"Old" Technology Responses to Dominant Technological Threats: Demand Heterogeneity and Graceful Technology Retreats

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Abstract: We explore the implications of a real and common alternative to attempting the transformation required to embrace a new, dominant, technology – the choice to maintain focus on the old technology. In considering this choice we distinguish between 'racing' strategies, which attempt to fight off the rise of the new technology by extending the performance of the old technology, and 'retreat' strategies, which attempt to accommodate the rise of the new technology by repositioning the old technology in the demand environment. Underlying our arguments is the observation that the emergence of a new technology does more than just create a substitute threat – it can also reveal significant underlying heterogeneity in the old technology's broader demand environment. This heterogeneity is a source of opportunities that can support a new position for the old technology, in either the current market or a new one. Using this lens we explore the decision to stay with the old technology as a rational, proactive choice rather than as a mark of managerial and organizational failure. We then consider the distinctive challenges and organizational dynamics that arise in technology retreats, and their implications for the ways in which managers and scholars should approach questions regarding the management of capabilities, lifecycles, and ecosystems.

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1. Introduction

Innovation scholars have long recognized that technology discontinuities present incumbent firms with a set of challenges that stand quite apart from the challenges of managing within continuous regimes. In studying reactions to technological threats, the field has considered a host of factors that influence the effectiveness of incumbents' response – e.g., impact on existing competences (Tushman and Anderson, 1986); subtlety of change (Henderson and Clark, 1990); reactions of dominant customers (Christensen, 1997); perceptions of threats (Tripsas and Gavetti, 2000) – and their role in contributing to firms' long term viability.

Implicit in many studies, and explicit in many others, is the assumption that the 'correct' incumbent response to technological change is to embrace its inevitability. Much of the literature has focused on the timing and means by which firms make the jump from the old technology to the new. Certainly, when reviewing the canon of technology change studies – e.g., the transition from sail to steam (Foster, 1986); from mechanical to electronic systems (Rosenbloom, 2000); from steam to diesel locomotives, piston to jet aircraft engines, and fountain to ball point pens (Cooper and Smith, 1992) – the dominant imagery is of that of winning firms that successfully executed the difficult transition to a new dominant technology, and of losing firms that were left behind.

Canonical though these examples may be, they address only part of the story. In reality the economy is full of firms that soldier on with an old technology long after the rise of a dominant substitute. Pagers persist today as messaging devices for emergency services, long after the arrival of mobile phones. Audio tape sales have not been eliminated by the rise of the

compact disc. Semiconductor manufacturing technologies three and four generations behind the frontier continue to be purchased and used. This pattern even appears in many of the canonical cases: sailboat makers like Linjett survived the rise of engine power and continue to succeed with their sailboat offer even today; Continental and other original piston aircraft engine producers continue to produce and sell their piston engines long after the rise of turbine engines; Pelikan and Waterman carry on successfully with fountain pens similar to those they produced before the emergence of the ball point pen. These firms may or may not be as prosperous as the exemplars that attempted the transition to the new technology and succeeded, but they are certainly better off than the multitude of old-technology firms that attempted the transition and failed.

In this paper we explore the implications of a real and common alternative to attempting the transformation required to embrace a new, dominant, technology – the choice to maintain a focus on the old technology. In considering this choice we distinguish between 'racing' strategies, which attempt to fight off the rise of the new technology by extending the performance of the old technology, and two distinct 'retreat' strategies, which attempt to accommodate the rise of the new technology by repositioning the old technology in the demand environment, either by retrenching into a niche position within the old technology's home market, or by relocating the old technology into a new market application Underlying our arguments is the observation that the emergence of a new technology does more than just create a substitute threat – it can also reveal significant underlying heterogeneity in the old technology's broader demand environment. Exploiting this revealed heterogeneity can allow the firm to create a new, more sustainable, position for the old technology in the face of competition from the new technology.

We explore the decision to stay with the old technology as a rational, proactive choice rather than as a mark of managerial and organizational failure (Reinganum, 1983; Dew et.al., 2006). To be clear, we do not suggest that foregoing the new should be regarded as the dominant strategy for dealing with technological change. We do, however, argue that it is often a viable though neglected option, and hence merits explicit consideration. We note that while the literature has made significant progress on the broad topic of technology evolution and competition, it has largely focused on the challenges and dynamics of emergence rather than maturity and decline[1]. Whereas the implied bias in the extant literature is to explore the ways in which firms reinvent their capabilities in order to preserve their market position, we explore the ways in which firms reinvent their market position in order to preserve the value of their existing capabilities.

We revisit the subject of technology competition, but with an explicit focus on the old technology. Drawing on a number of cases and examples to explore these dynamics, we identify three key dimensions that characterize the strategic space available to firms that choose to continue to pursue the old technology despite the emergence of the new: racing to extend the performance of the old technology; retrenching into a niche position in the current market; and relocating the old technology into a new market application. We then consider the distinctive challenges and organizational dynamics that arise in technology retreats. These differ from traditional innovation challenges – rather than stretching in order to reinforce a dominant position, the firm is proactively embracing change with the explicit aim of yielding its position in the mainstream; rather than trying to commercialize a new technology, the firm is trying to recommercialize a mature technology. More broadly, the goal and expectation of technology

[1] See Harrigan (1980, 1988), Utterback (1994), and Henderson (1995) for important exceptions.

retreats is not for growth and expansion, but rather for survival and contraction.[2] We examine how these goals, which run contrary to traditionally assumed firm objectives, change the ways in which managers and scholars should approach questions regarding the management of capabilities, lifecycles, and ecosystems. Finally, we consider the competitive implications of pursuing retreat deliberately, and empirical indicators to distinguish between deliberate retreat and concessions to defeat.

2. Racing in Performance Space

The canonical image of technology competition is Foster's (1986) depiction of competing technology S curves (see Fig 1): an established, now old, technology, T_O, has secured its position in its home market, M_A, over other available technologies ($T_{\emptyset}$), as it itself is confronted by a new technology, T_N, which promises to deliver superior performance at time t^*.

<INSERT FIGURE 1 ABOUT HERE>

In this representation of technology competition, attention is usually focused on whether old-technology incumbents recognize the rising threat and adopt the new technology sufficiently in advance of t^*, when the old technology becomes inferior. A prime focus of the literature has

[2] In this regard, the notion of a technology retreat also is quite distinct from the traditional concerns of diversification. While both involve a deployment of existing competences into new domains (e.g., Penrose, 1959), diversification is additive is both spirit and activity (e.g., Levinthal and Wu, 2005; Helfat and Eisenhardt, 2004) whereas retreat is explicitly subtractive.

been on characterizing and assessing the challenges associated with such transformations – the extent to which the transition is competence enhancing or competence destroying (e.g., Tushman and Anderson, 1986), and its effect on the value of firms' complementary assets (e.g., Tripsas, 1997) and external relationships (e.g. Christensen, 1997).

The pace of technology advance however, is endogenous to the efforts of innovators. This is true not only of the new technology, but of the established technology as well. The classic choice facing old technology firms is whether they should transition to the new technology or invest in extending the performance of the old technology platform. While the choice to pursue a technology race against the new platform is rarely heralded, it is a very common one. Utterback (1994) reports on the dramatic efforts, and resulting improvements, in pond ice harvesting technology that incumbents achieved in their race against refrigerated-ice manufacturing technology. In a different context, recent advances in hi-tensile steel alloys have their genesis in a directed effort on the part of the steel industry to avoid replacement by aluminum in automobile construction. Similarly, BMW's engineering efforts (branded "Efficient Dynamics") to extract additional fuel economy performance from the internal combustion engine have been initiated in direct response to competitors' innovation in substitute propulsion systems (e.g., plug-in electric and gas/electric hybrids). This race has been successful thus far, with automobiles equipped with "Efficient Dynamics" technologies offering fuel economy performance comparable to that achieved by competitors' hybrids.

The extension of an old technology's capabilities may also result from factors that are more "environmental" in nature, lying outside of the firm's direct control. Whereas performance improvements in above examples are primarily attributable to the direct efforts of the focal

producers, Snow (2008) shows that carburetor technology experienced a performance surge after the arrival of electronic fuel injection, and that this "last gasp" was due in large part to the inclusion of components borrowed from the substitute technology. Henderson (1995) reveals the role that innovations by suppliers and customers played in extending the performance trajectory of optical semiconductor lithography technology—innovations that have allowed for its continued dominance in the face of newer, non-optical approaches. Ansari and Garud (2009) examine how modular innovations in packet-switching technologies extended the life of 2G telephony. Beyond these, external institutional forces may also help to extend the performance of an incumbent technology Policymakers often channel resources to an old-technology industry (e.g., coal) because it employs constituents, and this support often carries with it the goal of performance improvement (e.g., clean coal). Similarly, industry consortia and standards-setting bodies may be subject to old-technology stakeholders who marshal community efforts to improve performance. These environmental influences need to be factored into expectations for the old technology's performance trajectory, and hence into incumbents' decisions regarding staying with the old technology.

The outcome of performance races depends on the relative rates of improvement of the new and old technologies. Framed as a head-to-head competition, however, the demise of the old technology in the face of a superior new entrant is assured – the only question regards the specific time at which the old technology is pushed out of the market. This framing, while consistent with the popular imagery of technology competition, is inconsistent with the many observations of old technologies surviving, and at times thriving, long after they have lost the performance race. Resolving this inconsistency requires a closer examination of the demand context in which technology competitions take place.

3. A Demand Perspective: Exploiting heterogeneity

The two alternatives presented above – transitioning to the new technology platform or extending the performance trajectory of the current technology – present firms with very different challenges. We note, however, that these alternatives are similar in one key regard: they both focus on changes on the technology production side, and neglect consideration of the demand context in which the technology is deployed. That is, while they attend to quantitative changes in market size and market share, they ignore the potential for qualitative changes in the composition of the customers that constitute the market for the old technology. In doing so, they overlook the critical role of the demand context as a determinant of outcomes.

a. Segmentation and Latent Heterogeneity: Retrenching in a revealed niche

i. Demand Heterogeneity

Implicit in any comparison of performance is the notion of a common metric along which the value of performance is to be evaluated. Such metrics, however, are not universal. Consider what is in some ways a best case scenario for universality – performance on an attribute that can be characterized by a single, objective measure on which all consumers agree (e.g., fuel efficiency, rather than style). Even in this case, the moment the measure is considered on a price-adjusted basis, or weighted against other attributes embodied in a given offer, we are confronted with the possibility of divergent evaluations; although all consumers may agree on the actual performance of each offer on any given attribute (e.g., an engine with 30% efficiency

is superior to one with 25%), they may disagree on the attribute's relative importance (e.g., their preference for fuel efficiency vs. reliability) and the value of a given performance improvement (e.g., the price premium justified by an increase in fuel efficiency). In this regard, the superiority of one offer over another is determined by a given customer's willingness to pay for its bundle of attributes, which in turn is determined by that customer's preference ordering and budget constraints (e.g., Adner 2002).

The degree of heterogeneity in consumer preferences is characterized by the extent to which customers differ in their preference orderings and budget constraints, which in turn determines the extent to which more than one offer can succeed in a given market (c.f., Malerba et. al. 1999; Adner and Zemsky, 2006).

Before the rise of the new technology platform, the old technology dominates its home market. Within this home market, all consumers prefer the old technology to the existing alternatives ($T_O > T_{\emptyset}$). Despite this agreement, however, we may observe some heterogeneity among these consumers with regards to budget constraints and performance requirements. This explains why some customers prefer high-end to low-end products derived from the old technology. The rise of a new dominant technology does not change these relationships – consumers in the home market still prefer the old technology to the previous alternatives (i.e., T_N dominates T_O, but T_O still dominates $T_{\emptyset}$), and still have the same heterogeneity in budget and performance requirements. Rather, the emerging new technology introduces a new option for customers to consider. We refer to the new technology as dominant when most consumers in the home market prefer to purchase the new technology rather than the old.

ii. Revealing Latent Heterogeneity

Although the new technology does not itself change consumers' preferences, its very emergence can act to reveal previously hidden differences in consumers' preferences. Whereas different versions of the old technology present consumers with different price-performance combinations, the distinctive feature of a new technology is that, apart from its price point, it delivers its performance in a new way. This new approach to performance delivery often results in a change in the attribute bundle presented to consumers. This holds an important implication for observed heterogeneity: Heterogeneity is revealed by differences in observed choices. Choices, in turn, are bounded by choice sets. When a new technology offers a new attribute bundle, it presents consumers with new couplings and de-couplings of attributes. This expands the choice set in which consumer preferences can be observed and the dimensions along which heterogeneity can be parsed, which, in turn, can be used to identify new niches within the existing market.

Consider, for example, the case of watches. Until the late 1960s, all watches used mechanical movement systems (T_O) to track the passage of time.[3] Superior performance was measured in terms of accuracy – the number of seconds a watch would 'lose' during the course of a day. With the rise of quartz movement systems (T_N), which exploited electronic measurement of vibration in a crystal to yield an order-of-magnitude accuracy improvement, and whose production was associated with strong economies of scale, the mechanical movement was quickly dominated. However, not all consumers switched. Before the rise of quartz, producers and consumers considered only 'watches.' It was only after, and due to, the rise of quartz

[3] Sundial watches excepted, of course. Inasmuch as sundial technology remained a viable offer for some set of customers, it did so for reasons similar to the ones discussed in this paragraph.

movement, that consumers and producers could consider ‘mechanical watches’ as distinct from non-mechanical watches.

In the old technology, the dimensions of ‘accuracy’ and ‘mechanicalness’ were coupled not by design but by an accident of birth. It was only when a new technology decoupled the dimensions that a relevant distinction could be drawn. The emergence of a non-mechanical choice allowed consumers who cared about mechanical movement, for reasons that had nothing to do with temporal accuracy, to demonstrate their preference. This subset of consumers could then be identified as belonging to a newly revealed niche within the larger watch market; and one whose needs could not be addressed by the new technology. With this niche in mind, old technology firms actively modified their offers, shifting from the norm of hiding the mechanism within an opaque watch case to making the case transparent in order to highlight increasingly complicated and visually stimulating mechanisms. Similar dynamics can be observed in many other settings – the benefits of a ‘corded’ phone (e.g., no interference; not powered by the electricity network; not prone to misplacement) were invisible until the rise of the cordless phone; the benefits of pager networks (e.g., complete coverage; non-interference with medical equipment) were invisible in the absence of mobile phone networks as an alternative technology for wireless communication. For this same reason, the existence of a “nostalgia value” dimension can only be revealed and exploited after the new technology has established its dominance in the market.

In all these cases, the new technology brought new and better functionality on many performance attributes. From the old technology’s perspective, however, the key to sustainability was found by focusing on the revealed attributes that the new technology neglected to address.

iii. Retrenching in a Revealed Niche

Losing the mainstream of the market need not be a signal of the impending loss of the entirety of the market. The key question is the extent to which consumers in the home market vary in their evaluation criteria. While it is possible that all consumers in the market uniformly prefer the new technology to the old, there are several drivers of variance that may lead parts of the market to continue to prefer the old technology to the new. This variance can be rooted in budget constraints, such that some consumers may prefer the new technology on a pure performance basis, but nonetheless choose the old technology on a price/performance basis (e.g., alkaline vs. lithium batteries). It can be rooted in heterogeneity of preferences over attribute bundles (e.g., higher refresh cycles of CRT monitors dominate the benefits of flat screen displays for high end video gamers). It can be rooted in more emotional or nostalgic attachments to the old technology (e.g., fountain pens and mechanical watches).

By revealing latent heterogeneity in the market, the introduction of the new technology exposes new lines of segmentation – niche opportunities within a market that previously had been regarded as homogenous. Within these niches, the old technology can maintain a sustainable advantage over the new technology. Exploiting this heterogeneity, however, entails redefining the size and composition of the market, and retrenching into the revealed niche.

It also entails a complete inversion of strategic imperatives: For racing firms, the key question is "What *new* attributes and performance does the new technology address, and how can I make up for it to maintain relevance in the market?" For retrenching firms, the key question is "What *old* attributes and performance did the new technology reveal by *not* addressing them, and how can I exploit this to create a sustainable niche?"

b. Shifting Application Domains: Relocating to a different market

In addition to revealing latent heterogeneity within the established market, the rise of the new technology can expose opportunities in markets not yet served by the old technology. It can do so in three distinct ways. First, the rising threat from the new technology can spur firms to extend their search efforts in new directions, which in turn can uncover new opportunities. Second, the declining attractiveness of the home market can act to increase the relative attractiveness of opportunities which were previously known but not appealing. Finally, the rise of the new technology can itself create opportunities for the old technology to be deployed as a complement to the new.[4]

These three different mechanisms are well illustrated in the context of the competition between stepper technologies in the semiconductor lithography equipment market. Semiconductor lithography is the process by which circuit designs are imprinted on to wafers. Manufacturers of lithographic stepper tools (e.g. Nikon, ASML) compete vigorously with one another to introduce tools that offer the highest levels of accuracy and resolution so that their key customers, semiconductor manufacturers (e.g., Samsung, Intel) can pack more circuits onto a

[4] Note that the rationale for why a firm would not have participated in the new market opportunity differs in each of these mechanisms. The first is explained by the cognitive capacity constraint of bounded rationality: the firm's inability to consider every possible option of relevance simultaneously. The second is explained by a resource capacity constraint: the decreasing ability to deploy resources in the home market frees these resources for deployment in other, less attractive, markets (e.g., Levinthal and Wu, 2005). The third is explained by non-existence: the emergence of the new market opportunity is endogenous to the emergence of the new technology.

given wafer and thereby improve their own product performance and production costs. In the early 1990s, the dominant stepper technology used a refractive lens system to transfer exact, unreduced (1x) images of circuit designs onto the wafer. These 1x refractive steppers (T_O) offered better performance than that available from other alternatives ($T_Ø$), and hence accounted for the bulk of industry sales. This dominance, however, was threatened by the emergence of a new generation of steppers (T_N) which used a new generation of optical lens systems to reduce image sizes by a factor of five (5x), allowing for significantly higher printing resolutions. The new 5x stepper technology was recognized by all participants, tool producers and semiconductor manufacturers alike, as the emerging dominant technology. Indeed, by the mid-1990s it had driven the 1x technology out of its position in the core market, taking over all critical layer applications. Most tool producers shifted their primary development and investment focus towards transitioning to the 5x technology. An exception was Ultratech whose management, resource constrained in the midst of an organizational and financial restructuring, made the proactive decision to forego developing and competing in the 5x technology and, instead, to maintain its core focus on the 1x technology.[5]

i. Changing search direction

Firms often are characterized as being boundedly rational (March and Simon, 1958), unable to identify and evaluate all possible opportunities simultaneously. Given their limited resources, they must prioritize their search efforts. In accepting the rising dominance of the new

[5] A more complete description of technology transitions in the semiconductor lithography industry can be found in Kapoor and Adner (2007).

technology, a firm embraces the elimination of potential opportunities in the home market. This elimination implies that continuing to expend resources on further search in the home market space is unlikely to be productive, and thereby frees up those resources for searching new areas of the market landscape. Note that while these areas are new to the firm, they need not be new to the world. As such, unlike the explicit revelation of previously *hidden* heterogeneity discussed under the rubric of retrenching in a revealed niche, which could be explained in terms of insufficient product variety, the identification of previously *overlooked* segments is explained more straightforwardly as a function of bounded rationality and resource constraints.

In the case of Ultratech, the recognition that 5x steppers would soon displace 1x steppers from core applications prompted a shift in its search strategy. As long as 1x was the dominant technology, the key development goals were to identify and shape customer requirements at the cutting edge of their production activities, and to improve the 1x tool performance to address these needs. The emergence of 5x, with its leap in delivered performance, negated the potential value of incremental improvements along the 1x trajectory to serve such cutting edge applications. Because customers no longer were open to considering 1x technology for printing their critical layer circuits, Ultratech's search and evaluation of new opportunities had to change.

ii. Changing evaluation of opportunities

The elimination of what had been the firm's best opportunities increases the appeal of other opportunities. Options that a firm would not have pursued previously – because they offered lower growth, margin, prestige, etc. compared to continuing to serve the best customers

in their home market – may well look attractive when that first best option is eliminated by the rise of the new technology.

With 1x stepper technology having lost its dominant performance position in semiconductor manufacturing, Ultratech expanded it search for new opportunities. Its first move was to retrench into a lower end position within its home market. Historically, chip manufacturers used lithography tools from the same generation in each of the multiple steps along their production line, regardless of the level of resolution actually required in a given step. Hence, production lines for leading edge chips used only leading edge lithography tools, even though this was technical overkill in many of the steps. Without a cutting edge offer, Ultratech was precluded from serving the full production line. However, under the heading of 'Mix and Match,' Ultratech broke with industry practice and targeted its tools at only those steps that did not need cutting edge performance. Pursuing this mix-and-match strategy required a shift in development priorities away from resolution enhancement and towards creation of a cross-tool compatibility platform. Although selling full, cutting edge lines may have, hypothetically, seemed a more attractive position, Ultratech's reality dictated that this was a non-option. In contrast, the retrenched position created by the 'Mix and Match' strategy was both profitable and sustainable.

Ultratech also searched for opportunities outside its home market, seeking to identify applications that would value high resolution printing, but that did not require performance at the highest resolutions. One such opportunity was in the manufacture of thin film heads. Thin film heads are a key component of hard disk drives, and are produced using a process very similar to that used for computer chips. Disk drive performance, which was improving at an even faster

rate than that specified by Moore's law, is critically determined by the performance of the head. As such, resolution requirements in head production were constantly increasing. However, the thin film head producers were less attractive customers for lithography than were chip producers. Chip manufacturers demanded the most advanced performance and were able and willing to pay for it. In contrast, although thin film head manufacturers also valued printing resolution, their technical requirements were lower; furthermore, their end market was less lucrative, and so they had a lower willingness to pay for resolution. By foregoing the transition to 5x steppers, Ultratech could not compete to maintain a leadership position with the chip manufacturers. With this option eliminated, the drive head opportunity, which had previously looked like a distant second best option was now first best. Whereas 1x was clearly positioned as an inferior technology to 5x in the chip production market, it emerged as the superior technology for head production where 5x, due to its high price, was not a relevant competitor.

iii. Emerging opportunities

Just as the set of threats confronting a technology changes with time, so does the set of opportunities which it may address. Clearly, the threat from the rise of the new technology is that it reduces the opportunity for the old technology in its home market. There is a possibility, however, that the new technology may itself create new opportunities for the old technology. In the case of semiconductor lithography, for example, the finer printing resolution of 5x, and later 10x, steppers pushed 1x stepper technology out of the critical layer of chip manufacturing. This move to even finer printing resolution, however, had an important and unexpected consequence beyond just allowing for more circuits to be printed on a given area of silicon – it also affected

production requirements throughout the chip manufacturing process. For microprocessor production in particular, higher circuit densities increased requirements for electrical signal and power management, which in turn affected requirements for the interface between the silicon chip and the printed circuit board to which it was connected. The 1x stepper technology was a much more attractive choice than the established wire bonding technology used to package chips to deliver this level of electrical performance, and it became the dominant microprocessor packaging technology. Thus, the very rise of the new technology created a new opportunity for the old technology; one in which the old technology was repositioned as a productive complement in an adjacent market space rather than as an inferior substitute in the old home market. This pattern is not unique to semiconductor lithography. For example, similar dynamics accompanying the rise of digital photography have tilted the market opportunity for specialty paper from the developers' labs to the home printer user.

4. Dimensions of Response

The strategic space mapped in Figure 2 presents the dimensions of response – "race," "retrench," and "relocate" – available to the old technology firm after the emergence of a dominant substitute. While a firm's ability to race against the new technology – improving the old technology's performance – depends largely on firm and technology attributes, the firm's ability to retrench or to relocate depends on the recognized sources of the demand heterogeneity.

<INSERT FIGURE 2 ABOUT HERE>

The relative attractiveness of progressing along each dimension depends on the interaction between these factors. Thus, the greater the extent of heterogeneity in budget constraints, revealed preferences, or emotional attachment, the greater the scope for carving out a sustainable niche within the home market. In turn, the specific nature of heterogeneity will dictate the specific position available to the firm. Hence, when the new technology dominates on performance, but heterogeneity in budget constraints is large, serving the low-price segment is a viable strategy (e.g., automobile manufacturers continue to equip cars with old, heavy, relatively short-lived lead-acid batteries instead of newer, higher performance technology lithium-ion alternatives because of price considerations). Alternatively, when the new technology reveals a previously overlooked performance dimension (e.g, 'mechanicalness' in watches; complete network coverage and no electromagnetic interference in pagers) we can expect that offers targeting the specialized niche will be positioned in the higher end and will be able to demand a greater premium in that niche than they had in the mass market.

Similarly, the relative attractiveness of a relocation strategy depends on the competitive structure within the new market, as well as the relative advantage of the old technology over the current substitute (e.g., Porter, 1980, Adner and Zemsky, 2006). For example, steel bicycle frame tube manufacturers have tried to identify customers outside the bicycle industry as newer aluminum and carbon fiber technologies have displaced it from most of its former volume (Snow et. al., 2009). In assessing new opportunities, such as manufacturing steel roller tubes for moving sidewalks, they must consider not only the relative value of deploying their unique mandrel-forming process against the machining techniques currently in use in the segment, but also the

nature of competition and go-to-market challenges they face. In addition, they must compare the expected potential returns to retrenching into the sustainable niches that have emerged in the bicycle market (e.g., very high end touring bikes).

Clearly, a firm can pursue multiple dimensions simultaneously within a single initiative (e.g., relocating to a new market may require additional development—'racing'—to adapt the offer), or with distinct projects (e.g. one team focused on retrenching into a niche, while another, in parallel, pursues a new market). In all cases, however, progress along each underlying dimension represents a distinct strategic choice. This matters because technologies do not adapt of themselves; rather, they progress due to actions of organizations operating in a competitive environment. Formulating a strategic technology response, therefore, requires consideration of internal as well as external organizational factors.

5. From Technologies to Organizations

Research has identified a long list of challenges that incumbents confront when they attempt the transition to a new technology base. These challenges encompass not only the technical competence base required for production, but also the organizational competence base which is critical for successful deployment. Largely neglected in the literature has been an examination of the challenges associated with *not* making the leap to the new technology. This omission likely is due to the implicit assumption that failing to pursue the new technology is not an active decision, but rather the passive byproduct of organizational inattention or inertia. In contrast to this view, we argue that the pursuit of a 'graceful retreat' can be an active, strategic choice. As

such, it too raises a collection of challenges. Like the challenges associated with technological transitions, the challenges associated with technological retreats impact the organization's relationship with both internal and external constituents. Their causes and effects, however, can differ substantially.

a. Internal challenges of retreat

Superficially, the choice to pursue a strategy of retreat might appear to be a choice not to change: the firm is maintaining its existing technology rather than transitioning to the new. In reality, remaining in the old technology requires the firm to develop new capabilities as well as new ways of interacting with the providers of the resources that underlie these capabilities. Consider, for example, the changes required to support a decision such as Ultratech's to remain in the older stepper technology rather than to embrace the newer generation.

Marketing capabilities previously devoted to persuading established customers that Ultratech's machines offered the best performance and deserved a price premium would be inappropriate for older-generation tools. Serving new markets such as packaging and drive heads, and therefore confronting customers with different performance and cost preferences, would require significant changes in the sales and support functions. Similarly, engineering capabilities developed to maximize performance for the industry's cutting edge may not be easy to adjust to accommodate the needs of customers with lower performance requirements and higher cost sensitivity, even if undertaken in support of a technology the firm already offers. In the imagery of March (1991), maintaining the old technology platform, a nominally exploitative

choice, is predicated upon the explorative act of creating the new capabilities that will support the technology in its new environment.

Even in the case of the purest technology retreat – selling the very same product to a smaller group of the very same customers, the firm may be confronted with significant innovation challenges. When technologies are in ascent, process innovation often entails the pursuit of economies of scale. Confronting a significant reduction in target market size may therefore require dramatic redirection of process innovation and manufacturing capabilities, reversing the traditional gradient from custom- to batch- to mass- production (i.e., Utterback and Abernathy, 1975). For example, a major production achievement of the chemical film industry was its transition from the batch processing that characterized its early days to the sophisticated mass production techniques and equipment that allowed the triumvirate of Agfa, Fuji and Kodak to dominate the market at maturity. At the height of its production, film was manufactured in enormous runs involving rolls of plastic or acetate, 60 inches (1.52 meters) wide and one mile (1600 meters) long. After being coated with layers of chemicals, the rolls were cut down to the various smaller sizes required for different film types. With the decline in film demand that has accompanied the rise of digital photography, the value of such scale-intensive techniques has fallen dramatically. In response, the industry, which continues to invest in film, is shifting production investments towards smaller batch runs, shedding scale and trying to improve flexibility. These activities and the capabilities they require are fundamentally different from those of previous decades.

A graceful retreat strategy may be difficult for an organization because it can be perceived as illegitimate by some internal stakeholders. When a retreating firm shifts its focus to a new

market, it can significantly impair the value of its employees' personal human capital by requiring engineers, salespeople, and marketers to recreate their knowledge of market requirements and market competition. Further, an explicit choice to forego the new technology may well be viewed as an indication that the firm is mired in the past and is resigned to defeat. This can make employee retention difficult, particularly when employees might be courted by rivals that that have embraced the emerging technology. For the same reason, a firm that signals its willingness to remain in the old technology may find it difficult to attract the best new talent.

b. External challenges of retreat

Technological retreats also challenge the way in which the organization relates to its external environment. Whereas a key determinant of success for an emerging technology is its ability to establish legitimacy in its target market, a retreating technology faces the challenge of maintaining legitimacy in the face of the new technology – not only with its customer base, but also with its entire ecosystem, including suppliers, complementors, distributors, regulators, and sources of funding.

Part of the challenge in coordinating the participation of these ecosystem partners lies in the fact that the driver of the technological retreat is not a decline in customer needs. Rather, it is driven by a decline in the old technology's ability to address these needs. In deciding whether and how to support the retreat, external partners must evaluate their own positioning vis-à-vis the new technology opportunity as well as their own opportunity costs. And because the value external partners derive from the technology depends not only on the prospects of the technology

itself, but also on the continued participation of other partners, the old technology depends on its ecosystem's maintenance of critical mass.

Consider, for example, the case of suppliers. Many technologies are bundles of components, and their performance depends on the performance of these subsystems (e.g., Rosenberg, 1976). While the literature has examined how emergence of such components acts as a critical determinant of the rate of emergence of new technologies (e.g., Hughes, 1983; Adner and Kapoor, 2008), their availability and development is also a critical determinant of the sustainability of retreating technologies. The rise of the new technology reduces not only demand for the focal old technology, but for components for the old technology as well. This contraction (and the expectation of future contraction) may have important implications for the firm's supplier base.

To the extent that the old technology relies on generic components that are sold to firms in a variety of industries, the contraction of the old technology itself is unlikely to impact its ability to access suitable component supplies. When components are specialized, however, the reaction of suppliers is key to the viability of a retreat strategy. Faced with declining demand in their own core market, suppliers to the old technology will reduce their own capacity and investments in proportion to the expected decline.

If suppliers contract with a lag, components may be inexpensive and freely available in the short term following the loss of end market demand, but then become scarce as suppliers rationalize their own industry structure. For instance, in the 1970s, most manufacturers of Hi-Fi audio equipment made the transition from offering vacuum tube-based systems to offering transistor-based systems. Demand for these vacuum tubes fell off sharply, leaving a large quantity of

finished goods inventory of vacuum tubes on warehouse shelves. For a time, the supply of "new-old stock" vacuum tubes was plentiful for the few tube-based Hi-Fi manufacturers that remained, but as the existing stocks were depleted, tubes became a rare and costly commodity. Thus, assessing the viability of a retreat strategy depends not only on the firm's own ability to identify a sustainable niche and adapt its organization to address is, but also on the willingness of ecosystem partners to participate in the effort (i.e. Adner, 2006).

6. Deliberate Retreats vs. Emergent Concessions

Given the explicit initial assumption that the new technology is preferred by most consumers in the old technology's market, technological retreat is an inevitable consequence of our setup. Our intent in this paper is not to introduce the gradually shrinking footprint of the old technology as a novel outcome, but rather to examine the key dimension along which this retreat might progress, and consider the opportunities available to old technology firms to embrace this retreat *proactively*.

a. Competitive Advantage and Proactive Retreat

There are reasons to expect that firms that proactively manage retreat will fare better than those that manage decline reactively. First is the strategic interaction among retreating old technology firms. Particularly in the case of niche retrenchment, early movers may foreclose the retreat opportunity for laggards because the niche's smaller size compared to the original market means that it can support a reduced set of producers. The smaller the niche, the greater the

impact of the early mover's entry with respect to residual demand (e.g. Porter, 1980). It may also be possible for early niche entrants to raise entry barriers into the niche by, for example, locking in key component supplies and suppliers in the expectation of broader industry decline (e.g. Harrigan, 1988). Second, and more directly, by making the retreat decision, management is able to redeploy resources that would be allocated to addressing the needs of the old mainstream market. With an explicit focus on subniches and/or new application domains, the firm can focus on developing offers (e.g. more complicated mechanical watches) tailored to these segments. Finally proactive, explicit retreat will also serve to reduce organizational conflict regarding investment priorities and organizational responsibilities. Firms often attempt to maintain a position in the old technology while at the same time developing the new technology. The organizational challenges of managing technological coexistence within a single firm are well explored in the literature (e.g., Christensen, 1997, Tushman and O'Reilly, 1997; Taylor, 2008). Firms that pursue a proactive retreat strategy may be better able to coordinate and separate not only the development strategies for the old and new technologies (i.e., Taylor, 2008), but their market targets as well. Because investments in production and market deployment tend to be significantly larger than investments in development, we suggest that the clear market focus inherent in retreat will significantly advantage those firms that approach retreat proactively.

b. Empirical Indicators

By construction, it is impossible for the old technology to maintain its position in the market in the face of a dominant new technology. What remains, then, is the empirical question of how to distinguish between retreat as a deliberate strategy to extend sustainability and retreat as an

emerging concession to inevitable decline. The observation of a firm's shrinking market presence in its home market is clearly insufficient because it may be caused either by a proactive choice or by a failed defense. Instead, we must to look clues regarding the ways in which the firm's activities and market footprint are changing – changing relative to its earlier activities and footprint, as well as relative to the activities and footprint of its old technology peers.

With respect to retrench strategies, we expect deliberate retreat to correspond to:

1. The reallocation of development resources away from mainstream projects and towards niche opportunities within the home market.
2. A change in marketing message and development emphasis to highlight and extend the narrow points of differentiation relative to the new technology, rather than general differentiation relative to old technology rivals.
3. A shift in the offer portfolio, manifested by a change in the balance between new offer introduction and old offer retirement, to move emphasis away from the mainstream market.

With respect to relocation strategies, we expect deliberate retreat to correspond to:

1. The reallocation of development resources away from mainstream projects and new markets that are less attractive than the home market had been (and hence it is demonstrably different from traditional diversification).

2. Marketing efforts directed at new application domains that had not earlier been a focus of sales and advertising resources.

3. Engagement with a new distribution base.

Among the set of old technology firms, we would expect firms pursuing deliberate retreat strategies to exhibit these changes in advance of firms that are grudgingly displaced by the new technology. We would also expect to deliberate retreaters to exhibit the competitive advantages discussed above.

7. Conclusions

An important motivation for writing this paper is to explore technology retreats as legitimate strategic choices for both scholars and managers to consider as they assess responses to dominant technology threats. The decision to forego adopting a rising substitute should not automatically be viewed as a sign of inertia or incompetence; rather, continuing the active pursuit of the old technology should be viewed as a potentially viable, rational, and profitable strategy.

While the field has developed a deep understanding regarding the broad patterns in technology life cycles (e.g., Abernathy and Utterback, 1978; Henderson, 1995; Klepper, 1996), and the dynamics of technology emergence (e.g., Sahal, 1985; Basala, 1988; Adner and Levinthal, 2001), far less attention has been focused on the question of strategy late in the

technology life cycle. In analyzing the fate of the old technology given the rise of the new, the tendency has been to assume that the old technology's terminal decline is simply a matter of time. Underlying this bias is a tendency to approach the demand environment in which success and failure is determined as fixed and homogeneous. As we argue, however, the inherent heterogeneity in the demand environment can create opportunities for the old technology to reposition itself and continue in new, sustainable niches. Ironically, it is the rise of the new technology that reveals the underlying heterogeneity that may allow for the survival of the old technology.

Retreat, of course, is not always a viable strategy (i.e., if revealed niches are too small to support the operations of minimally sized firms). Importantly, however, retreat is almost never a simple strategy. Retreat is not passive. Indeed, its pursuit requires an organization to resolve a host of new internal and external challenges that arise when aspirations shift from growth to contraction, from dominance to survival. This shift in perspective raises new research questions at the levels of firms, industries, and technologies, which merit development in future work.

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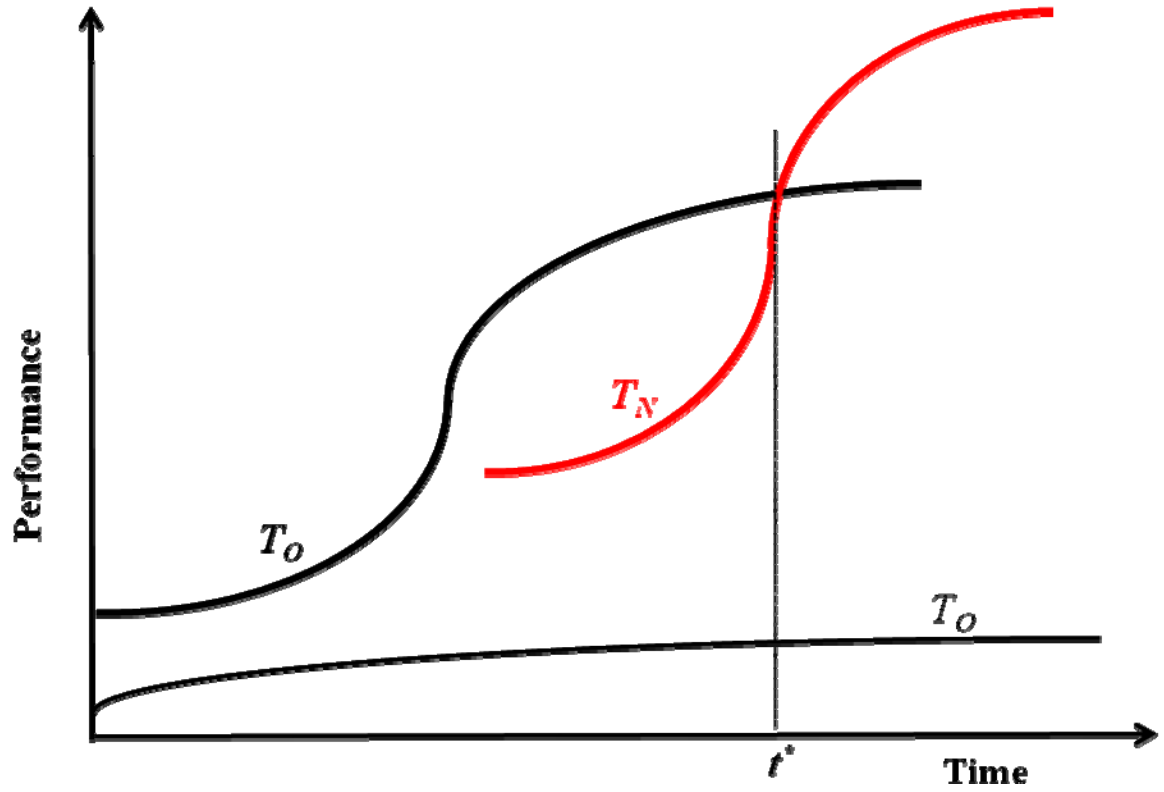

Figure 1: Schema of technology competition.

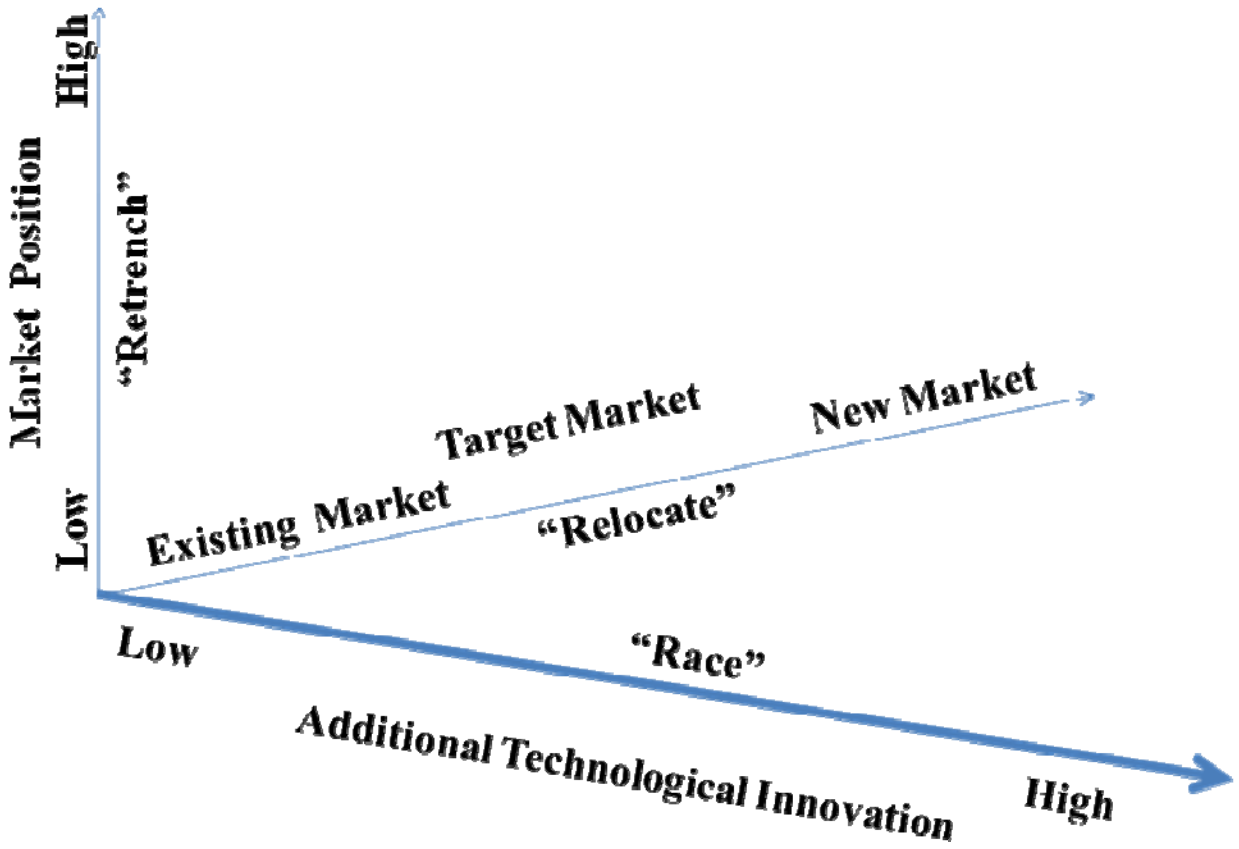

Figure 2: Dimensions of response.