articles, blogs, and so on. From these labels semantic connections can be constructed based on their co-occurrence with other category labels, enabling the study of categorical deepening (e.g., Kennedy, Chok, & Liu, 2012).

In conclusion, the well-established literature on technological designs and the more recent literature on categorical evolution have made much progress in furthering our understanding of industry emergence. However, these two bodies of literature have so far evolved largely separately. Given the importance of industry emergence for understanding the performance and survival of firms, integrating this literature is of utmost importance. This article constitutes an initial significant step in understanding how the evolution of designs and the evolution of categories are inexorably interlinked.

REFERENCES

Abernathy, W. J., & Utterback, J. M. 1978. Patterns of innovation in technology. ***Technology Review,*** 80: 40–47.

Agarwal, R., & Bayus, B. L. 2002. The market evolution and sales takeoff of product innovations. ***Management Science,*** 48: 1024–1041.

Anderson, P., & Tushman, M. L. 1990. Technological discontinuities and dominant designs: A cyclical model of technological change. ***Administrative Science Quarterly,*** 35: 604–633.

Archer, M. S. 1995. ***Realist social theory: The morphogenetic approach.*** Cambridge: Cambridge University Press.

Argyres, N., Bigelow, L., & Nickerson, J. A. 2015. Dominant designs, innovation shocks, and the follower's dilemma. ***Strategic Management Journal,*** 36: 216–234.

Autio, E., Dahlander, L., & Frederiksen, L. 2013. Information exposure, opportunity evaluation, and entrepreneurial action: An investigation of an online user community. ***Academy of Management Journal,*** 56: 1348–1371.

Barley, S. R. 1986. Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. ***Administrative Science Quarterly,*** 31: 78–108.

Baum, J. A. C., Korn, H. J., & Kotha, S. 1995. Dominant designs and population dynamics in telecommunications services: Founding and failure of facsimile transmission service organizations, 1965-1992. ***Social Science Research,*** 24: 97–135.

Benner, M., & Tripsas, M. 2012. The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras. ***Strategic Management Journal,*** 33: 277–302.

Berger, J., Bradlow, E. T., Braunstein, A., & Zhang, Y. 2012. From Karen to Katie: Using baby names to understand cultural evolution. ***Psychological Science,*** 20: 1–7.

Bijker, W. E. 1995. ***Of bicycles, Bakelites, and bulbs: Toward a theory of sociotechnical change.*** Cambridge, MA: MIT Press.

Bingham, C. B., & Kahl, S. 2013. The process of schema emergence: Assimilation, deconstruction, unitization, and the plurality of analogies. ***Academy of Management Journal,*** 56: 14–34.

Bowker, G. C., & Star, S. L. 2000. ***Sorting things out: Classification and its consequences.*** Cambridge, MA: MIT Press.

Bybee, J. L. 1985. ***Morphology: A study of the relation between meaning and form.*** Amsterdam: John Benjamins.

Christensen, C. M., Suarez, F. F., & Utterback, J. M. 1999. Strategies for survival in fast changing industries. ***Management Science,*** 44: S207–S220.

Clark, H. H., & Wilkes-Biggs, D. 1986. Referring as a collaborative process. ***Cognition,*** 22: 1–39.

Clark, K. B. 1985. The interaction of design hierarchies and market concepts in technological evolution. ***Research Policy,*** 14: 235–251.

Clemens, E. S., & Cook, J. K. 1999. Politics and institutionalism: Explaining durability and change. ***Annual Review of Sociology,*** 25: 441–466.

Crevier, D. 1994. ***AI: The tumultuous history of the search for artificial intelligence.*** New York: Basic Books.

David, P. A. 1985. Clio and the economics of QWERTY. ***American Economic Review,*** 75: 332–337.

Davis, G., & Marquis, C. 2005. Prospects for organization theory in the early twenty-first century: Institutional fields and mechanisms. ***Organization Science,*** 16: 332–343.

Dosi, G., & Nelson, R. R. 2013. The evolution of technologies: An assessment of the state-of-the-art. ***Eurasian Business Review,*** 3: 3–46.

Downing, P. 1977. On the creation and use of English compound nouns. ***Language,*** 53: 810–842.

Durand, R., & Paolella, L. 2013. Category stretching: Reorienting research on categories in strategy, entrepreneurship, and organization theory. ***Journal of Management Studies,*** 50: 1100–1123.

Durand, R., & Vergne, J. P. In press. Asset divestment as a response to media attacks in stigmatized industries. ***Strategic Management Journal***.

Economic Classification Policy Committee 1994. ***Economic concepts incorporated in the standard industrial classification industries of the United States.*** Available at https://www.census.gov/eos/www/naics/history/docs/report_1.pdf

Emirbayer, M., & Mische, A. 1998. What is agency? ***American Journal of Sociology,*** 103: 962–1023.

Engle, R. F., & Granger, C. W. J. 1987. Cointegration and error correction: Representation, estimation and testing. ***Econometrica,*** 55: 251–276.

Etzion, D., & Ferraro, F. 2010. The role of analogy in the institutionalization of sustainability reporting. ***Organization Science,*** 21: 1092–1107.

Farnetani, E., Torsello, C. T., & Cosi, P. 1988. English compound versus non-compound noun phrases in discourse: An acoustic and perceptual study. ***Language and Speech,*** 31: 157–180.

Garud, R., Jain, S., & Kumaraswamy, A. 2002. Institutional entrepreneurship in the sponsorship of common technological standards: The case of Sun Microsystems and Java. ***Academy of Management Journal,*** 45: 196–214.

Garud, R., & Kumaraswamy, A. 1993. Changing competitive dynamics in network industries: An exploration of Sun Microsystems' open systems strategy. ***Strategic Management Journal,*** 14: 351–369.

Garud, R., & Kumaraswamy, A. 2010. Path dependence or path creation? ***Journal of Management Studies,*** 47: 760–774.

Garud, R., & Rappa, M. 1994. A socio-cognitive model of technology evolution: The case of cochlear implants. ***Organization Science,*** 5: 344–362.

Gash, D. C., & Orlikowski, W. 1991. ***Changing frames: Towards an understanding of information technology and organizational change.*** Working paper No. 3320-91-MSA, Sloan School of Management, MIT, Cambridge, MA.

Gatland, K., & Jefferis, D. 1978. ***The world of the future: Future cities.*** London: Usborne.

Giegerich, H. J. 2004. Compound or phrase? English noun-plus-noun constructions and the stress criterion. ***English Language and Linguistics,*** 8: 1–24.

Gort, M., & Klepper, S. 1982. Time paths in the diffusion of product innovations. ***Economic Journal,*** 92: 630–653.

Granqvist, N., Grodal, S., & Woolley, J. 2013. Hedging your bets: Executives' market labeling strategies in nanotechnology. ***Organization Science,*** 24: 395–413.

Gurses, K., & Ozcan, P. In press. Entrepreneurship in regulated markets: Framing contests and collective action to introduce pay TV in the US. ***Academy of Management Journal***.

Habibullah, M., & Eng, Y. 2006. Does financial development cause economic growth? A panel data dynamic analysis for the Asian developing countries. ***Journal of the Asia Pacific Economy,*** 11: 377–393.

Hannan, M. T., & Freeman, J. 1989. ***Organizational ecology.*** Cambridge, MA: Harvard University Press.

Hannan, M. T., Polos, L., & Carroll, G. R. 2007. ***Logics of organization theory, audiences, codes ecologies.*** Princeton, NJ: Princeton University Press.

Hargadon, A. 2003. ***How breakthroughs happen: The surprising truth about how companies innovate.*** Cambridge, MA: Harvard Business School Press.

Hedström, P., & Swedberg, R. 1996. Social mechanisms. ***Acta Sociologica,*** 39: 281–308.

Henderson, M. R., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. ***Administrative Science Quarterly,*** 35: 9–31.

Hockstein, N. G., Gourin, C. G., Faust, R. A., & Terris, D. J. 2007. A history of robots: From science fiction to surgical robotics. ***Journal of Robotic Surgery,*** 1: 113–118.

Hsu, G. 2006. Jacks of all trades, masters of none: Audiences' reactions to spanning genres in feature film production. ***Administrative Science Quarterly,*** 51: 420–450.

Hsu, G., & Grodal, S. 2015. Category taken-for-grantedness as a strategic opportunity: The case of light cigarettes, 1964-1993. ***American Sociological Review,*** 80: 28–62.

Hsu, G., & Hannan, M. T. 2005. Identities, genres, and organizational forms. ***Organization Science,*** 16: 474–490.

Hsu, G., Hannan, M. T., & Kocak, O. 2009. Multiple category memberships in markets: An integrative theory with two empirical tests. ***American Sociological Review,*** 74: 150–159.

Jones, C., Maoret, M., Massa, F., & Svejenova, S. 2012. Rebels with a cause: Formation, contestation, and expansion of the de novo category "modern architecture," 1970–1975. ***Organization Science,*** 23: 1523–1545.

Justesen, M. 2008. The effect of economic freedom on growth revisited: New evidence on causality from a panel of countries 1970–1999. ***European Journal of Political Economy,*** 24: 642–660.

Kahl, S. J. 2007. Considering the customer: Determinants and impact of using technology. ***Academy of Management Best Paper Proceedings***.

Kaplan, S., & Orlikowski, W. J. 2013. Temporal work in strategy making. ***Organization Science,*** 24: 965–995.

Kaplan, S., & Tripsas, M. 2008. Thinking about technology: Applying a cognitive lens to technical change. ***Research Policy,*** 37: 790–805.

Kennedy, M. T. 2008. Getting counted, markets, media reality. ***American Sociological Review,*** 73: 270–295.

Kennedy, M. T., Chok, J. I., & Liu, J. 2012. What does it mean to be green? The emergence of new criteria for assessing corporate reputation. In M. Barnett & T. Polock (Eds.), ***The Oxford handbook of corporate reputation:*** 69–93. London: Oxford University Press.

Kennedy, M. T., & Fiss, P. C. 2013. An ontological turn in categories research: From standards of legitimacy to evidence of actuality. ***Journal of Management Studies,*** 50: 1138–1154.

Kennedy, M. T., Lo, J. Y.-C., & Lounsbury, M. 2010. Category currency: The changing value of conformity as a function of ongoing meaning construction. ***Research in the Sociology of Organizations,*** 31: 369–397.

Khaire, M., & Wadhwani, R. D. 2010. Changing landscapes: The construction of meaning and value in a new market category modern Indian art. ***Academy of Management Journal,*** 53: 1281–1304.

Kirsch, D. 2000. ***The electric vehicle and the burden of history.*** Newark, NJ: Rutgers University Press.

Klepper, S. 1997. Industry life cycles. ***Industrial and Corporate Change,*** 6: 145–182.

Klepper, S. 2002. The capabilities of new firms and the evolution of the U.S. automobile industry. ***Industrial and Corporate Change,*** 11: 645–666.

Lieber, R. 1983. Argument linking and compounds in English. ***Linguistic Inquiry,*** 14: 251–285.

Linoff, V. (Ed.). 2000. ***The typewriter: An illustrated history.*** New York: Dover.

Lounsbury, M., Ventresca, M. J., & Hirsch, M. 2003. Social movements, field frames and industry emergence:

A cultural-political perspective on U.S. recycling. ***Socio-economic Review,*** 1: 71–104.

Lupyan, G., Rakison, D. H., & McClelland, J. L. 2007. Language is not just for talking: Redundant labels facilitate learning of novel categories. ***Psychological Science,*** 10: 1077–1083.

Moreau, C. P., Markman, A. B., & Lehmann, D. R. 2001. "What is it?" Categorization flexibility and consumers' responses to really new products. ***Journal of Consumer Research,*** 27: 489–498.

Murmann, J. P., & Frenken, K. 2006. Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. ***Research Policy,*** 35: 925–952.

Murphy, G. L. 2002. ***The big book of concepts.*** Cambridge, MA: MIT Press.

Navis, C., & Glynn, M. A. 2010. How new market categories emerge: Temporal dynamics of legitimacy, identity, and entrepreneurship in satellite radio, 1990–2005. ***Administrative Science Quarterly,*** 55: 439–471.

Ocasio, W. 2011. Attention to attention. ***Organization Science,*** 22: 1286–1296.

Orlikowski, W., & Gash, D. C. 1994. Technological frames: Making sense of information technology in organizations. ***ACM Transactions on Information Systems,*** 12: 174–207.

Ozcan, P., & Santos, F. M. In press. The market that never was: Turf wars and failed alliances in mobile payments. ***Strategic Management Journal***.

Peirce, C. S. 1958. ***Collected papers of Charles Sanders Peirce.*** Cambridge, MA: Harvard University Press.

Plein, C. L. 1991. Popularizing biotechnology: The influence of issue definition. ***Science, Technology, & Human Values,*** 16: 474–490.

Pontikes, E. G. 2012a. Two sides of the same coin: How ambiguous classification affects multiple audiences' evaluations. ***Administrative Science Quarterly,*** 57: 81–118.

Pontikes, E. G. 2012b. ***Fitting in or starting new? An analysis of invention, constraint, and the emergence of new categories in the software industry.*** Working paper No. 12-61, University of Chicago, Chicago.

Porter, M. 1985. ***Competitive advantage.*** New York: Free Press.

Rao, H. 1994. The social construction of reputation: Certification contests, legitimation, and the survival of organizations in the American automobile industry: 1895–1912. ***Strategic Management Journal,*** 15: 29–44.

Rao, H. 2008. ***Market rebels: How activists make or break radical innovation.*** Princeton, NJ: Princeton University Press.

Riggs, W., & von Hippel, E. 1994. Incentives to innovate and the sources of innovation: The case of scientific instruments. ***Research Policy,*** 23: 459–469.

Rosa, J. A., Porac, J. R., Runser-Spanjol, J., & Saxon, M. S. 1999. Sociocognitive dynamics in a product market. ***Journal of Marketing,*** 63: 64–77.

Rosenbloom, R., & Cusumano, M. 1987. Technological pioneering and competitive advantage: The birth of the VCR industry. ***California Management Review,*** 29(4): 51–76.

Ruef, M., & Patterson, K. 2009. Credit and classification: The impact of industry boundaries in nineteenth-century America. ***Administrative Science Quarterly,*** 54: 486–520.

Sahal, D. 1985. Technological guideposts and innovation avenues. ***Research Policy,*** 14: 61–82.

Santos, F. M., & Eisenhardt, K. M. 2009. Constructing markets, shaping boundaries: Entrepreneurial power in nascent fields. ***Academy of Management Journal,*** 52: 643–671.

Schumpeter, J. A. 1934. ***Theory of economic development.*** Cambridge, MA: Harvard University Press.

Scientific American. 1867. Type writing machine, 17(1): 3.

Seidel, V., & O'Mahony, S. 2014. Managing the repertoire: Stories, metaphors, prototypes and concept coherence in product innovation. ***Organization Science,*** 25: 691–712.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. ***Organization Science,*** 11: 448–469.

Shapiro, C., & Varian, H. 1999. The art of standards wars. ***California Management Review,*** 41(2): 8–32.

Steyvers, M., & Tenenbaum, J. B. 2005. The large-scale structure of semantic networks: Statistical analyses and a model of semantic growth. ***Cognitive Science,*** 29: 41–78.

Suarez, F. F., Grodal, S., & Gotsopoulos, A. 2015. Perfect timing? Dominant category, dominant design, and the window of opportunity for firm entry. ***Strategic Management Journal,*** 36: 437–448.

Teece, D. J. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. ***Research Policy,*** 15: 285–305.

Tirole, J. 1988. ***The theory of industrial organization.*** Cambridge, MA: MIT Press.

Tushman, M., & Rosenkopf, L. 1992. Organizational determinants of technological change: Towards a sociology of technological evolution. ***Research in Organizational Behavior,*** 14: 311–347.

Utterback, J. 1994. ***Mastering the dynamics of innovation.*** Cambridge, MA: Harvard University Press.

Utterback, J. M., & Abernathy, W. 1975. A dynamic model of product and process innovation. ***Omega,*** 3: 639–656.

Utterback, J. M., & Suarez, F. 1993. Technology, competition and industry structure. ***Research Policy,*** 22: 1–21.

Vergne, J. P., & Durand, R. 2010. The missing link between the theory and empirics of path dependence: Conceptual clarification, testability issue, and methodological implications. ***Journal of Management Studies,*** 47: 736–759.

von Hippel, E. 1988. ***The sources of innovation.*** New York: Oxford University Press.

Vygotsky, L. 1986. ***Thought and language.*** Cambridge, MA: MIT Press.

Weber, K., Heinze, K., & DeSoucey, M. 2008. Forage for thought: Mobilizing codes for the market for grass-fed meat and dairy products. ***Administrative Science Quarterly,*** 53: 529–567.

Weick, K. E. 1979. ***The social psychology of organizing.*** New York: Random House.

Wooldridge, J. 2013. ***Introductory econometrics: A modern approach.*** Cincinnati, OH: South-Western.

Wry, T., Lounsbury, M., & Jennings, P. D. 2014. Hybrid vigor: Securing venture capital by spanning categories in nanotechnology. ***Academy of Management Journal,*** 57: 1309–1333.

Yamauchi, T., & Markman, A. B. 1998. Category learning by inference and classification. ***Journal of Memory and Language,*** 39: 124–148.

Yoxen, E. 1987. Seeing with sound: A study of the development of medical imaging. In W. Bijker, T. Hudges, & T. Pinch (Eds.), ***Social construction of technological systems:*** 273–296. Cambridge, MA: MIT Press.

Zerubavel, E. 1997. ***Social mindscapes: An invitation to cognitive sociology.*** Cambridge, MA: Harvard University Press.

Zollo, M., & Winter, S. G. 2002. Deliberate learning and the evolution of dynamic capabilities. ***Organization Science,*** 13: 339–351.

Zuckerman, E. W. 1999. The categorical imperative: Securities analysts and the illegitimacy discount. ***American Journal of Sociology,*** 104: 1398–1438.

Zuckerman, E. W. 2000. Focusing the corporate product: Securities analysts de-diversification. ***Administrative Science Quarterly,*** 45: 591–619.

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