

DOMINANT DESIGNS, INNOVATION SHOCKS, AND THE FOLLOWER'S DILEMMA

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A dominant design is thought to usher in a period of intense competition based on cost, causing an often-fierce industry shakeout. We aim to challenge the foundations of the dominant design literature, and develop new insights about the evolution of competition. We argue that strategic repositioning and elevated exit rates are often observed long before the emergence of a dominant design, and that a key cause is the introduction of a particular product for which demand is unexpectedly high (an “innovation shock”). This introduction creates a dilemma for followers, which we suggest is resolved based on followers’ comparative adjustment costs. We test implications of these ideas on data from the early U.S. auto industry, treating Ford’s Model T as the innovation shock. Copyright © 2013 John Wiley & Sons, Ltd.

INTRODUCTION

The notion of “dominant design” has long been featured prominently in the literatures on industry evolution, technology management, and strategy. Since Utterback and Abernathy’s (1975, 1978) seminal articles proposing a model of industry life cycles, numerous studies assume, investigate, or develop the idea that the emergence of a dominant design leads to an industry shakeout (elevated net exit rates over a short period of time) as cost becomes the primary basis of competition. Seminal contributions to business strategy such as Porter (1980), Teece (1986), and Anderson and Tushman (1990) also have been influenced by, and have contributed to, theories of dominant design.

While highly influential, theories of dominant design suffer from several shortcomings. First, scholars have argued that the theories lack a

clear causal logic explaining the role of dominant designs in industry evolution (e.g., Murmann and Frenken, 2006). Second, dominant design theories have been criticized for underemphasizing the role of demand in industry evolution in favor of engineering imperatives on the supply side (e.g., Klepper, 1996, 1997). Third, theories of dominant design are limited in their import for strategic management because dominant designs can only be identified in retrospect (e.g., Utterback and Suarez, 1993). Moreover, because the theories imply a very short menu of strategic responses by firms (e.g., either imitate the dominant design or exit), their contributions to managerial decision making are quite restricted (Murmann and Frenken, 2006).

In this paper, we aim to provide a new perspective on dominant designs that addresses the above shortcomings. We first argue that the major shift in industry dynamics and strategic choice often occurs not when a product design or architecture becomes dominant (i.e., comes to account for a majority of market share), but much earlier. The shift instead occurs upon the introduction of a pioneering new product design by a single firm,

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the demand for which surges in an unanticipated way. We call this shift an “innovation shock.” Examples of such pioneering products include the 1906 Underwood Model 5 typewriter, the 1908 Ford Model T, the 1952 RCA color television, the 1984 Apple Macintosh computer, the 2001 Apple iPod, and the 2007 Apple iPhone. We also suggest that while dominant designs do not typically initiate shakeouts, shakeouts sometimes do emerge as an *outcome* of the strategic dynamics launched by an innovation shock. When a dominant design does emerge, it can exacerbate a shakeout that is already underway.

Second, we characterize the industry dynamics that an innovation shock initiates—what we call “The Follower’s Dilemma.” While dominant design theories consider only imitation and exit as strategic responses, we suggest that an innovation shock can also lead to strategic repositioning by incumbents, and to changes in entry patterns. We develop the idea that an incumbent’s ability to reposition away from the firm that initiated the innovation shock is determined by the incumbent’s *comparative adjustment costs*. Firms are thus not entirely at the mercy of technological forces in the environment as suggested by dominant design theories. To the contrary, we suggest that strategic management and managerial decision making play important roles in determining a firm’s best response to, and therefore its likelihood of survival following, an innovation shock.

We conduct an empirical analysis of the early U.S. auto industry to test several implications of these arguments. The auto industry was the original setting in which Abernathy and Utterback (1975, 1978) developed the concept of a dominant design, based in part on Abernathy’s (1978) historical research. Using a more comprehensive dataset than was available to earlier researchers on dominant design in automobiles, we show that a period of increased exits in the U.S. auto industry began shortly after Ford’s introduction of the Model T, not later (i.e., around 1923) as had been assumed in earlier studies. The elevated exit rates suggest that it was the innovation shock represented by the Model T more than a decade earlier, not the later adoption of a common product architecture across the industry as a whole (a “dominant design”) that marked the transition between the initial stage of the industry’s evolution and the following stages of rising exit rates and the ultimate shakeout. While the eventual

emergence of a dominant design did *accelerate* this shakeout, it did not *spark* the shakeout.

We also examine firms’ responses to the introduction of the Model T as a way to begin to explore the role of comparative adjustment costs in conditioning the Follower’s Dilemma. We show that, consistent with resource/capabilities approaches to strategy and concepts from organizational ecology, the firms most likely to exit the segment defined by the Model T while remaining active in the industry were smaller, younger firms with a broader base of technological knowledge (by our proxy). We suggest that these findings are consistent with our arguments about comparative adjustment costs, while not inconsistent with other theories of industry evolution such as those based on Klepper (1996). We conclude by suggesting that a more complete theory of the Follower’s Dilemma requires greater understanding of the comparative adjustment costs that various kinds of firms face in responding to an innovation shock.

LITERATURE REVIEW AND THEORETICAL DEVELOPMENT

The notion of an industry life cycle has a substantial history in research in economics, management, strategy, and innovation. In early work, Abernathy (1978), Utterback and Abernathy (1975), and Sahal (1985) argued that industries tend to shift from an initial stage of product design experimentation by firms to a stage featuring process innovation aimed at cost reduction. At some point, this experimentation leads to the emergence of a dominant design, defined as “the concepts that define how the components of the product interact or relate to each other” (Christensen, Suarez, and Utterback, 1998: S208). The basis of competition then shifts from alternate product designs to low-cost production of products that are based on the dominant design. This cost competition leads to an industry shakeout, which is marked by a substantial portion of industry participants exiting during a brief window of time.

In Anderson and Tushman’s (1990) model of industry evolution, the dominant design marks the transition from an era of technological ferment to one of incremental improvements on the dominant design. Their model distinguishes radical innovations from dominant designs, proposing that a “discontinuous” innovation ushers in a period of

experimentation, which ceases with the emergence of the dominant design. In this characterization of industry evolution, a dominant design emerges through a variation-selection-retention dynamic, which poses real, albeit poorly understood, challenges for managers (Anderson and Tushman, 1990). The dominant design concept has also helped shape the strategy literature on entry timing (e.g., Lieberman and Montgomery, 1998; Mitchell, 1989; Tegarden, Hatfield, and Echols, 1999).

While the dominant design concept is not always considered in the organizational ecology literature, that literature has sometimes used the idea of a “dominant architectural solution” to demarcate historical period (e.g., Carroll and Hannan, 1995; Wade, 1995). The themes associated with the dominant design model emerge once again in this literature, which describes a period of high rates of experimentation with technical and organizational architectures, ultimately followed by a period of concentration and lower levels of variation, etc. The ecology literature implies that legitimation processes drive the selection of a dominant solution, so that such a solution is not necessarily the most efficient or effective from a technical standpoint.

A key feature of the organizational ecology perspective on industry dynamics is that it allows for differential levels of entry and exit in different segments of the industry. Beginning with Carroll (1985), researchers have studied how generalist vs. specialist firm entry rates may vary based on the size of the niche they occupy in the overall population. Consistent with industry life cycle research, over time density tends to decrease while concentration increases, yet allowance is made for the possibility of viable segments of the industry far from the market center. This part of the literature is relevant to our treatment of the Follower’s Dilemma. However, implications for strategic decisions by firms confronting a period of elevated exit rates remain underdeveloped in the ecology literature.

Innovation researchers and economists have also developed insights regarding the types and timing of innovation that use the dominant design concept. Henderson and Clark’s (1990) seminal paper on architectural innovation, for example, outlines the implications of distinguishing another dimension of product innovation beyond radical vs. incremental. In particular, they define an “architectural innovation” as involving a

reconfiguration of both demand-side and supply-side arrangements for commercializing the industry’s dominant design. Jovanovic and MacDonald (1994) developed a formal model depicting the pattern of increasing density and entry until an event such as a new technological solution triggers a shakeout. The shakeout involves a drop in entry and a rise in exits, leading to a decline in the overall number of firms. This model depends on the explicit assumption that the technological shock precipitating the shakeout is exogenous to the industry.

Klepper’s (1996) seminal model of industry evolution produces the same pattern of entry, exit, and density as classic dominant design theory, but the key dynamic is not the emergence of a dominant design, but the operation of increasing returns to scale over time. In the model, early entrants eventually gain an insuperable cost advantage over later entrants into the industry because the returns to investment in cost-reducing process R&D increase with scale. Thus, as firms grow, the gap in costs between early entrants and later entrants grows larger, leading later entrants to exit. A dominant design does eventually emerge in Klepper’s model, as firms imitate each other’s innovations and customer preferences converge. But the key driver of exit is not the (later) emergence of a dominant design, but process R&D investment, which is operating from the industry’s very beginning. Klepper (2002, 2006) finds evidence for this dynamic in multiple industries, and also finds that entrants with prior experience in related industries are much more likely to survive than *de novo* entrants.

Our own approach builds on and extends this literature in several ways. First, similar to Klepper, we argue that dominant designs as traditionally understood do not spark shakeouts, as the dominant design literature has largely assumed. Differently from Klepper, however, we argue that an innovation shock produced by a single firm is what often initiates a period of increased exit rates, rather than the gradual operation of increasing returns and prior experience mechanisms among several early entrants (though these latter mechanisms, as well as the emergence of a traditional dominant design, may be important in sustaining or accelerating the increase in exit rates). Similar to population ecology, our approach takes into account that many industries can be segmented in ways that open up strategic opportunities that

the traditional dominant design literature does not typically consider. Differently from population ecology, however, shakeouts are not sparked by increasing density alone, but by the introduction of an innovation shock.

Differently than Henderson and Clark's (1990) concept of architectural innovation, our notion implies that an innovation shock occurs before a dominant design has emerged, and does not necessarily involve disruption to both demand-side and supply-side linkages. Somewhat similar to Jovanovic and MacDonald (1994), we postulate that a new technological solution drives increases in exit rates (as well as repositioning) and can culminate in a shakeout. A critical point of difference is that, in our account, the solution is generated inside the industry, rather than outside it.

We define an innovation shock as the introduction by a firm of a new product that stimulates a substantial surge and acceleration in demand for that product—a surge that was generally unexpected by market participants. The new product, we suggest, is based on a new configuration of attributes that might include radical or incremental innovations, and might include components developed in-house or by other firms. The critical factors that identify the innovation shock are that the new product represents a novel *composition* of elements (even if many individual elements already existed in rival products) and that it benefits from a large, unanticipated surge in demand. We suggest that an innovation shock does not typically launch new industries. Rather, it comes along well into the industry's early development.

An innovation shock thus reveals information about demand that implies the discovery of a “pool of revenue.” The firm introducing the innovation shock is therefore in the position to reap a sudden windfall, and to potentially capture a durable first mover advantage. The financial returns and the potential for developing longer-term advantage do not, however, go unnoticed by rivals and potential entrants. The sudden and surprising revelation that a new composition of elements is highly desired reshapes rivals' and potential competitors' expectations. In the wake of the demand surge, rivals and potential entrants must reassess their strategic positions in the market.

The arrival of an innovation shock forces rivals to consider three strategic responses: imitation, repositioning, and exit, and leads potential competitors to consider entry and imitation. For

rivals, failing to respond to the newly revealed demand information, thereby allowing the firm introducing the innovation shock to build competitive advantage uncontested, greatly increases the likelihood of financial loss and exit. This motivates rivals to strategically respond. We describe each strategic response and explain why the innovation shock stimulates it. In what follows, we refer to the product or service design that acts as an innovation shock as “ISD” for “innovation shock design.” (In earlier drafts of this paper, we used the Latin term *compositio desiderata* to describe an innovation shock design.)

Imitating

Rival firms, which by definition are not offering the ISD at the time of its introduction, face powerful economic pressures to respond and compete for a portion of the profit pool discovered by the innovator. It is well known that supernormal returns (i.e., economic rents) attract imitators: both incumbents repositioning to compete for these returns and new entrants (we discuss entry below). Imitation can be an economically viable strategic response for incumbents for three reasons. First, imitating the innovator's composition of elements can lead to the capture of a share of the newly discovered profit pool. For instance, the unanticipated surge in demand may make it difficult for the innovator to satisfy all the latent demand for the ISD. Second, investing in low-cost production, a robust supply chain, developing distribution channels, brand capital, and any other co-specialized and complementary assets (Teece, 1986) needed to take full advantage of the new and growing demand (and to create imitation barriers) takes time, giving imitators a chance to respond (e.g., Markides and Geroski, 2004).

Rivals who quickly imitate may be able to copy some or all of the investments needed to serve the market, which diminishes or neutralizes potential advantages that otherwise might accrue to the innovator. If so, then even if imitation eventually instigates price competition, the innovator and imitators will share in the revenue pool that remains because, as their investments grow to serve the quickly expanding market, so too will grow the barriers faced by others considering entry. Third, if rivals don't respond by imitating, they risk allowing the innovator to gain a longer-term competitive advantage and resources

that can be used against them. At some point, it can become virtually impossible for those who are late to imitate to successfully challenge the innovator.

Repositioning

With the innovator having identified substantial demand from the information shock and rapidly accumulating advantage, rivals could choose to avoid direct competition by repositioning distantly from the ISD. With the rapid acceleration in demand for the ISD, rivals positioned in a niche near the ISD before it was introduced will likely experience falling demand as its customers flock to the new composition of elements demanded. In other words, the closer the rival's niche is to the ISD when it was introduced, the less demand the rival will realize once the innovator launches the new product or service (unless it imitates as described above). If a rival's demand decreases and that rival does not imitate, then remaining viable in the industry requires repositioning to a more distant niche. The more successful the ISD, the more distant must be the rival's position. Of course, distant repositioning requires the existence of residual demand in alternate market segments not served well by the ISD and its underlying co-specialized investments. If sufficient heterogeneity in customer preferences exists and the ISD is unable to serve all demand, niche positions will exist and may be economically viable.

Exiting

With the ISD attracting imitators and remaining available niche spaces attracting firms that are repositioning, capturing profit will become increasingly difficult. Competition will drive rivals to pursue sources of competitive advantage, leaving those unable to accumulate advantage to be selected out. Those rivals that choose to compete with the innovator of the ISD will seek to acquire and/or build capabilities to capture economies of scale and scope, network externalities, etc., in order to compete. As rivals become stronger, the level of competition will ratchet upward, and exit rates will rise (e.g., Barnett, 2008).

Entering

The arrival of the innovation shock generates knowledge about the constellation of product

features needed to access the newly discovered pool of revenue, which may stimulate entry of two kinds. First, firms operating in other industries may choose to enter if they possess resources and capabilities that are sufficiently redeployable or fungible to compete with the innovator. For instance, firms that have competed in related industries or markets, e.g., component manufacturers or firms that compete in other geographic markets, may now find that they can compete in the focal industry because the innovation shock reveals new information about not only the magnitude of profits available but also the capabilities and resources needed to capture a share of those profits. It is precisely the availability of this new information that reduces the uncertainty of entering by imitation.

De novo entry also can be stimulated by the arrival of an innovation shock. Because the composition of product and service elements that attracts a revenue pool is now known, potential entrants can now calculate their expected profits upon entry with greater precision. The reduction in uncertainty not only occurs for products and services near the ISD but also occurs for distant niches, which become better defined. Reduction in demand uncertainty can therefore stimulate additional entry across all industry positions.

On the other hand, if an innovation shock generates a large enough first mover advantage, it could actually reduce entry into the focal industry or industry position of the ISD. The firm introducing the innovation shock may be able to capture and retain a large enough share of the demand quickly enough that entry is deterred. We suggest that the pattern of entry following an innovation shock will depend heavily on the degree of industry segmentation. For example, if the degree of segmentation is not too high, an innovation shock may generate a significant first mover advantage that deters entry into the segment in which the shock was introduced, while also deterring entry into other segments. On the other hand, when segmentation is high, an ISD in one segment may not have a major negative effect on entry into a different segment. Entry into neighboring segments may even increase if the ISD stimulates ideas for how to incorporate elements of the novel design into products offered in those other segments.

Primary implications

Our perspective implies that strategic responses to the arrival of an innovation shock will take time—even a decade or more—to play out. For instance, a robust stream of research in organizational ecology argues that organizations vary in their degrees of inertia, defined as the inverse of adaptation speed (e.g., Amburgey, Kelly, and Barnett, 1993; Barnett and Freeman, 2001; Carroll and Hannan, 2000; Dowell and Swaminathan, 2000; Hannan and Freeman, 1984). Therefore, even if all firms become aware of the information shock at the same time, not all firms will respond immediately. The greater an organization's inertia (which often is proxied in the population ecology literature by factors such as organizational age and size), the longer it will take to undertake “core” change and repositioning.

On a different dimension, the narrower the technological base of the firm prior to the introduction of an innovation shock, the less likely it will be able to switch segments quickly if doing so requires a different technology base. This lag in adjustment is due to the cost and time required to acquire, develop, and apply the requisite knowledge (e.g., Dierickx and Cool, 1989). Because of heterogeneity in inertia and in prior knowledge among rivals, response times will vary significantly after an innovation shock is introduced. Many slow responders will be forced to exit.

A second implication of our perspective is that a dominant design emerges long after the ISD, in part because it is an endogenous outcome of the innovation shock. Because the impact of the emergence of a dominant design on exit rates occurs only after its emergence, its effects come much later in the industry's life cycle. Thus, after an innovation shock is introduced, competitive intensity will increase in the industry segment in which it is introduced, and possibly in adjacent segments as well. Competitive intensity will continue to increase over time because, after the innovation shock arrives, an increasing number of firms try to execute their best strategic response. With increasing competitive intensity, firms find it in their interest to search for sources of competitive advantage, creating additional pressures for slower and weaker firms to exit. Imitating, repositioning, and searching for competitive advantage, as well as attempts to neutralize others' competitive advantages, will

in turn naturally lead to architectural similarity of products within each industry segment (even though individual features may continue to evolve as part of the competitive process). For instance, a rival may reposition to closely copy the ISD by imitating the first mover's product or service features exactly, or may offer more (fewer) incremental innovative product or service features to the same product architecture in order to achieve a price premium (or cost advantage). If numerous firms choose to imitate the first mover in these ways, the industry segment in which the innovation shock was introduced becomes more homogeneous in terms of the features of the segment's products and services. Eventually, the homogenization may spill over to adjacent segments, ultimately giving rise to a dominant design for the industry as a whole. By the end of this process, the eventual dominant design may contain some of, but not necessarily all, the features of the ISD.

Once the dominant design is established, competition based on economies of scale and incremental, component-level innovation will lead to further exit, as Abernathy and Utterback (1978) proposed. Firms not producing the dominant design, and unable to switch to it, are likely to exit the industry (Anderson and Tushman, 1990). But the exits associated with the emergence and establishment of the dominant design come much later in the industry's development, and therefore cannot explain the elevation in exit rates that occurs earlier, around the time that the innovation shock was introduced. Indeed, the fact that researchers define the dominant design as the majority of industry participants providing products with the same architecture (e.g., Tegarden *et al.*, 1999) itself suggests that much of the competitive action occurs long before the dominant design becomes established.

Who chooses which strategy?

The four strategic responses we describe above are, of course, hardly new to the strategy literature. Indeed, they represent foundational strategic issues, and there is a robust and extensive literature to understand many of the consequences of these decisions (e.g., Grant, 2008). What is absent from much of the foundational literature, however, is a clear articulation of what triggers such responses. For instance, what processes or events generate the differentiation and low-cost positions that Porter

describes (1980, 1985)? We suggest that an innovation shock is an important antecedent for the four strategic responses. Practitioners and scholars alike would benefit from a theory that predicts which strategy a rival or potential entrant will choose in response to an innovation shock, and when they will choose it. Although our paper does not offer such a complete theory, we nonetheless sketch the outline of a theory that makes some testable predictions, and can serve as a basis for future theorizing. Our thinking is based on the idea that an organization's likelihood of successfully repositioning in response to an innovation shock depends upon its initial stock of technological knowledge and human, physical, and other intangible resources on the one hand, and the comparative adjustment costs it faces of acquiring, reconfiguring, or eliminating resources as needed to support a new strategic position (e.g., Teece, Pisano, and Shuen, 1997).

Comparative adjustment costs

The arrival of an innovation shock creates an exigent environment in which a swift response is required. Delay is costly due to the very real threat of obsolescence, the likely exacerbation of poor positioning as competitors reposition, and the limited availability of viable mergers and niches. Yet despite the urgency, organizations are constrained by inertia, but more broadly by what we call *comparative adjustment costs*: the costs and risks of moving from an existing strategic position to each of the alternative positions of imitating, differentiating, or exiting (relative to other rivals' adjustment costs). These adjustment costs differ for different organizations, hence our reference to *comparative* adjustment costs. We suggest three categories of adjustment costs, though what we offer next is not so much intended as an entirely novel theory, but rather a synthesis of factors known to affect mobility within an industry.

The three broad categories of determinants of comparative adjustment costs that we consider are: (1) internal resources, knowledge, and capabilities; (2) internal organization structure and incentives; and (3) relationships with external parties such as suppliers, buyers, and regulators. The first category includes the firm's financial strength. Firms with greater financial resources can obviously survive longer than those firms that face more severe

capital constraints. It also includes the technological knowledge currently embedded in the firm's human and physical assets. We suggest that the broader the knowledge embedded in the firm's assets, the lower will be the firm's adjustment costs as it adjusts from one position to another. By contrast, firms whose embedded knowledge is narrower will face higher adjustment costs as they reposition. These higher adjustment costs arise because acquiring new knowledge, especially if some of it is tacit, is often subject to a number of failures in the strategic factors market (Barney, 1986). Markets for knowledge often suffer from severe information asymmetry (e.g., Caves, Crookell, and Killing, 1983). Technology is also often embedded or lumped together with other technologies that are less desirable to the buyer, creating indivisibilities that hinder quick acquisition and development (e.g., Penrose, 1959; Teece, 1982). Learning new knowledge also is often subject to time-compression diseconomies, making quick learning infeasible (e.g., Dierickx and Cool, 1989). While knowledge can be gained by acquiring rivals or suppliers or through relationships with other firms or with outside institutions such as universities, there are often significant costs in the acquisition process and in the formation and management of interorganizational relationships. Often, geographic location is important in determining the ease of access to such knowledge. Regardless, however, the more that repositioning requires knowledge that the firm does not currently possess, the greater are the adjustment costs it faces.

Our second category of comparative adjustment cost determinants is internal organization structures and incentives. Organization structures that are rigid and hierarchical with limited ability to support high-powered incentives possess high adjustment costs. The high comparative adjustment costs arise because such firms find it difficult to support new ventures with special incentives and other governance arrangements (Nickerson and Zenger, 2008; Williamson, 1985). Sociologists argue that older, larger firms suffer from structural inertia that is due in large part to the greater accountability to which these more publicly visible firms are subject (Hannan and Freeman, 1984). That said, larger firms also might have larger financial resources that enable them to survive for extended periods even though their comparative adjustment costs may be great.

Finally, in many cases firms will have lower adjustment costs to the extent that they do not have long-term contractual commitments to employees or their unions, to suppliers, to buyers, to government agencies, etc. (Argyres and Liebeskind, 1999; Nickerson and Silverman, 2003). While strong, long-standing relationships with these external parties can be important in reducing adjustment costs if those relationships are built on trust and norms of reciprocity, they can be a hindrance if based more fundamentally on highly formalized contractual or regulatory relationships, as is often the case (e.g., unions in the U.S. auto industry). Comparative adjustment costs associated with repositioning, therefore, are higher to the extent that firms rely on durable legal-contractual commitments.

HYPOTHESES

In this section, we draw on the above discussion of innovation shocks and comparative adjustment costs to develop four testable hypotheses. While there are doubtless other hypotheses that could be developed from our framework, we examine a few major implications that we are able to test on data from the early U.S. auto industry (the industry is described in the next section).

Our first hypothesis concerns the impact of an innovation shock on industry exit. It has been observed that a rise in exit rates often begins after a single pioneering firm introduces an innovation shock. The introduction of Underwood Model 5 in 1906 led immediately to a rise in exits in the typewriter industry, as did the introduction of the RCA color T.V. and the U.S. government's adoption of its technology as a standard in 1952 (Utterback and Suarez, 1993). IBM's introduction of the PC in 1981 encouraged the entry of clonemakers, but it also elevated exit rates such that the net effect was an immediate and severe shakeout (Dinlersoz and MacDonald, 2009). In each of these cases, a single firm transformed the industry by introducing a design with a composition of elements that immediately appealed to a very broad set of customers.

Our contention is that, in many industries, an innovation shock is the central driver of increasing exit rates and eventual industry shakeouts. The competitive responses unleashed by an innovation shock are so intense that the survival of all firms whose products are sold in the same industry or

industry segment are severely threatened. As we noted above, other theories have emphasized different drivers of exits. Population ecology, for example, has emphasized that the force of legitimation that accounts for early industry growth eventually gives way to competition as the density of firms increases beyond what is supportable in the environment (e.g., Carroll and Hannan, 1995). This theory does not feature any special role for one firm or another in driving increased exit rates and the shakeout; rather, density alone is the culprit. It does not afford any role for an ISD introduced by a single firm in causing shakeouts.

The theories of industry evolution due to Klepper and colleagues (e.g., Klepper, 1996, 2002; Klepper and Graddy, 1990) also do not afford a clear role for a single innovating firm. In Klepper's model (Klepper, 1996), for example, the firms most likely to survive are those that entered early and those with pre-entry experience in a related industry. Early entrants are able to build a cost advantage that becomes insuperable due to increasing returns from process R&D as production scale increases. In empirical tests, early entry is usually proxied by firm size (e.g., Klepper, 2002). In Klepper's theory, multiple early entrants could benefit from these advantages. While not inconsistent with Klepper's theory, our argument emphasizes the role of a single firm introducing an innovation shock as a key driver of increased industry exit. We therefore hypothesize that

Hypothesis 1: The effect of an innovation shock on firms' hazard rates of industry exit is positive and significant.

Our next two hypotheses have to do with what we are calling the Follower's Dilemma. Following the introduction of an ISD by a focal firm, incumbent rivals face a number of strategic options, including exiting the industry and repositioning within it. Firms operating in the industry segment in which the ISD is introduced are the most severely affected by it, so their responses are the most urgent. As discussed above, firms face different levels of adjustment costs in responding. Firms that are older are thought (and have been found) to be at greater risk from structural inertia (Hannan and Freeman, 1984). Such firms are also more likely to have rigid, bureaucratic organizational structures and

incentive systems that raise their adjustment costs. In addition, older firms are more likely to have made durable legal-contractual commitments to external parties that inhibit adjustment. Thus, setting aside the option of exiting the industry, which is discussed in regard to Hypothesis 1, inertia makes older firms less likely to reposition away from the industry segment in which an innovation shock is introduced. We therefore hypothesize that

Hypothesis 2: Older incumbents are less likely to reposition away from the industry segment in which an innovation shock is introduced.

Firm size is another variable that is frequently used as a proxy for structural inertia. Large firms are often more highly scrutinized by various audiences, more accountable to them for consistent behavior, and therefore less likely to make strategic changes (Hannan and Freeman, 1984). In addition, large firms typically have made larger fixed investments in complementary assets that are specific to a set of customers (e.g., Ghemawat, 1991). Indeed, these past asset commitments are often an important reason why the firm has been able to grow large in the first place, achieving either economies of scale and scope or effective differentiation (e.g., Chandler, 1990). Moreover, larger firms are thought to suffer from more rigid bureaucracy (e.g., Burns and Stalker, 1961; Thompson, 1967) and lower-powered incentives (Williamson, 1985) that inhibit repositioning. Therefore, we posit that larger firms face higher adjustment costs, and are therefore less likely to strategically reposition following an innovation shock:

Hypothesis 3: Larger incumbents are less likely than other incumbents to reposition away from the industry segment in which an innovation shock is introduced.

The strategy literature has emphasized that sustainable competitive advantage rests on a firm's bundle of unique capabilities and assets, where capabilities based on unique organizational knowledge are often of particular importance (e.g., Dierickx and Cool, 1989; Grant, 1996; Kogut and Zander, 1992; Rumelt, 1984). Moreover, the literature on dynamic capabilities suggests that the "paths" open to a firm at any point in time (i.e.,

its strategic alternatives) are determined by the firm's current "asset position," which includes "technology, intellectual property, complementary assets, customer base, etc." (Teece *et al.*, 1997: 518). We therefore suggest that in many industries (especially those serving consumer markets in which consumer preferences are heterogeneous), the broader a firm's base of technological knowledge, the greater the likelihood of it being able to reposition away from the ISD. Avoiding direct competition with an ISD, we have argued, is often necessary for survival and for eventually gaining competitive advantage. The possibility of repositioning arises because a broader technological base reduces adjustment costs associated with acquiring or internally developing the kinds of extensions to the firm's technology base that are needed to successfully reposition. Thus,

Hypothesis 4: Incumbents with a broader base of technological knowledge are more likely to reposition away from the industry segment in which an innovation shock is introduced and focus instead on a different segment(s).

EARLY AUTO INDUSTRY

To perform our empirical analysis, we rely on an extensive database on the U.S. passenger automobile industry assembled from numerous historical sources by Glenn Carroll and his former students. Various parts of the database have now been analyzed in several published studies (e.g., Argyres and Bigelow, 2007, 2010; Bigelow and Argyres, 2008; Carroll *et al.*, 1996; Dobrev and Carroll, 2003; Dobrev and Kim, 2006; Dobrev, Kim, and Carroll, 2002, 2003). In this section, we describe some of this data, provide historical background, and offer some examples, all in order to suggest the plausibility of our four hypotheses and to illustrate some of the competitive and organizational mechanisms underlying them. The next section describes the database in more detail.

First, consider Figure 1. The year in which it has been assumed that the dominant design emerged fully enough to cause a shakeout is 1923 (e.g., Utterback and Suarez, 1993, 1995). The data show, however, that there were precipitous declines in the number of firms beginning much earlier—in the first decade of the century (see also Table 1). In addition, the United States' formal participation

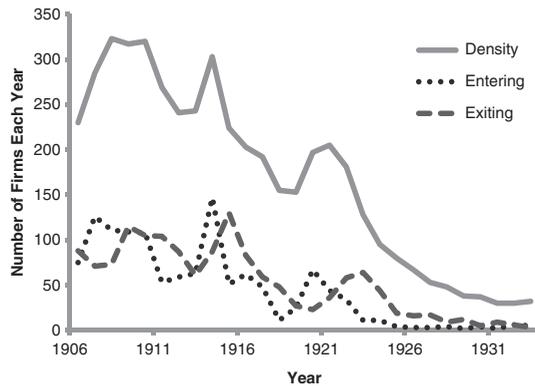


Figure 1. Exit, entry, and density of the early U.S. auto industry

in World War I began in April 1917 and ended in June 1919, which created a surge of new entrants that exceeded exits in 1920. However, by the next year, exits again exceeded entries and the number of firms resumed its decline, not to increase again until after World War II. The reason for the discrepancy in shakeout period dates is that the older data on which Suarez, Utterback and others relied was not comprehensive.

A quite plausible interpretation of our data, then, is that the auto industry shakeout attributed to the mid- and late 1920s actually began much earlier. It picked up speed in the 1920s, but did not begin in that decade. Exit rates were substantial starting in the early 1900s, and were briefly interrupted by a truly exogenous event: World War I and its aftermath. The database unfortunately does not contain information on the war-related production activities of the 1920 entrants. However, it seems likely that some, and perhaps many, of these entrants were hoping to capitalize on knowledge gained from fulfilling government contracts for production of armaments such as personnel carriers, ambulances, tanks, and other war-related industrial goods during the war. Most of these 1920 entrants exited within a few years.

Table 1 also includes figures on Ford's production of the Model T, which began on October 1, 1908, and peaked in 1923. Ford was a dominant player in the industry during this time, as shown by the evolution of its production share. The role of Ford as a dominant player has not been much discussed in analyses of the auto industry life cycle.

The introduction of the Model T was highly anticipated by auto dealers, but Ford was not fully prepared for the tremendous demand it

generated. Production was "to order" during the first several months of its production, but by the spring of 1909, the company found that it lacked capacity to process new orders, and stopped taking them for two months (Nevins, 1954: 396). Ford began construction of its new, larger-scale Highland Park plant in 1909, but it was not completed until 1910. Even as it scrambled to increase production capacity, Ford found that it also lacked adequate marketing and distribution assets to handle the additional volume of output. During 1909–1913, Ford built a network of distribution offices ("branches") as well as several geographically dispersed assembly plants to reduce shipping costs. It also expanded its network of independent dealers (Nevins, 1954: 400–404).

By 1911, Ford was closer to meeting demand. In that year, production increased by 118 percent. In 1912, 1913, 1914, 1915, and 1916, Ford's production levels increased year over year by 12 percent, 114 percent, 83 percent, 63 percent and 48 percent, respectively. In the three years leading up to World War I, Ford accounted for about 50 percent of total industry production. This unanticipated surge of demand for the Model T has been widely written about, and the Model T is widely considered to be the most important car model ever introduced in the auto industry. Its popularity was largely driven by its ease of use, reliability, and low price.

One might think that because the Model T captured over a 50 percent market share at its peak, it was the *de facto* "dominant design." Recall, however, that a dominant design is defined in the literature as a single product *architecture* that becomes widely adopted in an industry, not a single *product* that becomes widely adopted (e.g., Utterback and Suarez, 1993). Indeed, for many years the Model T did not conform to the dominant design identified by Abernathy (1978) because it lacked, among other attributes, a closed body. (The elements of the dominant design for automobiles included internal combustion, water-cooled engine in front, hydraulic brakes on all four wheels, left-hand-side steering wheel, four-gear transmission with shaft or floor shifter, electric ignition, and an all-closed steel body. The Model T did not contain all of these attributes until the 1920s.) As noted above, Abernathy (1978), Suarez and Utterback (1995), and others argue that the dominant design did not emerge until around 1923, whereas the Model T was introduced in late 1908. In any case, our analysis aims to help clarify

Table 1. Entry, exit, and production in the U.S. auto industry

Year	Number of firms	Industry production	Ford's production	Annual increase in Ford's production (%)	Ford's share of industry production (%)
1906	230	24,250	8,729	n/a	36
1907	285	33,200	14,887	71	45
1908	323	43,000	10,202	-31	24
1909	317	63,500	17,771	74	28
1910	320	123,990	32,053	80	26
1911	269	181,000	69,762	118	38
1912	241	199,319	170,211	12	39
1913	243	356,000	202,667	114	47
1914	303	461,500	308,162	83	91
1915	224	548,139	501,492	63	82
1916	203	895,930	734,811	47	25
1917	192	1,525,578	622,351	-15	87
1918	155	1,745,792	435,898	-30	49
1919	153	943,436	820,445	88	67
1920	197	1,651,625	419,517	-2	69
1921	205	1,905,560	903,814	58	80
1922	181	1,686,813	1,179,257	-10	47
1923	128	2,274,185	1,825,766	60	52
1924	95	3,624,717	1,756,880	-6	54
1925	80	3,185,881	1,651,675	-3	45
1926	67	3,735,171	1,377,241	-14	37

See text for sources.

some of the confusion around the dominant design concept.

Ford's production levels dropped dramatically during World War I as its Rouge plant, construction of which began in 1917, was converted to produce Eagle Boats for the U.S. Navy, and as other parts of its production capability were converted for production of tanks and ambulances. In addition, private demand for Ford's cars no doubt dropped during wartime. In 1919, however, the last year of the war, Ford's production surged again. There were more substantial surges in 1921 and 1923.

These figures suggest a plausible alternative explanation for the pattern of exits in the auto industry. Rather than a shakeout simply being caused by the emergence of a dominant design around 1923, it seems quite likely that the shakeout was really started by the tremendous demand for Ford's Model T around 1910–1911. The shakeout gained steam after the dominant design emerged, but was arguably initiated much earlier.

It is also instructive to consider Ford's pricing behavior during this period. During 1908–1922, the price of Ford's Model T fell from \$440 to \$335, a 24 percent drop. An increase to \$393 in 1923 was followed by a decline to \$380 in 1924, and then by another 24 percent drop to \$290 in 1925

(Lester-Steele, 1960). These price declines were made possible by Ford's legendary production system based on interchangeable parts (Hounshell, 1984). (Ford's Model T may have represented process more than product innovation, whereas other innovation shocks may feature more product innovation.) Once again, economic logic suggests that these large price reductions by the dominant player—the player representing 40–50 percent of production output at key points—must have contributed to the elevated exit rates during the dominant design period.

Our price data, which covers 31 percent of the car model years in the population of U.S. auto firms, indicates that the unweighted mean car price during the period of our study was \$2,104, while the median price was \$1,695. Thus, Ford remained positioned in the low-end segment throughout the period. The mean auto price decreased throughout the period, likely reflecting attempts by surviving firms, especially those competing in the lower-price segment, to maintain or reduce their price gaps with Ford.

Sales of Ford's Model T began to fall in 1924, and Ford's production dropped significantly in 1927 as it retooled to introduce the Model A in December of that year. Consumers were beginning

to demand cars with more features than those offered by the relatively “stripped down” Model T (e.g., Kuhn, 1986). But because Ford was slow to introduce higher-priced, more differentiated models, General Motors was able to surpass Ford as market share leader in 1927, and maintained its lead for decades thereafter.

Our interpretation of the evolution of the early U.S. auto industry can be compared with that of Klepper. As noted above, Klepper’s (1996, 2002) model of (and findings regarding) industry shake-outs is based on numerous early entrants gaining insuperable cost advantages through cumulative investments in process R&D. His model does not invoke dominant designs to explain industry shakeouts. These two points are quite consistent with our interpretation. However, Klepper (1997) interprets his data on entry, exit, and production in the early U.S. auto industry as consistent with the dominant design theory. Our more comprehensive data leads us to question that consistency. Moreover, differently from Klepper (1996), our data points to the role played by a *single* dominant firm at the time: Ford. Theories of industry life cycles are only just beginning to consider the roles of single dominant players and the strategic interactions they spark (e.g., De Figueiredo and Silverman, 2007).

It may be useful to consider some examples of firms in our data that faced the Follower’s Dilemma that we analyze. The Arbenz Company is an example of a company that failed to reposition. When the Model T was introduced, Arbenz was producing a single model in the low horsepower segment. Managers attempted to reposition by producing 6- and 8-cylinder automobiles (much higher horsepower engines compared to the Model T), in order to avoid the competition created by Ford (*Motor Age*, August 1, 1915, v. 18: 152). To do so, it hired an engineer who had worked with those who had developed 8-cylinder engine technology. But other than this single engineer, Arbenz had no prior technical or organizational knowledge for producing larger cars. Arbenz ultimately continued to produce only a 4-cylinder model until it was forced to exit in 1917 (Kimes and Clark, 1989).

Nash Motors provides an example of a successfully repositioning firm. In 1916, Charles Nash, a former Buick executive, acquired the Thomas B. Jeffrey Company. Jeffrey at the time was producing two successful and innovative models:

the Rambler, which featured an innovative hybrid engine and advanced starter and ventilation system, as well as one of the first successful four-wheel-drive vehicles, the Quad. The Rambler was a 25-hp car selling at a price that was 60–70 percent higher than the Model T, and while initially successful, its sales began to drop after the Model T was introduced. Within two years of acquiring Jeffrey, Nash was able to replace the Rambler with multiple car models in the mid-price range based on an innovative overhead valve engine to which newly recruited Buick engineers had contributed (Norbye, 1981). This example thus illustrates how a firm with a wider technological base (its two diverse models reflected its innovative engineers) was able to attract additional innovative engineers who helped the firm reposition away from the innovation shock of the Model T.

MODEL ESTIMATION

The database for our study was constructed from a larger database that includes a range of information on auto companies and car components for virtually every auto producer in the U.S. auto industry during the period 1885–1981. From this data, we analyze the crucial period during which the shake-out occurred. The larger database was constructed from a variety of historical sources, especially Baldwin *et al.* (1987), Georgano (1982), Gunnell (1987), Kimes and Clark (1989), and Flammang and Kowalke (1989). Each of these sources represents the culmination of many years of research by historians, journalists, collectors, and others. The main difference between this database and those analyzed by previous studies of dominant design in the auto industry is that our database includes substantially more firms, especially smaller firms operating between 1905 and 1910.

Our analysis follows the general approach taken by Carroll *et al.* (1996) and Klepper (2006) in their survival analyses of the U.S. auto industry. We estimate a Gompertz hazard rate model of firm mortality because nonparametric analyses suggest that the Gompertz specification shows superior goodness of fit relative to the Weibull and other specifications. We conduct this analysis at the level of the firm rather than at the level of the car model because our theory is about firms.

Between 1908 and 1927, Ford produced only the Model T. We evaluate the effects of the

Model T up to 1926, at which point its sales were declining substantially. While Ford began production of the Model T late in 1908, as discussed above, Ford was unable to fully meet the unanticipated and dramatic increase in demand until 1911. We therefore identify 1911 as the year in which we expect effects on industry exit from the innovation shock to begin to show in the data. For comparison's sake, we also evaluate the effects of Ford's production level from 1909 (because the Model T was introduced only in the last quarter of 1908) and from 1910.

Our first main independent variable is a dummy variable representing the industry segment in which the Model T was introduced. Recall that no other firm posed nearly the kind of competitive threat posed by Ford's Model T. Therefore, we assume that our dummy variable for LOW SEGMENT would be picking up the effect of the ISD only. The price data from Lester-Steele (1960) indicates that this was the low-price segment in the industry. Thus, our LOW SEGMENT variable takes the value of 1 if a firm was positioned near the Model T at the low end of the market, and 0 otherwise.

Because our price data is not comprehensive, we identify those firms that participated in the lowest price segment using horsepower data. Our database includes information on the horsepower of the car models sold by each firm in the population (some firms produced multiple car models in a given year during this period, though most did not). Horsepower was used as the basis for measuring organizational niches in organizational ecology studies using data upon which we draw (e.g., Dobrev, Kim, and Hannan, 2001; Dobrev *et al.*, 2002). Organizational niches are similar to notions of industry segments. Indeed, in the sample of firms on which we have price data, the correlation between model price and model horsepower is 0.5 ($p < 0.04$). We identify firms as competing directly with Ford if they produced a vehicle with a horsepower ≤ 25 (LOW SEGMENT = 1; otherwise = 0). We chose 25 as our cut-off because the Model T's horsepower was 20 or 22 (depending on the model year) during our period of interest, and because the distribution of minimum horsepower shows a large, natural break at 25 in our data over the relevant time period. The next natural break in the data comes at a horsepower level of 50. We therefore identify a middle segment between 26 and 50 (MID SEGMENT). Our omitted category

is the high-end segment consisting of cars with horsepower levels greater than 50. Thus, based on Hypothesis 1, we predict a positive and significant sign for the coefficient on LOW SEGMENT, indicating a significantly greater hazard of exit associated with the arrival of the innovation shock in the low price segment.

We might also expect the competitive effects of the innovation shock to spill over to some degree into the middle segment, although our framework suggests that the effect would be weaker than for the low segment. We might therefore expect a positive but smaller coefficient estimate on the MID SEGMENT variable. We also included control variables from our database that have been shown by Carroll *et al.* (1996) and Klepper (2006) to be (positively) associated with firm survival in the auto industry, and by others to have similar effects in other industries (e.g., Dunne, Roberts, and Samuelson, 1988): firm age (AGE), log of firm size (LOG SIZE), and pre-entry experience (if entered from a related industry, DEALIO = 1; otherwise = 0). These variables are all expected to carry negative and significant signs. We also included a variable, NUMODEL, which measures the number of car models produced by the firm in the year in question. This variable is meant to capture possible economies of scope that could contribute to survival chances. We added the log of gross national product (LOG GNP) to proxy for macroeconomic conditions that might impact firm exit rates.

Population ecology emphasizes the role of density and density squared in driving exit rates. Including both of these variables in our regressions would not be appropriate, however, because we study the population well after the industry's birth. Population ecology predicts an inverse-U relationship between density and exit rates only in data that begin from population birth (Carroll and Hannan, 2000). The time frame for our study begins only after the very earliest stage of industry development in which, according to population ecology, "legitimacy" was increasing, and instead focuses exclusively on the later "competition for resources" stage. We therefore include a measure of density alone (DENSITY), expecting a positive coefficient estimate on that variable's coefficient (rather than the negative one found in ecological studies) given our focus on the period of elevated exit rates.

Finally, we constructed two dummy variables to account for historical events in the industry

that we expect would affect exit rates. WWI takes the value of 1 for the years 1917–1918, and 0 otherwise. This controls for the period during which the U.S. participated in World War I. DOMINANT DESIGN takes the value of 1 for the years 1923–1926, representing the time frame in which there is agreement that the dominant design emerged. We predict a positive and significant sign on this variable, consistent with the notion that the dominant design did accelerate the increase in exit rates when it finally emerged.

To test Hypothesis 2 to Hypothesis 4, which focus on those firms that remained in the industry but were at risk of repositioning, we construct a subpopulation consisting of data on only those firms that were active in the lowest industry segment between 1906 and 1926 (i.e., did not exit the industry during that period). For those firms that repositioned from the low segment to some other segment during the period, we coded the time at which the repositioning occurred. We conducted a hazard rate analysis on this subpopulation, seeking to predict which firms were more or less likely to reposition out of the low segment (but not leave the industry) after the introduction of the Model T. We again used the Gompertz specification, although our results are robust to Weibull specification. Because our subpopulation by construction did not exit the industry, we omit DENSITY from our estimation here. Hypothesis 3 predicts a (more) negative and significant coefficient on the AGE variable for the post-innovation shock period compared to the pre-innovation shock period, reflecting organizational inertia. Hypothesis 3

makes a similar prediction with regard to LOG FIRM SIZE. Hypothesis 4 predicts that producers of more car models were more likely to reposition out of the segment after the innovation shock. We therefore expected a (more) positive and significant sign on the coefficient estimate for NUMODEL for the post-innovation shock period compared to the pre-innovation shock period.

EMPIRICAL RESULTS

Table 2 contains descriptive statistics and definitions of the variables used in the study. We note the high correlations between AGE, SIZE, and NUMODEL. These correlations may tend to inflate the standard errors in our regressions. However, the coefficient estimates for each of these variables carry the expected signs at expected significance levels, suggesting that the underlying relationships we are theorizing about are not being masked by excessive multicollinearity. The variance inflation factors for all covariates are below 3.0.

Table 3 shows the coefficient estimates for the regressions aimed at examining our hypotheses. The estimation of Model 1, which covers years 1909–1926, yields expected coefficient estimates. Firm size, age, number of models, and related pre-entry experience all improve the average firm’s survival chances, consistent with prior findings with the various subsets of this dataset (e.g., Argyres and Bigelow, 2007; Carroll *et al.*, 1996), as well as with other auto industry databases (Klepper, 2006). GNP’s positive and significant

Table 2. Variable descriptions, descriptive statistics, and intercorrelations

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1 AGE	2.90	4.60	1								
2 LOG SIZE	2.60	3.10	0.57	1							
3 DEALIO	0.45	0.50	0.15	0.10	1						
4 LOG GNP	4.70	0.24	0.31	0.29	-0.18	1					
5 LOG NUMODEL	0.41	0.57	0.61	0.56	-0.09	0.59	1				
6 DOMINANT DESIGN	0.08	0.27	0.37	0.27	0.03	-0.09	0.42	1			
7 WWI	0.07	0.26	0.38	0.28	0.04	-0.09	0.43	0.97	1		
8 DENSITY	246.70	79.80	-0.11	-0.05	0.00	0.02	-0.40	-0.29	-0.29	1	
9 LOW SEGMENT	0.59	0.49	-0.34	-0.28	-0.02	0.19	-0.47	-0.19	-0.28	0.07	1
10 MID SEGMENT	0.15	0.35	0.21	0.16	0.01	-0.02	0.28	0.01	0.21	-0.11	-0.30

Variable descriptions: AGE = firm age in years; LOG SIZE = log of firm size in number of units sold; DEALIO = 1 if firm has pre-entry experience from a related industry, else 0; LOG GNP = log of gross national product; MULTI MODEL = 1 if firm produced more than 1 car, else = 0; DOMINANT DESIGN = 1 for the years 1923 onward, else = 0; WWI = 1 for the years 1917–1918, else = 0; DENSITY = number of firms in each year; LOW SEGMENT = 1 if vehicle horsepower is less than or equal to 25, else = 0; MID SEGMENT = 1 if vehicle horsepower is greater than 25 and less than 50, else = 0.

Table 3. Gompertz hazard rate of industry exit models

	Model 1 1909–1926	Model 2 1909–1926	Model 3 1910–1926	Model 4 1911–1926	Model 5 1911–1926
AGE	−0.78*** (0.09)	−0.78*** (0.09)	−0.84*** (0.09)	−0.90*** (0.10)	−0.90*** (0.10)
LOG SIZE	−0.23*** (0.02)	−0.23*** (0.02)	−0.24*** (0.02)	−0.25*** (0.02)	−0.25*** (0.02)
DEALIO	−0.13** (0.07)	−0.13** (0.07)	−0.16** (0.08)	−0.19** (0.09)	−0.19** (0.09)
LOG NUMODEL	−0.60*** (0.11)	−0.59*** (0.11)	−0.56*** (0.12)	−0.52*** (0.13)	−0.52*** (0.13)
LOG GNP	3.03*** (0.56)	3.05*** (0.53)	4.66*** (0.70)	8.10*** (1.24)	8.02*** (1.24)
WWI	−2.01*** (0.26)	−2.01*** (0.26)	−2.21*** (0.27)	−2.70*** (0.31)	−2.71*** (0.31)
DENSITY	.005*** (0.001)	.005*** (0.001)	.007*** (0.001)	.009*** (0.002)	.009*** (0.001)
DOMINANT DESIGN	2.72*** (0.24)	2.74*** (0.24)	2.90*** (0.24)	3.19*** (0.26)	3.20*** (0.26)
LOW SEGMENT		0.07 (0.08)	0.11 (0.08)	0.16** (0.09)	0.21*** (0.10)
MID SEGMENT					0.16 (0.12)
CONSTANT	−17.0*** (2.94)	−17.1*** (2.93)	−25.4*** (3.65)	−42.9*** (6.44)	−42.6*** (6.43)
Gamma	0.70*** (0.08)	0.71*** (0.08)	0.76*** (0.09)	0.83*** (0.10)	0.83*** (0.10)
No. of observations	3,648	3,648	3,284	2,909	2,909
Log likelihood	−1067.8	−1067.4	−899.8	−742.0	−741.0
No. of subjects	887	887	797	625	625
Prob > χ^2	0.000	0.000	0.000	0.000	0.000

Standard errors are in parentheses.

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; one-tailed test.

effect likely reflects auto supply outstripping demand as the economy grew over the period as a whole. Models 2 and 3 include LOW SEGMENT, with Model 2 estimated on data starting in 1909, and Model 3 beginning in 1910. The coefficient estimate on LOW SEGMENT is positive but nonsignificant in these two models, providing no support for Hypothesis 1. However, as explained above, Ford was not able to fully meet demand for the Model T until 1911. Models 4 and 5 restrict the estimation to 1911, and in those regressions, the coefficient estimate on LOW SEGMENT becomes positive and statistically significant, thus we cannot reject Hypothesis 1. The lag between the introduction of the Model T and its impact on exit likely resulted from constraints on Ford's production and distribution capacity in the first couple of years after introducing the Model T.

Model 5 adds the variable MID SEGMENT, whose coefficient estimate is positive but not

statistically significant. This indicates that the competitive effects from the innovation shock did not spill over into the middle segment significantly more than they spilled over into the high-end segment (the omitted category). However, the estimate is consistent with our assumption that the middle segment (as well as the high segment) to which many firms fled after the innovation shock was introduced did in fact offer more defensible positioning, likely because of the numerous types of differentiated positions distant from the Model T that could be established in the segment (Argyres and Bigelow, 2010).

The dummy variable for the dominant design period, DOMINANT DESIGN, carries a large positive coefficient estimate across all models in Table 3. This finding is consistent with the emergence of a dominant design leading to an increase in exit rates. It also is consistent with our own arguments about innovation shocks. Note

that the coefficient for DD is much larger than the coefficient for LOW SEGMENT. The smaller coefficient on LOW SEGMENT suggests that it was the innovation shock that *initiated* the industry shakeout, even if the emergence of the dominant design later had a large effect. As we argue above, an innovation shock can set off a set of industry dynamics that can lead to the later emergence of a dominant design, so the two variables do not represent rival theories of shakeouts, but rather are part of the same dynamic. The innovation shock is key to understanding the dynamic in full.

Table 4 provides regression results on data that include the subpopulation of low segment firms only. The regressions examine the likelihood of low segment firms repositioning to other segments, while remaining in the industry until at least 1926. Model 6 is limited to the pre-innovation shock period of 1906–1910, while Model 7 examines the post-innovation shock period. We omit DENSITY, DOMINANT DESIGN, and WWI from the regressions for ease of comparison with Models 4 and 5, and because we have no reason to suggest that these covariates should influence segment repositioning (as opposed to industry exit). Because strategic repositioning is not discussed in population ecology, that literature provides no theoretical or empirical precedence for including industry or segment density in our regression on repositioning. In unreported regression models that included these three omitted covariates, we found that the signs, magnitudes, and statistical significance of our main variables are essentially the same as those found in Models 6 and 7.

The coefficient estimate on AGE in Model 6 is positive and significant, while it is negative and significant in Model 7. This implies that older firms were significantly less likely to exit the low segment after the innovation shock occurred there, consistent with Hypothesis 2. The positive and significant coefficient on AGE in Model 6 likely reflects the fact that, early in the industry’s history, organizational inertia was not a major factor limiting repositioning, because firms were not yet old enough to have developed significant such inertia. The coefficient estimate on LOG FIRM SIZE is negative in Model 7, as predicted, but is not statistically significant. Thus, no evidence is found in support of Hypothesis 3.

Finally, the coefficient for NUMODEL is positive and significant in Model 7, while negative in Model 6, providing support for Hypothesis 4.

Table 4. Gompertz hazard rate of segment repositioning models

	Model 6 1906–1910	Model 7 1911–1926
AGE	0.04*** (0.02)	−0.43*** (0.05)
LOG SIZE	0.03 (0.02)	−0.01 (0.02)
LOG NUMODEL	−0.48*** (0.10)	0.35*** (0.08)
DEALIO	−0.33*** (0.10)	−0.18** (0.27)
LOG GNP	.94 (1.04)	3.73*** (0.73)
CONSTANT	−6.14 (4.86)	−19.8*** (3.54)
Gamma	0.33*** (0.05)	0.58*** (0.18)
No. of observations	2,106	2,042
Log likelihood	−832.9	−427.5
No. of subjects	418	444
Prob > χ^2	0.000	0.000

Standard errors are in parentheses.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; one-tailed test.

This implies that firms producing a larger number of models, reflecting a broader technological base, were more likely to reposition away from the low end segment after the innovation shock arrived. Thus, while the positive and significant coefficient estimate on NUMODEL in Model 6 suggests that firms with a broader technology base were more likely to establish themselves in the low-end segment prior to the shock, the Model 7 result implies that they were also better able to reposition away from that segment after the shock.

DISCUSSION AND CONCLUSION

The notion of an innovation shock design offers a new approach to understanding the strategic management of industry evolution prior to the arrival of the so-called dominant design. Like Klepper (1996, 1997, 2002), we suggest that important industry dynamics play out long before a dominant design emerges or a shakeout occurs. Differently from Klepper, however, our theory is predicated upon the discovery, from an innovation shock, of substantial unanticipated demand. The arrival of this new information launches a set of industry dynamics, especially a rise in exit rates. We emphasize that often it is one pioneering firm’s innovation shock design that triggers the

industry dynamics from which the dominant design, only later, emerges.

We also argue that an innovation shock creates a Follower's Dilemma that launches a series of responses by rivals and potential competitors. Empirical analysis provides preliminary support for our hypotheses that an innovation shock stimulates exit from the industry, and especially exit from the industry segment in which the shock occurs. It also suggests that comparative adjustment costs play an important role in determining which firms reposition in response to an innovation shock.

From a strategic management perspective, our theory offers an advance over the dominant design literature by highlighting a vital role of strategic choice. In particular, when faced with an innovation shock, managers have the responsibility to explore and identify alternative strategies for exit, entry, or repositioning, and estimate the attendant comparative adjustment costs for each alternative considered. Although not elaborated in this paper, managers also are responsible for leading and implementing these strategies, thereby coping with inertia and managing adjustment costs. In contrast, the dominant design literature offers only a limited role for managers or for strategic management.

Our hypotheses and empirical analyses are appropriately characterized as exploratory. Our primary focus in this paper is to introduce and begin to develop a new and potentially impactful concept. The empirical portion of the paper focuses on the industry exemplar with reference to which much of the dominant design literature developed—U.S. automobiles. This industry is therefore particularly appropriate for exploring the concept of innovation shocks and for evaluating its contribution over and above that of the concept of dominant design.

We suggest that future research build on the innovation shock design concept. For example, it is important to identify the key characteristics of innovation shock designs, and to understand the conditions under which they become or do not become dominant designs. Anecdotal observation suggests that there is variance on both of these counts across innovation shocks, indicating opportunities for further theoretical development. In addition, future conceptual work could seek to provide a theoretical foundation for the emergence of Porter's (1980) typology of strategies: low cost, differentiation, and focus. We suspect that the

typologies often emerge because of a Follower's Dilemma. Developing this theoretical antecedent would provide a more integrated and cumulative theoretical perspective for the positioning school in strategic management. In addition, a broad research in strategy focuses on entry, exit, and repositioning decisions (including mergers and acquisitions), but a review of this literature suggests to us that rarely are the antecedents of these strategic moves in terms of industry evolution identified and integrated into the theoretical explanation of the decisions. We therefore posit that building a theory to connect innovation shocks with these other decisions may provide the foundation for a more integrative theoretical framing of a wide variety of strategic decisions.

Finally, we believe there is much value to be added to the strategic management literature—especially to notions of dynamic capabilities—by developing a more thorough and comprehensive theory of comparative adjustment costs. Doing so may enable the prediction of best responses whether they involve exit, entry, or repositioning, which not only may be of value for advancing understanding of competitive dynamics but also prove valuable for managers attempting to strategically manage their organizations.

We aimed in this paper to challenge the foundations of the dominant design literature, and to draw new insights about implications for competition and strategic management. In contrast to the literature's focus on the supply side and the exogenous emergence of dominant designs leading to industry shakeouts, we introduced the notion of an innovation shock, which emphasizes the role of the arrival of an unanticipated, sudden, and substantial demand for a particular composition of product and service elements. We argued that an innovation shock initiates a Follower's Dilemma that triggers a set of industry dynamics involving firm strategies of imitating, repositioning, exiting, and entering. Critical to predicting which strategy followers choose is the magnitude of their adjustment costs associated with alternate strategic moves. While the paper does not offer a comprehensive theory of comparative adjustment costs, it nonetheless offers an initial framework within which to assess them. Implicit in the concept of an innovation shock is the view that managers—and strategic management—matter for identifying alternative strategies and their attendant adjustment costs, as well as for leading and implementing adaptations.

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