Three Essays on the Dynamics of Industry Formation

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This dissertation contributes to three sub-literatures in strategic management: strategic timing of exploration; incumbent-challenger dynamics for radical innovation; and, first-mover advantages. Each essay makes contributions to both theory and methodology.

Essay One proposes a new theory of the strategic timing of within-industry exploration, *Harmonic Oscillation Theory*. Synthesizing decades of marketing and strategy research, this theory proposes that industry maturity is best understood as an oligarchy of firms who have found a *harmonic fit* – both to the overall industrial rhythm of exploration and to each other's product initiatives. The essay presents a model of *Four Generic Timing Strategies***:** 1) *in-phase* for durable goods; 2) *anti-phase* for cultural goods; 3) *multi-phase* layers of super-harmonic and sub-harmonic firm activities for any focal industry; and 4) *managing chaos*, in the case of risk mitigating, and/or exchange market-managing, firms. I provide exemplar cases for durable goods (Silicon Valley consumer hardware) and cultural goods (Hollywood theater releases). My extension of entrainment theory explains how to model technical timing waves (zeitgeber) and demand timing waves (zeitmacher) to arrive at a theoretically optimal timing pattern.

Essay Two examines patterns of radical exaptation in new industry formation. I show that, in contrast to the "wholly new" technologies responsible for disruptive/moonshot innovations, radical exaptation involves "partially new" innovation trees that trigger stand-alone industries. I resort the strategies of incumbent-challenger dynamics into Four Radical Innovation Strategies*:* 1) *Moonshots* 2) *Disruptive Innovations*; 3) *Rebel Alliances*; and 4) *Blue Oceans*. The essay examines 12 qualitative cases of radical exaptation to confirm ten Rebel Alliance and Blue Ocean scenarios.

Essay Three is a deep dive into the emergence of market leadership cohorts. I theorize that proofpoints are an excellent predictor of market leadership. This is the first study using Crisp-Set

Qualitative Comparative Analysis to predict emerging market leadership cohorts. The essay focuses on the *Rebel Alliance Strategy* – the radical exaptation of a technology by enterprising, cooperative lead users of the incumbent technology. I model automobile, microcomputer, and 3D desktop printer leadership cohorts. I confirm a new *Rebel Alliance Model* of six *Promethean* proofpoints for pioneering commercialization and six *Mercurian* proofpoints for firm takeoff.

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Preface

This document evolved from a series of studies conducted from 2013-2018. Each of the three essays started as a simple query: a single, abstract idea independent of the popular literature. At every turn, I did my best to reduce my intuitions to extremely modest empirical studies of clear and simple strategic mechanisms, as is befitting of a doctoral student. But no matter how simple I tried to make the study, the refined version eventually turned into a complex "big idea".

Essay One began as a very simple conjecture: that a strategic group of firms would tend to seek a "smooth distance" from each others' strategic initiatives, all else aside. As I kept refining this idea, it became apparent to me that "smooth distance" varies by industry, and specification would require deep research into the causes and consequences of typical industrial patterns of strategic timing. Thus, a simple idea became a multi-year dive into literally hundreds of papers.

Essay Two started as a question as to why all Schumpeter Mark I creative destruction scenarios are assumed to be well-covered by the theory of disruptive innovation – it seemed to me that many radical innovation scenarios were systematically excluded by that theory. I noticed that lead users sometimes collectively invented the new architecture to serve alternative functions: *whatever <u>they</u> wanted to do with it*. This observation led to a typology of radical innovation types.

Essay Three began as a recognition that pioneering firms in microcomputers embraced radical ideals. I wondered if the visionary ideals that motivate product pioneers (Prometheans) might limit their ability to subsequently scale up, whereas Mercurians could easily do the job.

Starting with a repertoire of such difficult questions, I stumbled through and across a wide variety of literature, seeking deep insights. Due to my tendency to foray completely into the unknown and touch *every possibly pertinent literature*, it was quite difficult to identify a chair who was willing and able to steer my mind towards practical studies. When shopping around my "very rough drafts", I received many irritable questions from early reviewers, such as:

> "Essay One: Why is a doctoral student attempting to write a major view of the firm when there are only about six successful attempts in 100 years?... If these timing patterns existed, people would assume such a phenomenon would have been discovered by some senior scholar by now…. You've got your work cut out for you."

> "Essay Two: Why do you think you can pull off a paper about a "Schumpeter Mark III" matrix of radical innovation, when the strategy literature still doesn't have broad agreement on strategizing the Schumpeter Mark I/II dichotomy?... You might want to try dramatically narrowing your idea."

> "Essay Three: a Promethean/Mercurian dichotomy is intriguing, but microcomputers and 3D desktop printers is not enough evidence to build a theory…. I don't buy that this pattern happens in other major industries – like, say, automobiles."

Fighting the clock and facing a difficult job market, I decided there was no time to turn back and do a safe database study on well-established constructs. Instead, my best course of action was to use appropriate case studies to demonstrate these "big ideas" are already well fleshed out in prior literature, but somehow systematically overlooked. And indeed, I believe this essay achieves that goal.

I look forward to follow-up studies to examine the implications of these three essays. My goal was to start lines of new inquiry. Essay one was intended to stimulate complex timing studies that consider how super- and sub- harmonic patterns emerge when industries are interlinked. Essay two was intended to spur studies that get us over the hump of excessive generalization about industry emergence. Patterns of innovation should be studied as "opening moves", similar to how chess players study dominant opening lines of chess play. Essay three fleshes out the first such opening sequence, and implies future work on the other four major sequences, as well as a host of minor (niche) strategic sequences for peripheral players in new industries.

I would like to acknowledge the amazing support of my family, especially: John, Connie, Sean, Megan Ryan; Stephanie and Scott Lindell; and Ron and Nancy Proesel. My father, John, was a generous proofreader. I would like to acknowledge my committee and the Katz doctoral program, with special thanks to Carrie Woods for supporting me on a personal level. I originally developed the conjecture behind essay one for Dr. Fritz Pil's seminar – although he found it interesting, he sternly reminded me that it was "not what he asked for"! I want to thank Roger Williams University and Oakland University for providing me visiting professorships while I finished the dissertation. I want to thank the city of Pittsburgh for being my home away from home. I want to thank my daughter, Isabella Ryan, for being the driving force that kept me going, even when I passed through deep emotional hardship and reached the depths of despair. And last, I want to thank Dr. Barry Mitnick for rescuing what was otherwise a broken plan. Rarely is a faculty member called to be the chair of a dissertation outside of their own field of study; especially for a dissertation that re-conceptualizes some of the core constructs for a field. It takes a genius and a saint to pull that off, and those two words seem quite fitting for him.

With gratitude,

Robert Conan Ryan

1.0 Harmonic Oscillation Theory: A Temporal View of the Strategically Entrained Firm

Since the late 1990s, *Organization Science* has enjoyed an increasing interest in literature on the nuances of strategic timing (i.e., Slawinski and Bansal, 2015; Gulati and Puranam, 2009; Raisch et al., 2009; Katila and Chen, 2008; Nickerson and Zenger, 2002; Orlikowski and Yates, 2002; Huy, 2001; and others). The classic question of strategic timing involves understanding what moment is best for taking a *new strategic initiative within an established market* (Pettis et al., 2017; Liao and Seifert, 2015; George and Jones, 2000; Fine, 1998; Burgelman, 1983). Firms must master exploratory timing of substantial product/process redesign initiatives. Indeed, strategy practitioners are largely responsible for the periodic (re) construction of market categories (Cattani, Porac, and Thomas, 2017). How often should, say, an automobile company or media company commit resources to explore a major category redesign?

Initiatives, not entry/exit. The reader is here cautioned that this timing question should not be confused with two related, but separate, questions of timing.

First, the initial decision to enter or exit an industry, and the associated patterns of firm performance vis a vis order of entry, is covered in *Incumbent-Challenger Dynamics* (Ansari and Krop, 2012; Agarwal and Bayus, 2004). This essay's research question assumes the firm already has made such decisions to participate, has already launched an initial product, and now is deciding on the timing of its *next* within-industry activities, on a marginal analysis of the industry's *clockspeed* (Fine, 1998). It must repeatedly make such decisions all along the industry lifecycle. For example, Apple entered the microcomputer business in 1976, but by 1977, it faced the dilemma of exploiting its initial Apple I product design, or shifting all efforts towards the Apple II. They chose to switch (Veit, 1993), to take advantage of a color capability, at a time when all its competitors were also exploring distinguishing features suitable for a dominant design. Next, they incrementally extended (exploited) the original Apple II design for several years, adding annual upgrades. By 1981, in anticipation of the IBM PC and a 16-bit generation, they were making bold redesigns: the Lisa and the Macintosh: and new timing dilemmas followed. This essay addresses such dilemmas as Apple's choice of timing of exploratory redesign initiatives as the personal computer lifecycle matures. Rhythm may be essential to oligopolistic (Stigler, 1964) competition. Second, this essay does not concern timing with regards to truly competence-destroying, industry-replacing discontinuities (Anderson and Tuchman, 1986) – only generational technical improvements. For a clarifying example: consider Mazda's launch of its category-defining model, the 2016 CX-3. To create the CX-3, Mazda hybridized its Mazda 2 platform with the features typically found in the "luxury all-wheel drive subcompact" category (Audi Q3, BMW X1, etc.). While the Mazda 2 was among the lowest price cars in the world, the CX-3 became a mid-priced alternative to luxury brands. Such an initiative does not create a new industry or destroy incumbent's technical competences. However, their aggressive category redesign appealed to shifting trends and repositioned their strategy toward the midpoint of the subcompact crossover market. The CX-3 employed new capabilities but destroyed none.

Achieving Timing Mastery. "Temporal change does not necessarily involve the "what" of the change, but the "when."' (Perez-Nordvedt et al. 2008, p. 6). The basic variable of concern here is timing of *strategic vacillation* (Nickerson and Zenger, 2002) between initiatives: when to explore new sources of profit, and when to exploit existing knowledge. March's (1991) dilemma of exploration/exploitation has been heavily extended by scholars to nearly every unit of analysis possible (Gupta, Smith, and Shalley, 2006). But we still lack a theoretical understanding of how firms must balance timing of these alternative initiatives on two different levels: 1) with respect to the pace of industry lifecycle changes in technology and demand and 2) with respect to the marginal, seasonal timing of product launches of rival firms. Profit maximizers must correctly time strategic initiatives *from start to finish*, not just the final product launch dates (Calantone and di Benedetto, 2007; Eisenhardt and Brown, 1998). Projects can benefit from such mechanisms as knowledge spillovers, or suffer such setbacks as bidding for co-specialized resources.

Limitations to the classic innovation-diffusion model. There is a widespread awareness that prevailing theory on mature competition is based on consumer durables: a special case model driven by dominant designs (Windrum and Birchenhall, 1998) and the dynamics of Bass/Roger's S-Curve/Diffusion Model (Bass, 1969; Rogers, 2010). There is a need for an approach to modeling of exploration and exploitation timing that can handle other forms of goods, especially for industries with strong "demand side" effects on value creation (Priem, Li, and Carr, 2012).

Consumer Durables are only 1/10th of GDP. According to the Federal Reserves' free database, FRED, average sectoral shares of GDP have been stable over the past few decades. Consumer categories of goods and services account for roughly 70 percent of GDP. Durable goods consumption, such as automobiles and kitchen appliances, comprises merely 10 percent of GDP. Services/software account for 40 percent – four times the expenditures! [the other 20 percent is nondurables]. Obviously, many industries are not going to conform to the durables model. Herein I frequently refer to "durables" or "durable firms", dropping the "goods".

Cultural Goods. The greatest chunk of consumer activity are intangibles and services: entertainment and personal services, media, cultural reproductions of art/nature, luxuries, and popular software, otherwise collectively known as *cultural goods* (Throsby, 1999). As before with durables, in this paper, I will often refer to "cultural firms" and "culturals", dropping the "goods"." Culturals' utility derives from consumers' collective/individual learning, not by some durable (reliable) product functions (Lampel, Lant, and Shamsie, 2000). Cultural entrepreneurs (Gehman, and Soubliere, 2017) are those responsible for exploratory cultural innovations. Eisenhardt and Brown (1998) referred to continuously changing competitive landscapes – most especially software markets – as "markets that won't stand still" (title of paper). More discussion on cultural timing can be found later in this essay.

Blockbusters and genres. Whereas durables are stabilized by dominant designs for years at a time (Anderson and Tushman, 1990) – consider that the I-Phone is entering its 7th generation of incremental change – culturals evolve much more rapidly, as categories are redesigned frequently. For example, consumers learn to appreciate Hollywood films within a fast-changing, networked, yet increasingly localized cultural context (Scott, 2004). Firms in personal services are dedicated to make their clients look fashionable or extend their cultural knowledge. Cultural collectibles like sports memorabilia and the infamous Beanie Babies capture iconic historical moments: gold rushes of the hot moment. Most profits to the *creator* are made from initial releases, such when a Hollywood film like *Black Panther* tastefully capitalized on extremely timely facts, fads, and issues. But, a *curatorial* process [Mitnick and Ryan, 2015] makes meanings new-to-audience and captures residual value beyond the technical creative process. Hirsch (1972, p. 32) referred to curators as "surrogate consumers". Replication and reinterpretation are relentless cultural processes (Toeffler, 1964). Profits are highest from a high impact *blockbuster* theme – also known as a subgenre, hit, series, icon, franchise, and so forth.

The S- Curve or the Λ-Curve? Research exists to show that Hollywood films have their own classic product curve – *declining exponential sales*, what I call the Sawtooth or Lambda(Λ-) curve, based on the sharp downward slope of sales from product debut. The Λ-curve is subject to brief, repeating re-releases of related products with the same shape – creating a much different competitive dynamic than the low, slow, unfolding of sales of the S-curve, for durables (Krider and Weinberg, 1998; Simonoff and Sparrow, 2000). Similar declining monotonic sales have been observed in music, novels, and most other culturals (Beck, 2007). The Λ-curve has potential as a culturals exemplar. Furthermore, as the field shifts its attention toward platform-based competition, there is need to consider the other extremes: temporally chaotic environments and super-/sub-harmonic platform patterns (Rochet and Tirole, 2003; Gawer and Cusumano, 2008). A general timing-diffusion model would permit complex waveform analyses.

Harmonic Oscillation Theory. This paper updates and synthesizes the strategic literature on the timing of organizational initiatives, and arrives at a new model of *Four Generic Timing Strategies:* 1) *in-phase* durables; 2) *anti-phase* culturals; 3) *multi-phase* layers of super-harmonic and sub-harmonic firm activities for any focal industry; and 4) *managing chaos*, in the case of risk mitigating, and/or exchange market-managing, firms. In the 21st century, industry convergence and increasing technical complexity forces most major industries to employ blends of durable and cultural layers of technology; thus, most complex industries are 3) multi-phasic, and also likely to involve 4) management of some chaos. Still, scholars cannot analyze these complexities until we first establish the analytical basis point for the simplest expressions for 1) in-phase and 2) anti-phase industrial timing. Therefore, this paper will tackle in-phase and anti-phase strategies, and leave the other two for future work.

I shall revisit the literature for patterns of mature competition to construct a general lifecycle theory rooted in the industrial timing patterns of firm initiatives. I refer to this view of firm timing as Harmonic Oscillation Theory (or HOT). Indeed, from the perspective of the general manager, entrainment must always be a problem of finding *harmonic fit*. This term is selected to distinguish this essay's argument from the more generic term of *temporal fit* (Shi and Prescott, 2012; Jansen and Kristof-Brown, 2005). Firms find harmonic fit to their changing strategic environment by entrainment (Ancona and Chong, 1996) to environmental drivers of change. Under some industrial conditions of mature competition, oligarchs tightly imitate the timing of firms in their *strategic group* (Reger and Huff, 1993). In other mature conditions, firms will tend to leapfrog each other, seeking to optimize distance between each other's initiatives. Leading durables firms take explore/exploit initiatives *in-phase* – i.e., redesigning product categories at the same time. On the other hand, oligarchic cultural firms tend toward *anti-phase* explore/exploit actions - i.e., "when one firm zigs, the other(s) zag(s)".

Essay outline. This essay presents HOT in the following sections. First, I touch on lifecycle history and challenge the *four prevailing assumptions in lifecycle theory*. Second, I provide a restatement of the industry lifecycle in terms of *exploration/exploitation timing*. Third, I discuss the next level of analysis down: *initiatives launched with respect to competitor firms*. I use examples of categorical explorations for personal computing devices and film releases. Fourth, I specify the theory of four Generic Timing Strategies: *in-phase, anti-phase, multi-phase, and managed chaos*. I also address details of how organizations move in or out of phase, or *overclock* their competitors. Fifth, the paper briefly revisits the literature supporting the organizational advantages gained from accurate in-phase and anti-phase timing. This section revisits four theories: *vacillation, co-specialization, intertemporal ambidexterity, and leapfrog spillovers.* Section six concludes with the usual discussion of limitations and research directions.

1.1 Loosening the Four Historical Assumptions of Lifecycle Theory

Strategy scholars need to overcome four key assumptions driven by historic dependency on reliable S-curve adoption for durable features (Abernathy and Utterback, 1978; Clark, 1985; Henderson and Clark, 1990): the assumption of objective measures of performance; technical dominance; steadily incremental mature innovation; and, a strictly in-phase strategic alignment of firms to the lifecycle, rather than to each other's anti-phase actions. But first, let us summarize the history of the scholarly focus on durable goods.

The historical product lifecycle. Scholars started describing industrial "product cycles" (Rink and Swan, 1979; Anderson and Zeithaml, 1984) as a feature of capitalist mass production. Industry lifecycle models are known as proceeding in four stages: emergence, growth, maturity, and decline – although the labeling of stages varies. Scholars currently focus their attention on deeper dives into industry emergence and growth (Agarwal, Moeen, and Shah, 2017; Suarez, Grodal, and Gotsopoulos, 2015). The lifecycle view of technological and industrial change is a widely known and used collection of theories concerning cyclical technological change patterns (Clark, 1985; Dosi, 1982; Kaplan and Tripsas, 2008; Klepper, 1996; etc.). But industrial patterns of innovation are more than a study of firm entry and exit: they have widespread implications for within-industry strategic and organizational timing (Gort and Klepper, 1982; Abernathy and Utterback, 1978). Most scholars have extended from Abernathy and Utterback's (A-U) consumer durables model (1978).

Classic lifecycle studies began with modeling the historical evolution of automobiles and similar durables produced on assembly lines, and then cross-industry comparisons on broad factors, such as rate of firm entry/exit, and firm size (Gort and Klepper, 1982; Klepper, 1996; Agarwal and Bayus, 2004). Scholars focused on *assembly lines themselves* as the standard mythology for what a mature industry is and does. It is because of mass production that firms compete in a sequence for sales takeoff, dominant designs, and other early locked-in advantages (Agarwal and Bayus, 2002; Chandler, 1992). Firms develop capabilities in a progression from early exploration to later exploitation, ending in a creative destruction process that supplants old forms (Schumpeter, 1934; Clark, 1985; Dosi, Malerba, and Orsinigo, 1994). In emergence and growth, frequent upgrades to designs occur, and it is hard for a firm to rely on incremental extension, until a dominant design emerges. By maturity, it is assumed that firms settle into routine generational upgrades. Mature firms compete on bundling features at price points, because of high standardization: processes, product categories, parts, organizational structures, etc. In industries such as personal computers, firms race to establish dominant form factors (Bell, 2008), and then ride out incremental innovation until technological advances enable new form factors. Firms can anticipate planned obsolescence, measured by the number of years until industry-wide technical updates (Fishman, Gandal, and Shy, 1993). Industry renewal is driven by a radical, discontinuous technology (Tuchman and Anderson, 1986; Helfat and Peteraf, 2003).

The Abernathy Utterback (A-U) Model. The A-U Model explicitly approaches "industry" in terms of the manufacturing of durable goods. It describes the "specific pattern", also known as a "locked-in" (Lieberman and Montgomery, 1998) oligarchy: cost-driven competition, standardized products, incremental process innovation, and high automation. Thereafter, the field also accepted Klepper's (1996; also, Gort and Klepper, 1982) well-known lifecycle model of firm entry and exit rates, driven endogenous by a cycle of product/process R&D expenditures. Scholars also continued with the A-U Models' dominant design perspective (Anderson and Tushman, 1990; Suarez and Utterback, 1995), whereby the bulk of the growing/mature industry is stabilized by convergence on one design, until disrupted by a technical discontinuity, trigging a consequential renewed search for a dominant design, etc.

Extending the durables model. The field then looked for more variables, levels, and units of analysis. Scholars sought multilevel analysis of sociotechnical systems (Murmann and Frenken, 2006). Lifecycle analysis includes such literatures as: product platforms (Robertson and Ulrich, 1998), firm capabilities (Helfat and Peteraf, 2003; Fortune and Mitchell, 2012), product categories/waves (Ghodal, Gotsopoulos, and Suarez, 2015; Golder and Tellis, 2004), strategic organization design (Sirmon, *et al.* 2011; Jawahar and McLaughlin, 2001), and even alliance networks and industry clusters (Chao, 2011; Hwang and Park, 2007). Some of these strands of literature are theoretically divergent, but that issue is beyond this essay. Let us turn to developing a general model of explore/exploit initiatives.

Breaking Assumption #1: functional value. Culturals are driven by qualitative perceptions, consumer knowledge, and fashionable status more than price/performance ratio. Primary resources for producing such goods are "cultural capital" (Throsby, 1999; Bourdieu, 2011). Cultural capital includes individual/firm/industry institutional statuses, cultural knowledge, and artistic design training. There is no universal "functional" expectation that all consumers eventually adopt a given cultural good: demand for these goods are culture-specific. Most consumers view them as a leisure expense, and the only expected adopters are those of a predetermined cultural audience of an approximate size.

All cultural goods share four common tendencies. First, they are *experience goods* that are hard to evaluate prior to the situation of consumption (Reinstein and Snyder, 2005). Experience goods are therefore affected by a performativity of value within an embedded, time-specific context (Garud, Gehman, and Guiliani, 2014). Second, aside from niche collectible markets, the average consumer willingness to pay for culturals is tied to specific moments representative of, and embedded in, *cultural history* (Gehman, and Soubliere, 2017). Not just individual consumers' long run utility function. Firms must control networks for the timely "mainstreaming" of the moment (Patriotta and Hirsch, 2016). Third, they are *positional goods* (Solnich and Hemenway, 2005), meaning that the value of the good for a focal consumer is at least somewhat tied to the perceived utility that others assign to them; thereby, timely consumption/possession imparts some relative status within the pertinent audience, albeit imparts no status effect outside that audience. Fourth, consumers evaluate culturals on *interpretive meaning* more than on functional performance. This fact applies not just to artistic productions, but also most software and organizational innovations (Orlikowski and Yates, 2002). As socially constructed forms of value (Berger and Luckmann, 1966; Bourdieu, 2011), culturals are reproductions of cultural capital resources (Toeffler, 1964; Throsby, 1999, Bourdieu, 2013). These include: a live performance, a copy of performance/text, an aesthetic experience, collectible art, symbolic work, A.I. services, a media product/service distribution, and any primary service interaction, even if by service robots.

Breaking assumption #2: technical dominance. Durables focus on a supply side trajectory (Dosi, 1982), and how new technologies and niches disrupt the prevailing technical order (Christiansen, 1997).

In durables, each product category becomes associated with a standard architecture – leading to mutli-level coopetive strategic challenges (Gnyawali and Park, 2009; Murmann and Frenken, 2006). The idea that dominant designs typically define the rules for categories of demand appears in dynamic capabilities work (Teece, 2007).

Mature durables launch in concert with industry-wide technical generational rollouts, and this entire sequence fits with the traditional S-curve of innovation diffusion (Mahajan, Muller, and Bass, 1991; Rogers, 2010). Thus, durables firms would be wise to align to a sequence of activities of increasing exploitation until an industry-wide update. This also entails that firms initially focus heavily on product design capabilities, especially those who understand lead users (von Hippel, 2005); but later, firms need to focus on process design and the late adopter profile – therefore, firms seek *capabilities* that follow this progression, planning accordingly.

Research on Hollywood (Rosen, 1993; Simonoff and Sparrow, 2000) indicates that firms must *partially redesign* categories of demand frequently, and the concept of a dominant design does not apply. Standardizing culture is more difficult than standardizing technology. Firms do not face an S-curve of adopters, but rather face mainstream markets and niche markets, with a jagged landscape of brief Lambda curve-shaped releases of projects that take over a year to plan and execute. Hollywood firms must decide how frequently to conduct an expensive search for new aesthetic features, and how much new to mix with the old; and, how much to reuse old design elements across similar, genre-based reproductions. Blockbuster designs only temporarily stabilize a wave of imitator products (Hirsh, 2000). A selection of fashionable design elements across the avant garde landscape end up in new blockbusters. Cultural firms must also perpetually balance continuity and radicality internally (Lampel, Lant, and Shamsie, 2000).

Breaking assumption #3: incremental maturity. Chamberlin (1949) defined the general dynamics of maturity (paraphrased here): monopolistic competition among an oligarchy of firms who have reached an equilibrium state where reciprocal, collusive actions are the natural competitive response. This definition does not require incremental innovation to be the consistently prevailing strategy. Caves and Porter (1978) defined the quintessential measure for attainment of maturity: *market share stability*. Product design contests are classically considered to be connected to the instability of the exploration-dominant emergence stage, while exploitative process innovation among oligarchs has little impact on market share. *Thus, durables firms are expected to reduce the rate of exploratory initiatives as the industry matures.* However, this assumption does not apply to meanings. Sociocultural phemonena – including software, organizational culture, business models, media, and cultural capital – are not constrained by physical laws, and so have the potential to evolve continuously (Orlikowski and Yates, 2002; Garud et al, 2014). Thus, when it comes to cultural meanings, market share stability must be achieved by an oligarchic stabilization of the meaning-making process (Mitnick and Ryan, 2015; Gehman and Soubliere, 2017).

Breaking assumption #4: Stabilizing without dominant designs. For all goods, we can describe timing for the sociotechnical system (STS) for a given industry (Geels, 2002; 2004) in terms of the appropriate explore/exploit strategies prior to, and during, periods of institutional stability. The industry's STS is a cluster of firms and institutions entrained to common technical and demand cycles. We usually assume the industry explodes in growth during a battle for a dominant design. An industry with dominant designs has stable demand and progresses via exploitative technical innovation (Adner and Kapoor, 2010), but a cultural industry with "lenient categories" (Pontikes and Barnett, 2015) allows for widespread disagreement on the boundaries of categories, on the part of firms as well as on the part of consumers. For such industries – especially entertainment and software – firms frequently redraw categorical boundaries.

How cultural firms stabilize the industry. Top firms establish an oligarchy at the top of the cultural design hierarchy by controlling the elite talent pooling and selection process, and the process for bidding on projects (Hirsch, 2000). So, the leaders control the institutions through which ideas flow and the contracts are made. They hire "hot talent", and harvest emerging popular trends, fads from elite design shows, additional market research, and often draw on horizonal institutional ties for tips. But since culturals don't have a dominant design, maturity is instead a period of *dominant institutions for design*. Shared knowledge makes possible the harmonic timing of strategic initiatives among oligarchs. Firms focus on exploring laterally to find design ideas emerging in allied industries and institutions, an approach known as design driven innovation (Verganti, 2009; see also Patriotti and Hirsh, 2016). *Firms aren't expected to reduce the rate of exploration in maturity, but the timing of exploration should stabilize.*

Figure 1: The HOT Lifecycle Model

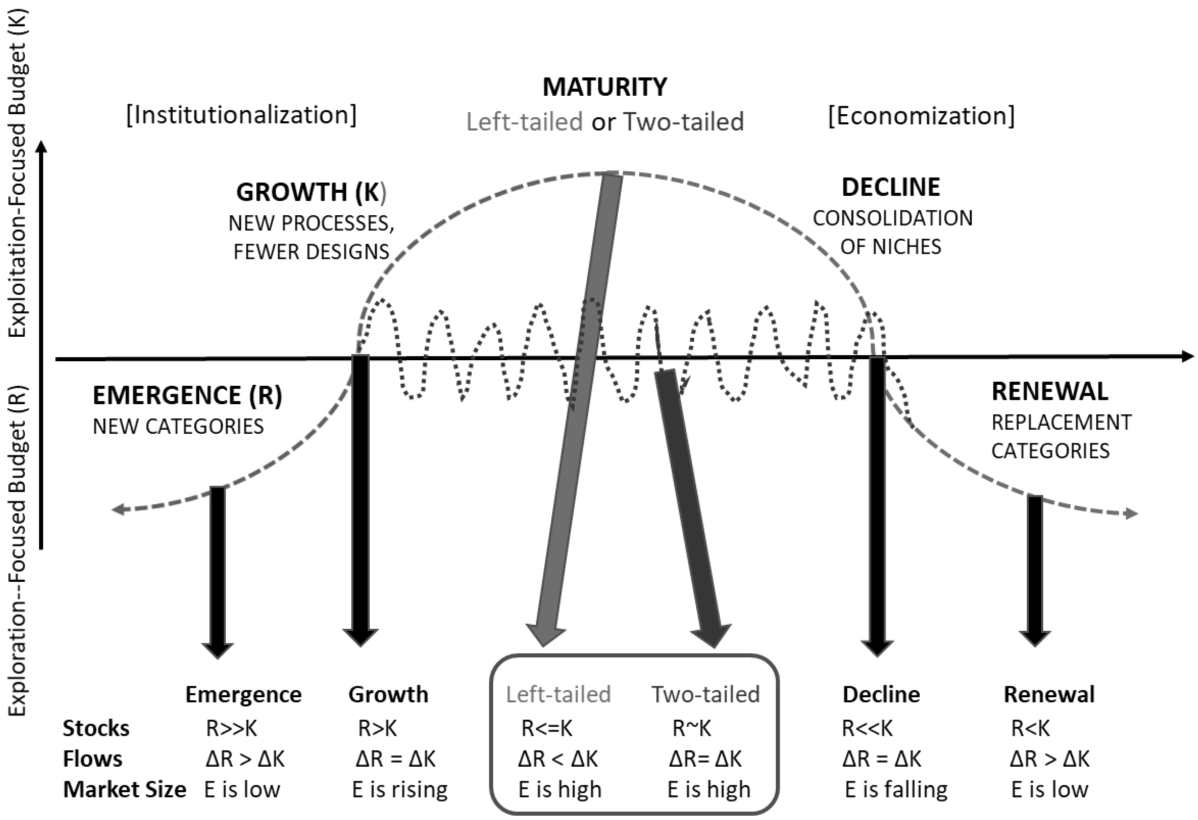


Figure One: Firm Behavior Across a Socioeconomic Lifecycle
Total Expenditures = E; New Explorations= R, New Exploitations= K

1.1 The HOT Lifecycle Model

This general HOT lifecycle model covers both consumer durables and cultural patterns of exploration and exploitation. A firm accumulates stocks in total expenditures, E, via marginal expenditures in exploration r, or exploitation, k. See Figure 1 for a graphical depiction of how these variables relate to each other.

Figure 1 illustrates two separate patterns of maturity for the industry lifecycle, each in terms of budgets committed to exploration and exploitation. Then, I contrast maturity patterns to emergence patterns.

In-phase competition focuses firm alignment with durable goods' prolonged technical trajectories, with demand stabilized by dominant designs. As the lifecycle progresses towards decline, exploratory research budgets grow at a decreasing rate: see Figure 1.

Anti-phase competition features an oligarchy of leapfrogging firms, rapid cycling in their strategic oscillation. In Figure 1, the dotted line depicts a focal firms' strategic oscillations in r and k investments; but each firm tries to align their behavior such that the sum of all oscillations equals zero. When in harmonic fit, the sum of explorations and exploitations are evenly split across all firms, while each individual firm is specializing its efforts one at a time. Akin to r selection in organizational ecology (Pianka, 1970), the approach is to produce high variation, and then select only a few projects for large budget commitments.

Defining exploration and exploitation. Some confusion still exists over March's terminology for exploration/exploitation. A recent attempt to clarify terms comes from Lavie, Settner, and Tushman (2010) (pg. 114): "As long as the organization persists within an existing technological trajectory and leverages its existing skills and capabilities, its operations are geared toward exploitation". However, I raise the critical, classic caveat from Henderson and Clark (1990): a major architectural redesign, although not truly competence-destroying in terms of the underlying technical language employed in the firm, is still exploratory in terms of knowledge on the demand side – a new architecture involves a substantial shift in end user-facing knowledge. Herein we focus on architectural/categorical design innovation that is not competence-destroying. *Note: Business model innovation timing is not covered*.

Locked-in advantage via harmonic fit. Maturity is herein alternatively defined as a period of locked-in *harmonic fit*, where firms tend to stay in the same temporal pattern of initiatives. Periods pre-/post-maturity are movements towards/away from that harmonic fit, and tend to cause "turbulence" (Chakravarthy, 1997). The lock-out of challenger firms is a simultaneous consequence of locked-in oligarchy, and harmonic fit is the key mechanism of how an industry can produce abnormal returns (Burgelman, 2002; Schilling, 1998).

Understanding March's Model. Although March's seminal (1991) paper is widely cited, rarely have scholars used his key conclusion about what he called "left-tailed versus right-tailed" competition. Note: his terminology is confusing because it refers to the specific graph he used to illustrate the phenomena – I only use his terms here to remain consistent for the moment. March's paper concluded with a description of two types of competitive environments. The first kind is the one typically described as "mature"; where firms seek to reduce average error and incrementally increase average performance across all its activities. This focus on efficiency is caused by an exploitation-dominant environment. The second environment, however, involves a brutal contest that permits only a few relative winners, such that relative rank order of a firms' best few offerings matters more than improving average performance (1991, pg. 84-85):

"If relative position matters, as the number of competitors increases, strategies for increasing the mean [of a focal firm's short term performance] through increased effort or greater knowledge become less attractive relative to strategies for increasing variability. In the more general situation, suppose organizations face competition from numerous competitors who vary in their average capabilities but who can choose their variances. If payoffs and preferences are such that finishing near the top matters a great deal, those organizations with performance distributions characterized by comparatively low means will (if they can) be willing to sacrifice average performance in order to augment the right-hand tails of their performance distributions. In this way, they improve their chances of winning, thus force their more talented competitors to do likewise, and thereby convert the competition into a right-hand tail "race" in which average performance (due to ability and effort) becomes irrelevant."

"Right-tailed and left-tailed" emergence and growth. In the classic model, industry emergence and growth favors the most successful of exploring firms: just a few elite "first movers" (Lieberman and Montgomery, 1998) competing for rank order. Maturity, in contrast, favors efficient, incremental exploitation by already-established oligarchs. Thus, the industry gradually progresses from a winner-take-all contest towards a "leveling out" of profits across product portfolios. But in an industry that never settles down, profits continue to be based on rank order competitive dynamics. Indeed, most cultural goods industries are "two-tailed", meaning that firms must continually produce a balance of blockbusters and incremental (genre imitation) innovations to maximize market share across all channels and audiences. *Of course, in the real world, industries are not either/or, but exist on a continuum in terms of the skewness.* For simplicity's sake, durables and culturals are modeled with extreme assumptions.

Emergence and growth in durables. For example, in automobiles, emergence ran roughly from 1893 until 1909. Once the top few leaders were established around 1909, the general nature of industry competition was to follow a dominant design (Geels, 2005), sustaining exploitative improvements to efficiency. Every few decades, the industry was remade by sweeping radical changes, but in general, firms try to maximize the average performance of their portfolio of car models. Recall that the variable k denotes exploitation, akin to k-selection – or, capital intensive investments – in organizational ecological strategy (Hurst and Zimmerman, 1994).

Emergence and growth in culturals. In Hollywood, emergence and growth was also a competition to establish first mover advantages (Miller and Shamsie, 1996). Emergence saw the arrival of a rapid series of technical categories of film (silent movies, cartoons, "talkies", etc.), and multiple levels of genre rules (comedy/drama/history, or shorts/features/epics). But the "Golden Era" growth period was stabilized by institutional stability more than by dominant designs: the establishment of an aristocratic treatment of A-list actors, awards organizations, advertising standards, consolidated major studios, talent management, and of course, major theater distribution chains. Firms focused on locking in supply networks, scouting elite, emerging talent and locking them into long, low-paying contracts – a common pattern occurring across other culturals, such as modern music (Negus, 1992) and sports industries (Heylar, 2011).

1.2 Seasonal Timing of Durables and Culturals

In this section, I will address the second level of timing: seasonal timing. The industry level provided a basic picture of how durable firms launch initiatives across the lifecycle, but cultural goods timing is indeterminate on the industry level; so, we must dig deeper. I address a series of differences between the

Table 1: Variables for the HOT Lifecycle Model

	Mature in-phase competition	Mature anti-phase competition	Emerging or renewing
Mean/Variance source of profits	High Average Performance Leaders seek high mean product performance, economies of scale and complementary assets. The trend for k investments increases over time	High Variance Performance High variance in product performance, economies of scope and network centrality (platforming)	High variance in designs and the search for new economies
Product Timing	Delayed launches face earlier obsolescence, and thus lower lifetime revenues. So, firms make Head-to-head releases in annual cycles during incremental competition.	A products' total lifetime revenue has a high correlation with choice of launch date. Staggered releases; generations are fuzzy because innovations roll out at staggered release dates, spread across blockbusters	Uncertain
Industry stabilization method	Dominant Designs for main categories	Dominant institutions for design (an oligarchy of design institutions)	First mover advantages
Product Type	Durable goods Blockbuster product architectures and low cost/niche alternatives	Cultural goods/services Blockbuster hits and genre-based replications (series, franchises, niches)	Any
Diffusion and sales pattern	Classic S-curve variants approximately follow a sine function in HOT.	Exponential decline in sales follows a sawtooth pattern: lambda Λ-curve	S-curve for durables, Λ-curve for cultural
Example Industries	High Tech durables: Telecommunication networks: currently 4G, ~10 years Computer industries: CPU, Moore's Law, ~2 years, or about 4 years for lower end product architectures LED industries, such as televisions, lightbulbs, etc. Haitz's Law, ~3 years [Lower tech durables evolve in slower intervals, but still have "generations"]	Fast evolving cultural goods: Cross-platform video games Hollywood movies Television series Broadway plays Festivals Wedding/event services Collectibles Fashion goods and services Performance athletic wear Other personal (seasonal) services	Any
Strategic Bias	Inertia from exploitation $r \ll k$	Explore/exploit cycle $r \sim k$	Exploration $r \gg k$
Length of mature period	The length of the mature period is determined by ZM, the length of the technology generation. The entire industry lifecycle is equivalent to one technology generation. Since the industry is renewed rather than destroyed, technology generations are often competence-sustaining, but each new generation causes massive obsolescence.	Indefinite. Industry maturity persists as long as firms can capture value from genre fare. The industry enters decline if firms lose the ability to capitalize on anything but blockbusters, as happened with music. Renewal is the construction of new business models for capturing value from cultural capital.	N/A
Zeitmacher (Demand)	Seasonal market cycles; product replacement for the majority market focuses around an annual product update- early/late updates are costly.	This function often peaks more than once a year; thus, timing for product launches must be evenly distributed across peaks.	Uncertain

	Mature competition, in-phase competition	Mature competition, anti-phase competition	Emerging or renewing industry
Zeitgeber (Technical Standards)	Rate of radical product innovation is determined by the generational renewal rate of the industry. The renewal rate is a stable trajectory, usually in 2-10 year intervals.	Rate of radical design innovation determined by competitive dynamics involved with juggling reverse salients against demand windows; each blockbuster tends to include technical upgrades, spreading them over time.	Randomly distributed breakthrough events
Amplitude of Vacillation	Amplitude, A, determines how skewed the industry is towards exploitation. The amplitude is as function of the lifecycle stage, as given by the industry. As the industry matures, the amplitude of exploration expenditures dampens relative to the overall exploitation budget of a firm.	Culturals split budgets between r and k ($\Delta r = -\Delta k$). Amplitude, A, is the intensity of periodic budget swings between new r and k expenditures. k is based on success rate: the more evenly distributed that profits can be, the more exploitation a firm will attempt. Thus, amplitude increases when average profits from k declines, and when co-specialized resources can be rapidly outsourced	Fast radical changes, No stable trajectory
Spillovers from following	Low spillovers during maturity, as all firms already have the design knowledge to create new feature bundles for incremental products	High spillovers for fast-acting followers, but sharply declining over time, as all cultural concepts are anchored to an ideal time in history. Innovations in blockbusters provide design elements for multiple genre products/services, and for cross-industry brand spillovers.	Moderate spillovers, but timing is difficult
Vacillation rate	The rate of vacillation s determined by the industry's fastest evolving technical trajectory. Firms vacillate by diversification efforts. Minor vacillations might exist at subsystem levels of product and process design.	The rate of vacillation is determined by that particular industry's pattern of peaks and troughs of seasonal demand.	Somewhat chaotic vacillation
Diffusion rate	Somewhat slow diffusion of new categories, but very high adoption rate of new features over the long run	Fast, but innovation diffusion is limited to target audiences	Erratic changes in technology standards cause limited diffusion
Co-specialized resource cycles (i.e., the temporal behavior of partner firms)	High velocity vendors are subharmonic B2B services that change faster than the focal industry; co-specialized, fast changing technologies leads to a higher average r for the industry Low velocity industries are simple organizations that provide superharmonic B2B industrial services and tools for many industries across long economic cycles. Superharmonics causes lower average r for the industry	Ambidextrous organizations with high levels of dependency on co-specialized resources external to the firm (talent, specialist vendors, locations, etc.) Exploration requires cross-functional product teams and custom work from vendors. Many resources are used on a per-project basis, but some are retained for follow-up work. Exploitation requires making a series of goods/services with the same capital.	Chaotic timing of co-specialized innovations causes a "temporary chaos" in emerging industries

timing of durables and culturals. I contrast consumer electronic devices based on Silicon Valley's semiconductors to theater releases of major Hollywood films. Table 1 presents the variables described.

The paradox of simultaneous search. Obviously, heavy use of strategic imitation leads to competitive parity – the question is if firms are accepting parity via collusion as the best outcome. Strategy researchers assume the goal of the field is to describe sustainable competitive advantage, not parity. But, the classic description of mature competition is to create parity (Chamberlin, 1949). In game-theoretic terms, it is a much tougher challenge to preserve a profit-maximizing, advantageous position without collusion. Katila and Chen (2008) concluded that firms who search early are more innovative, but firms who follow will launch more products in a cost-oriented tradition; either choice would be superior to simultaneous exploration initiatives. But, their findings came from a highly fragmented industry in a long growth period with no firmly established oligarchy: a sample of 124 firms in diverse industrial robotics categories, from 1984-1998. Such an industry has many strategic groups, thereby permitting firms to seek complex timing patterns – a phenomena for which they did not test. During mature oligarchy, on the other hand, most consumer industries are highly concentrated, and leading firms prefer to explore or exploit simultaneously. Katila and Chen (2008) used the example of video game consoles (hardware) to illustrate how most industries eventually converge on synchronous initiatives. Van den Ven (2005) also explains that knowledge intensive industries produce strong incentives to "run in packs".

All cyclical demand is collusive. Economists have previously demonstrated that firms' ability to tacitly collude depends on the timing of a demand cycle more than the technology cycle (Rotemburg and Soloner, 1986; Haltiwanger and Harrington, 1991). If current industry demand is weak but technical opportunities persist, evidence suggests that firms tend to invest in product innovation to rejuvenate lifecycles (Berchicci, Tucci, and Zazzara, 2013); on the other hand, if demand is currently strong, firms temporarily focus on squeezing the most profit out of proven techniques. Therefore, to understand strategic timing, seasonality of demand is essential. Most durable firms make annual decisions to either explore new categories or exploit. Cultural firms plan a more complex landscape of initiatives.

Technical Generations. The Silicon Valley steady state is one where disruptive technical innovation interrupts the entire industry's exploitation focus. Highly stable exploitation happens for a few years, and then the entire industry explores and radically upgrades periodically. Disruption periods come at regular intervals. Other examples: telecom networks upgrade every 10 years, and Haitz's law means LEDs exponentially improve every 3 years. Following Geels (2002) and Christiansen (1997), niches inevitably produce radical new architectures that capitalize on such exponential leaps. Early and late launches are costly (Bayus, Jain, and Rao, 1997). There is little incentive to launch a major new television until the new LED generation, just as firms gain very little from skipping an entire technical generation. Surrendering a whole generation of consumers to competitors is extremely risky. Therefore, within these stable trajectories, durables firms focus on exploratory initiatives during generational updates.

Seasonal timing of durable goods: electronics. Consumer durables industries are single-peaked in seasonal timing, with respect to the introduction of innovative products, but sometimes have multiple discount sales events throughout the year. Most annual innovations are introduced at the Consumer Electronics Show in Las Vegas. At other peak sales points of the year, firms unload discount merchandise based on aging technology. With a very predictable calendar, firms take exploratory actions in-phase with the entire industry, and therefore can synchronize initiatives easily. For example, Silicon Valley's electronic hardware is dominated by the trajectory (Dosi 1982) of generational upgrades in upstream process technology (Moore's Law). Major new designs are announced for each category at the Consumer Electronics Show (CES) in the Spring, with most debuts planned for December, when 30-50% of all category sales occur. There is no economic benefit to seeking alternative launch windows: early and late launches happen, but nearly always involve loss of revenue (Souza, Bayus, and Wagner, 2004). Cost-focused consumers buy end-of-year products at Cyber Monday. The value chain is synchronized to these peak points of demand, while technological innovation peaks around CES. Firms who fall out of sync lose millions in sales to rivals. Note: It is poorly understood why, but television sales are a rare consumer durable without concern for a sales peak: sales are distributed very evenly.

Timing for culturals: films. Cultural firms' timing is determined by the complex mediation of upstream technological change and a multi-peaked downstream landscape, with frequent redesigns to capture value from recent consumer preference discontinuities. Typically, each of the calendar seasons contains at least one, or multiple, peak product launch events, corresponding to the major holidays and festivals, when consumers most intensely consume. Off-holiday sales are focused on highly loyal, genre-based audiences that consume niche offerings at a much higher rate than the average. Hollywood studios capture fickle downstream audiences with intermittent, exploratory blockbusters, and endure a "long" statistical tail of weakly performing, exploitation-driven genre fare (Radas and Shugen, 1998; Simonoff and Sparrow, 2000). But even when much of the genre fare sells at a loss, the firms benefit highly from market information garnered about how audiences shift in response to genre fare; studios incorporate that knowledge into future designs, to make blockbusters even more profitable. Hollywood formulaic content occasionally results in an unexpected "sleeper hit", earning outsized profits at unusual release times (Eliashberg, Elberse, and Leenders, 2006). But most major studios accurately predict success by employing the industry's most elite talent: hitmakers like Quentin Tarantino or Steven Spielberg *frequently succeed.*

Seasonal Demand Windows. Hollywood new releases face about six seasonal demand windows (Radas and Shugen, 1998; Eanov, 2007), and a similar number of key technical/design conversations occur around multiple annual events, including the Oscars, Golden Globes, Cannes, and others. Hollywood firms, thus, stagger attention on many supply/demand events per year. They have high incentive to collude to ensure product releases are evenly distributed to avoid "zero sum" contests over short term demand windows. They face frequent disequilibrium pressures from mistiming: too many extravagant films at once, and everyone splits the market at a loss. The industry can only bear a very short list of blockbusters in a given year, and only about 10 or so per peak season. Firms who announce the biggest film launches promptly "get the ideal time slot", while competing films must be moved to avoid simultaneous release. Studios evenly disperse their blockbusters across each peak season (especially

Memorial Day weekend, July 4 week, or the weeks before/after Christmas), and do the same for low budget genre fare releases throughout slow seasons.

Hollywood must reproduce films, genres, stars, and brands. Major movies typically don't fit the S-curve model, and instead have a monotonically decreasing pattern of sales, with sales peaking during the "opening weekend" (Krider and Weinberg, 1998). Each subsequent market reproduction is an attempt to capture more value from the original brand — studios must decide how much aftermarket effort to exert. The hope of capturing lucky aftermarket value, or even a sleeper hit, drives the industry to support a large field of imitation products. A single sleeper that grossly outperforms its budget can pay for the small losses incurred in 10 or more flops. An ongoing hunt for blockbusters continues unabated– firm must make a lot of weakly performing films, with only 3 out of 10 breaking even (Radas and Shugan, 1998).

Capturing Residual Value. Some design elements end up as uncaptured "memes" (Shifman, 2014), whereas others become well-captured Brand Platforms (Kapferer, 2012). As Mel Brooks famously said in the movie, *Spaceballs*: "merchandising, where the real money from the movie is made! We put the movie's name on everything!". Strategy depends on acting to not only create, but capture, the brand value. Sometimes the reverse happens, and a movie is made to capture an existing brand. For example, Rio Games's Angry Birds is a huge franchise that began as a video game, but was reproduced across many formats. *But optimum difference from the past design is key, because very innovative cultural reproductions often perform poorly* (Alvarez et al., 2005; Garud, Gehman, and Guiliani, 2014).

Demand-driven obsolescence. In Hollywood, demand shifts by a combination of endogenous creative efforts by studios, and exogenous shocks to consumer's cultural knowledge (Lampel, Lant, and Shamsie, 2000). Of course, technical innovation is relevant. The switch from film to digital was a big change for the industry; however, scant few studios suffered or failed because of digitization. Unlike the product-dominant predictions of disruption theory (Bower and Christensen, 1995), the major studios were virtually unscathed. Studios typically source their technology from shared suppliers (Miller and Shamsie, 1996). Big cultural shocks affecting change included the Production Code Era (about 1934-1962) and the World Wide Web (1994).

Preference discontinuities and bandwagon effects. Trispas (2008) discusses how customer preference discontinuities took slow effect in the industrial printing (typesetting) industry; but cultural preference shocks are frequent. Categories displace each other, reflecting psychological issues (Janssen and Jager, 2001) such as shifting identities, values, politics, and institutions.

Pre-release announcements help turn spillovers into captured value. Consumers of culture, especially in mature categories of goods like film, can anticipate sales of blockbusters. Pre-announcements trigger bandwagon cascades (Bikhchandani, Hirshleifer, and Welch, 1992; Rosen 1993). An example is the Super Bowl halftime performance. Fans react to announcement of the elite pop artist, giving early signals as to which ads might perform well. By the time the performance takes place, advertisers have a pretty good estimate of the hype for the current year.

Managing the timing of Hollywood production. Interestingly, film studios know that head-to-head blockbuster releases are damaging to industry profits, so they overtly collaborate on setting seasonal schedules (Rosen, 1993). Studio executives intentionally pre-announce release dates so all studios are aware of each others' potential blockbusters, and then alter the actual release dates based on a fair and objective assessment of top grossers. Collusion via legal pre-announcements is essential to efficient timing (Krider and Weinberg, 1998; Simonoff and Sparrow, 2000).

Anti-phase competition and niche displacement. However, Hollywood does not have such an extreme industry-wide lifecycle, and is characterized by a saturation of attention. To draw more viewers, a product must displace the attention a consumer would give another product, or a substitute form of entertainment. Thus, a blockbuster temporarily displaces other blockbusters, and a new genre or series is "one in, one out" in terms of number of competitive film fitting in the annual rank order. In durable goods, a challenger firm attempts to disrupt the timing of the entire industry STS from a niche (Christiansen, 1997). In culturals, a challenger firm only needs to displace *one* leading firm in the rankings. For example, in the 2000's tiny, fledgling Marvel Studios' first movie, *Iron Man*, was a blockbuster production (Kim, Mauborgne, and Olenick, 2011) – Marvel quickly turned a $200 million venture into a multi-billion dollar studio, rapidly moving into the top 10.

The length of stability. There is no path for a film studio to create enduring dominant designs. No one technology or product design can ever be responsible for, say, 50% of annual sales for multi-year intervals – *blockbusters only dominate sales for about 3-10 weeks*, and re-releases must compete with the entire back catalog of all other re-releases. Genre films, however, can imitate technical and design elements popularized by blockbusters for a few years, saving search costs. For example, *The Matrix* was a film that impacted sci-fi action design. Followers used "genre repetitive" action sequences and film editing styles to delight audiences.

Perpetual maturity? Despite many technical and cultural shocks, the American film industry has been in oligarchy since the 1940s (Miller and Shamsie, 1996). Interestingly, since the 1940s, most cultural industries like Hollywood legally lost the ability to vertically integrate, for the risk of propaganda machines being installed, and instead have diversified (Miller and Shamsie, 1996). Firms have been price takers for almost a century (Rosen, 1993).

1.3 Four Generic Timing Strategies

This section shall examine how firms may be entrained to four different kinds of timing environments. To arrive at these strategies, I extend theory on organizational entrainment (McGrath and Kelly, 1986; Ancona and Chong, 1992; 1996; Klarner and Raisch, 2013; Pérez-Nordtvedt, et al., 2008). Social cycles at various organizational levels tend to naturally entrain, or synchronize, to a dominant cycle. Firms that invest out of sync suffer diminishing returns. Being too early, too late, or erratic in timing are all more costly than finding a rhythm for orchestrating activities across the value chain, and in seasonal cycles. *From this "view of the entrained firm", maturity is defined as the achievement of a stable, harmonically fit rhythm* (Shi and Prescott, 2012).

Entrainment theory is a still emerging approach for strategy; that is, the mechanisms/constructs for a strategic model of entrainment are not fully stated. The Social Entrainment Model (McGrath and Kelly,

1986) defines entrainment [here paraphrased] as the phenomenon whereby a cyclical process is captured by, made synchronous with, and set to oscillate in rhythm with, another process by means of a pacer or dominant cycle. The pacer is referred to as a *zeitgeber,* German for "timekeeper". Since then, authors have elaborated on the notions of tempo and phase in organizational rhythms, both internal to (Gulati and Puranam, 2009) and external to (Klarner and Raisch, 2013; Shi and Prescott, 2012) the firm. Durables are technology-dominant, as explained above, and thus can be simplified to a one-pacer timing model.

Exploration only occurs when new technical generations are anticipated. However, I propose the new term *zeitmacher* (time shaper) for industries that must also align to a multi-peaked downstream market cycle. The zeitmacher is always there, but largely hidden form the action because its role is so boring in durable goods- it aligns in a single annual peak. But for culturals, these two cycles are complex enough to make analysis of both necessary. Each firm attempts to align its initiatives to match the peak periods of opportunity for exploration (zeitgeber) and exploitation (zeitmacher). Temporal patterns of firm activities thus stems from harmonic oscillations between zeitmachers and zeitgebers. Harmonic fit can be easily modeled abstractly as a system of waves that cancel out in an equilibrium condition of zero interference.

A competitively entrained firm is defined as a harmonically fit "synthesizer" that aggregates and integrates capabilities and resources into a pattern of action to sustain profitable parity in oligarchic leadership, rather than a competitive advantage. Quoting Casson (2005, pg. 337): "If different synthesizers plan to use the same resources in different ways then they must compete." Competitive entrainment helps them to use resources in similar ways, profitably. Like ripples on a pond, competitive interference represents movements away from equilibrium – deadweight losses. Mistimed firm strategies are the cause of such ripples. Citing Ancona and Chong (1992, p. 168): "When entrainment occurs energy flows more effortlessly, and performances are enhanced. If an individual, group, or organization, is changing more frequently than the entraining zeitgeber, it is expending energy with no reward."

Strategy #1: In-phase competition. For in-phase competition, the industry eventually entrains to a dominant technical clockspeed, and is relatively stable on the demand side. Therefore, all firms share some mutual industry-level technical dependencies, such as how personal computing devices must maintain compatibility with Intel processors of the current generation. With stable trajectories in a platform ecosystem, firms exploit firm-specific product/price bundling choices (Fine, 1998). Highest level standards are often collectively created and widely shared, while firms compete aggressively on secondary level features, components, etc. Explorations fall into synchronicity with the fastest pertinent generational cycle (Brown and Eisenhardt, 1997; Eisenhardt and Brown, 1998). At a secondary level of innovation, firms might experience a complex landscape of minor technical bottlenecks: reverse salients (Hughes, 1987) limitations to feasible design. These sublevels evolve based on outside firms' breakthroughs in technical design. *A durables firm has leeway to strategize freely on the pace of some subsystem innovations, in order to practice a low cost or differentiation strategy.*

Strategy #2: Anti-phase competition. Anti-phase rhythm, however, is an emergent process. Firms must endogenously produce an evenly distributed landscape of initiatives that synchronizes the zeitgeber and zeitmacher: Firms entrain to each other to create a stable rhythm across technology and demand cycles. The baseline assumption is that each new cultural good incorporates at least one substantive technical advance within a timely cultural design innovation. The timing process is greatly aided by the legality of pre-announcements, or other such collusive mechanisms. Each firm attempts to stagger Λ-curve products so that its exploration peaks when the zeitgeber is at a local maximum (peak R&D opportunity), and exploitation when the zeitmacher is at a local maximum (peak demand).

Firms can immediately sanction troublemakers in clever ways. For example, in the music event promotion business, sometimes rival A will attempt to seize a promotional weekend from rival B's usual timing slot by booking a bigger, more costly talent. Rival B retaliates by giving away free tickets, thereby neutralizing the threat at a loss, but causing more severe financial losses to Rival A. Therefore, cultural firms do their best to evenly distribute new product project cycles.

Juggling reverse salients: surviving technical change in hardware. Culturals often must interface with hardware, such as how video games interface with game consoles. How can cultural firms manage waves of hardware technical innovation, without disturbing the cultural leapfrogging pattern? By avoiding any long-term commitment to innovating toward one dominant hardware feature, firms can take turns debuting forays into emerging features. Recent work on the PC gaming industry (Mäkinen and Dedehayir, 2014) has shown firms to be impacted by multiple "reverse salients" (Hughes, 1987). For example, CPU and GPU technologies are but a few of the many limiting factors in video game design. However, the most salient of the season is socially constructed, and not objectively tech-driven. It ultimately depends on the technology in vogue. Mäkinen and Dedehayir (2014) show a series of four graphs of intermittent bursts of innovation for computer subsystems, four "reverse salient" technologies that present persistent bottlenecks to game design – however, since they progress at inconsistent rates, they aren't all equally as constricting each year. Their graphs demonstrated that the PC video game industry has an emergent "ecosystem clockspeed" (Fine, 1998) that appears to be a smooth curve, but when plotted against each subsystem, game design innovations oscillate in timing *with respect to each of four subsystems, taking turns acting as a reverse salient*.

Optimal mutual distance. Firms must find a game theoretic solution whereby the total industry lifecycle is an emergent outcome based on *dynamic steady states*. Anti-phase firms seek an optimal distance in timing initiatives, consistent with imitation deterrence theory (Polidoro and Toh, 2011; Liao and Seifert, 2015). Since content is always differentiated, strategic groups (Reger and Huff, 1993) will imitate each others' practices instead. Firms must invest in a costly vigilance of each other to a much higher degree than is required in a single pacer industry.

Strategy #3: Multi-phase entrainment. Some firms provide b2b value chain activities: components, peripherals, professional support services, and so forth. Such firms are acting at super- or sub-levels of innovation (Murmann and Frenken, 2006), with respect to a focal consumer product industry. An example of sub-harmonics would be to examine the relationship between the typical rate of exploration in Playstation console video games – third party software – relative to the rate of exploration for the Playstation console platform itself. An example of super-harmonics would be the rate of machine tool innovation relative to the rate of innovation in multiple manufacturing industries. Indeed, research on super-/sub harmonic patterns complete treatments of in-phase and anti-phase dynamics. Due to space constraint, multi-phase strategies must be explored in future analysis.

Strategy #4: Managing Chaos. If firms were completely asynchronous, it would be a sign of no entrainment: inherent market instability from an industry facing punctuated equilibrium. Some industries have initiatives that are best characterized by exploitative responses to random events, followed by exploratory learning in preparation for the next shocks. The question of timing is thus inverse to normal: firms only exploit when called to action, but typically explore otherwise. These include: private financial markets (New York Stock Exchange); public environmental disaster response (USA's FEMA-coordinated business activities); and, basic research activities (i.e., W.L. Gore and Associates commercializes a technology when it finds a "Hit" among its patent research projects). Thus, the triggering of exploitation events is affected by a "random walk" (Spitzer, 2013), although future research may show that exploration flows according to a rhythm. Currently, not enough research exists to make claims as to the exploratory rhythms for this quadrant, and more work is needed to resolve this issue.

1.4 Incorporating Four Additional Timing Literatures

Now that I have spelled out the fundamental differences between in-phase and anti-phase patterns of mature strategic initiatives, it is necessary to synthesize the timing literature, to create a sufficient general model. Let us consider how four additional theories justify the economic value of optimal timing: vacillation, co-specialization, intertemporal ambidexterity, and leapfrog spillovers. In addition, I will address how entering or exiting entrainment affects a firm.

Vacillation theory: why cultural firms are internally efficient when in anti-phase. Vacillation Theory (Nickerson and Zenger, 2002) proposes that firms alternate kinds of organizational reforms, such that every few years they tend to alternate between polar initiatives. From a learning perspective, firm capabilities benefit from a regularly rotating focus on exploration and exploitation initiatives. This is how

Table 2: Four Generic Timing Strategies

	Standardized product designs	**Nonstandard product designs**
Weak follower spillover effects	In-phase strategy Durables with a Dominant technology: Exploit with increasing fervor until periodic, industry-wide technical updates; explore to renew incumbent advantages. Minor updates to singular features, and coping with reverse salient of component technology, are exploitations, as they don't require an extensive category redesign.	"Managing chaos" strategy Market and infrastructure providers, both public and private, are tasked with reaction to, and management of, technical and demand shock (McGuire and Schneck, 2010). Such firms reduce rate/size of risks and shocks (Miron, 1986). Exploration of market redesign is triggered by unpredictable technical, regulatory, or social discontinuities; also, basic research labs can improve on erratic innovation search rates (Bers et al., 2009)
Demand Pattern	Single-peaked seasonal demand cycle, Single-peaked exploration wave	Volatile speculations and random shocks. Note: Some temporary chaos will occur at the onset of most emerging industries.
Firm Type	**Most durable goods creator firms**	**Market-creating firms (i.e. financial, insurance, shipping schedule, energy, etc.); Crisis mitigating work; Commodities; Basic research firms**
Rhythmic leader-follower spillover effects	Multi-phase strategy Super-/sub-system level firms 1) Subharmonic innovation patterns	Anti-phase strategy Leapfrogging rivals: Firms explore and exploit in a continuous cycle of new projects; Adapt to hardware advances by "juggling reverse salients". Firms try to find mutual optimum distance form each other as they continue to leapfrog each other in exploration and exploitation.
Demand Pattern	providing components to or services as an extension of a focal industry, but changing at a faster pace – such as fast changing software services to an automobile assembly company	
Firm Type	**B2B transactions, especially software**	
Demand Pattern	2) Superharmonic innovation patterns Firms who entrain to "bearish" economic swings: firm exploration with long cycles, as often modeled by economists (Bernard et al., 2014; Pavitt, 1984). Providing services across industries, acting procyclical with socioeconomic long cycles, with long term project horizons.	Multi-peaked demand cycle and a multi-peaked technical change in "reverse salients".
Firm Type	**Retail; Construction; heavy industry**	**Most cultural goods creator firms**

internal fit (Miller, 1992) reinforces the external environment. A firm seeking maximum internal efficiency must endogenously switch between r and k investments, because of diminishing returns to stagnant routines. Firms at the top of the design hierarchy are indeed knowledge-based (Grant, 1996) and constantly alter their organizational behaviors/structures to maintain adequate organizational learning (Starbuck, 1992; Gulati and Puranam, 2009).

Classifying industries by lifecycle type. Peltoniemi (2011) conducted an extensive review of the literature on exceptions to the classic lifecycle pattern (see also Pavitt, 1984). Although she was not specifically investigating temporal dynamics, her research is of note here. She did not find counter-examples to the classic lifecycle model among consumer durables. Instead, she found exceptions in business services, cultural industries, and what she called "complex products and systems". In Table 2, I sort her exceptions, making just a slight change to her categorization scheme so to fit a strategic timing analysis. See Katila and Chen (2008) and Pérez-Nordtvedt et al (2008) for additional compatible typologies for external and internal timing; their typologies are not sorted by industry type.

Co-specialization and vacillation. In-phase oligarchs align themselves to generational step functions for technical trajectories, and vacillate together, whereas anti-phase oligarchs take turns vacillating with the external aid of co-specialized (r or k -oriented) business partners.

In mature competition, firms may not need to own all the assets it uses for exploration and exploitation initiatives (Amit and Schoemaker 1993), since firms can rely on alliance and supplier networks to provide co-specialized assets (Stettner and Lavie, 2014). If firms jealously guard resources for sustainable competitive advantage, then they face a cyclical demand problem when they are "stuck" with the costs of maintaining those resources during periods of low demand but those specialized partners could easily provide those services continuously throughout the year to most, or all, of the major studios. One famous example is Industrial Light and Magic, the firm that George Lucas used to provide cutting edge special effects throughout Hollywood in the 1980s (Smith, 1986). Hollywood studios depend on many such elite supporting firms to widely provide talent, technology, post-production, market research, and so on. The major studios will bring in only what elements it needs for a project. This strategy has been labeled *design-driven innovation* (Verganti, 2009). Thus, a strategic factor market for elite vendors often causes studios to defer alliance projects rather than to pursue a bidding process.

Another classic example of co-specialization is the intermittent release of stop-animation films – a highly technical subgenre of film that is responsible for only a few blockbusters per decade. Claymation is a stop-motion method of animation: painstaking, and specialized work, with production time often triple that of average films. According to the Director commentary on the DVD release of *The Nightmare Before Christmas*, Tim Burton temporarily tied up the services of all the best Claymation talent in the world for several years, so competitors had to wait it out.

Intertemporal ambidexterity. Vacillation can improve organizational learning (O'Reilly and Tuchman, 2008; Raisch, *et al.* 2009) by achieving *organizational ambidexterity* (Duncan, 1976; Gibson and Birkenshaw, 2004; Tushman, *et al.* 2010) sequentially across time, and the anticipation of frequent initiatives can help. Ambidexterity is greatly enhanced by interorganizational linkages (Taylor and Helfat, 2009). A vacillating firm becomes more organizationally efficient than one aiming in too many strategic directions at once (Baumgarden, *et al.* 2012; Klarner and Raisch, 2013).

Leapfrog Spillovers. The fourth contributing theory is that of leader-follower spillover effects (Griliches, 1992; Vandekerckhove, and De Bondt, 2007). Simultaneous selections of rival strategies are the chief cause of uncertainty in the value of strategic assets (Robinson, 1953; Cohen and Harcourt, 2003). The classic leapfrogging studies focused on countries, but the same principles apply to firms (Brezis, Krugman, and Tsiddon, 1993; Schilling, 2003). Hollywood profits are heavily based on spillovers within and across industries (Huang, Markovitch, and Strijnev, 2015). Leapfrogging powerfully lowers costs and raises benefits (Pacheco De Almeida, and Zemsky, 2008; (Lieberman and Asaba, 2006). Firms that release blockbuster films early or late, or on the same weekend as a stronger film, suffer diminishing spillovers and diminishing returns. They also suffer from brand erosion, due to excessive following (Alpert and Kamins, 1995). *Thus, oligarchic cultural firms find a "rotating equilibrium" of leadership.*

1.5 Harmonic Oscillation Patterns of Duopolistic Competition

Demonstrating antiphase is easiest when visualized as a duopoly. Using two cultural firms of equal size, the figures provided assume they have no material advantage. Both firms attempt to maximize long run profits by alternating (vacillating) 3rd party exploratory alliance/vending partnerships.

Constructive/destructive interference. Summing two waves with positive values results in an additive wave intensity (constructive interference), whereas summing opposing waves cancels each other out (destructive interference). Any value other than zero represents deadweight losses – suboptimal profit and revenue – for both the individual firms affected and the industry as a whole.

Figure 2 depicts harmonic vacillation as a theoretical equilibrium pattern of action, where firm A emphasizes exploratory resources in the industry value chain at the same time that firm B capitalizes on exploitative resources in the industry value chain- thereby minimizing competitive technical/market pressures. As the waves cancel to zero, firms attain a local equilibrium, and the industry as a whole operates at peak efficiency. The two firms equally split profits.

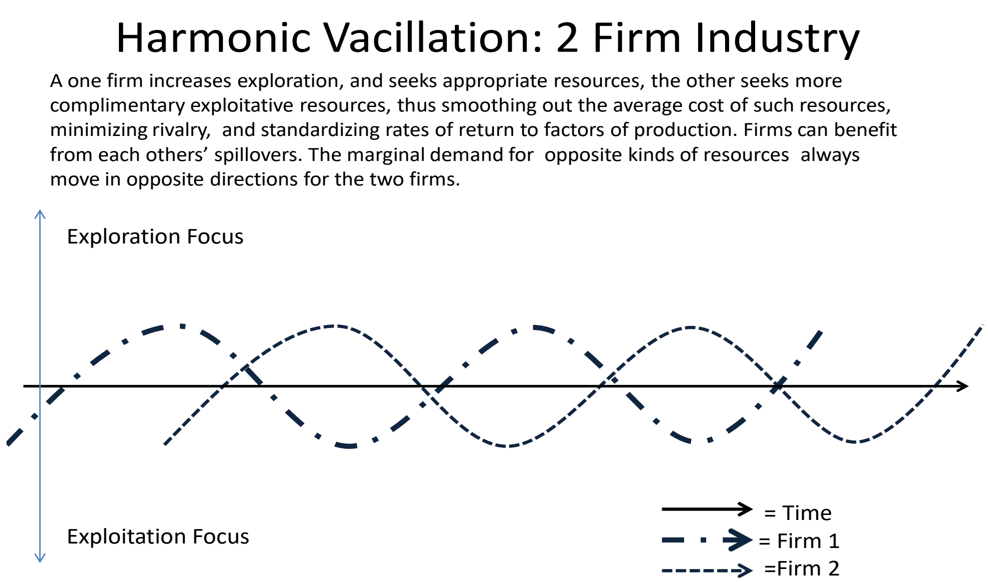


Figure 2: Harmonic Vacillation

Figure 3 Shows disharmonic vacillation for a duopoly. Summing the waves reveals constructive interference, representing deadweight economic losses for both firms, and for the industry. Both firms suffer in terms of competition over scarce resources, which drives costs up for both firms as they overbid for resources, and at other times leave resources underutilized. On the other hand, both firms also suffer for making simultaneous bids for scarce customers, while leaving customers underserved at other times of the cycle. Such a market is in disequilibrium.

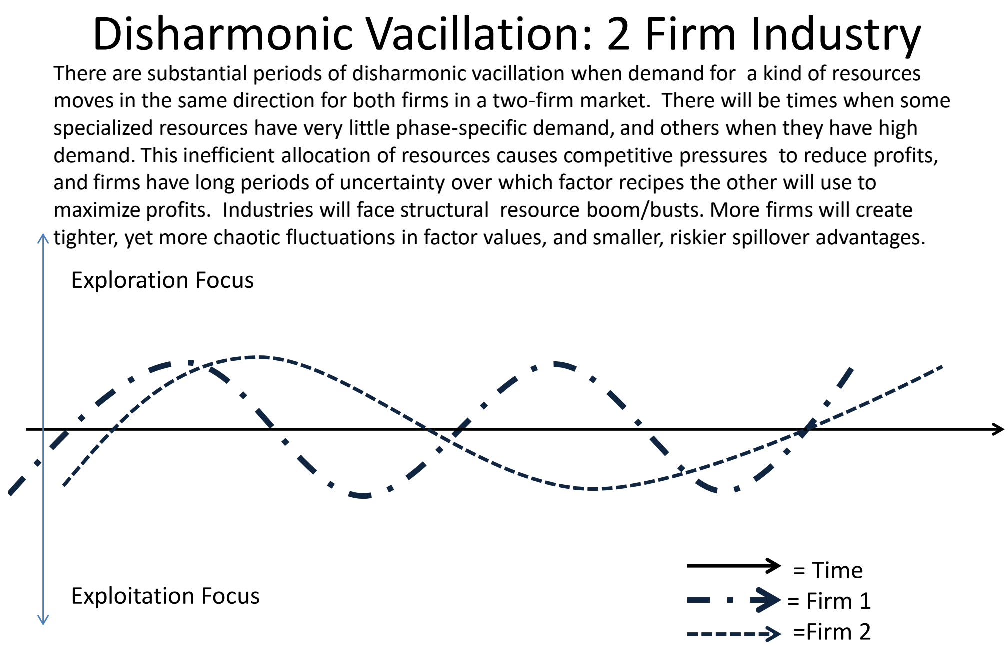


Figure 3: Disharmonic Vacillation

Overclocking. So far, this paper has stressed that mature firms gravitate towards a sustainable competitive parity due to entrainment. However, some readers may be wondering how a mature firm might seek sustainable competitive advantage via good timing. Overclocking is when a first-moving firm manages to leap an entire temporal cycle ahead of competitors. An *overclocking* firm commits its resources and capabilities towards monopolizing a new/updated category. While overclocking seems very tempting, it has two major risks. First, a firm could fail to overclock, and contribute to a Red Queen Effect, discussed below. In game theoretic terms, this is represented as two firms simultaneously defecting instead of colluding, and both losing profits for it. Second, a firm could successfully overclock to such an extent that it loses technical and/or historical compatibility – also discussed below.

Racing to the Red Queen Effect. Entrainment is also a mechanism to prevent the Red Queen effect: running faster and faster to the point that profits disappear. If resources specialized for restructuring are available, both firms will be pressured into making use of them, but neither will get "ahead" (Derfus, *et al*. 2008; Kauffman, 1995; Robson, 1993). The switching costs from any resource-based activity to its alternative configuration sets the tempo of vacillation. In-phase and anti-phase industries might feel time pressure to keep pace with accelerating technical change, but anti-phase industries feel great pressure when there is an acceleration in demand for novelty.

Losing Technical Compatibility: Steve Jobs' NeXT. Price (1993) told the infamous story of how Steve Jobs invented the greatest PC architecture of its time. After being fired from Apple, he formed a new company, NeXT. When he released the NeXT workstation in 1988, it was the most technically impressive model on the high end market. The NeXT prototyped many new, category-defining features. Jobs intended to redefine the high end of computing, and he largely succeeded in that respect. However, the project was a financial failure. The main problem was incompatibility. Its powerful software and coding environment used features that were incompatible with the rest of the booming industry. For example, Tim-Berners Lee, the designer of the World Wide Web (Berners-Lee and Bischetti, 2001) wrote his original version of the server code on the NeXT. Berners-Lee spent over a year downgrading and porting code to a more standard language for the common user's convenience. Jobs also added the world's first optical disk drive; but, due to excessive overclocking, *there were no optical storage disks yet on the market!* Instead of juggling reverse salients, he spent lavishly on technology too far ahead of the industry to be useful.

Losing Historical Compatibility. There are multiple ways in which a film can be "Ahead of its time". It could portray ideas beyond the audience's understanding – a common risk of ambitious creators. For now, let us consider a classic example of being overly controversial to institutional authorities. *Citizen Kane* (1941) is one of the most universally celebrated films by critics (Mulvey, 2017). Despite being nominated for nine Academy Awards, it only won Best Screenplay, and lost money on its lavish budget and limited theater release. The predominant reason? Orson Welles's masterpiece loosely critiqued the life of William Randolph Hearst – the richest and most powerful media mogul of the time. Hearst did everything in his power to block distribution, advertising, and screening, and was partially successful. Had the same script appeared in the 1950s – after Hearsts' death in 1951 – it would have been profitable. While nobody questioned Welles' artistic and technical innovations, the industry resisted the obvious personal digs.

1.6 Limitations and Future Research

This section addresses next important steps for extending and refining Harmonic Oscillation Theory.

Industry-specific conditions: everything from specific solution landscapes to institutional histories and regulations can separate one industry from another (Porter, 1998). Thus, error and shock will make entrainment elusive – many exogenous variables could distort the landscape. Structural factors complicate the dynamics: firm size, barriers to entry, alliances, and strategic groups (e.g., niche categories).

Super-harmonics: Diversification across multiple industries. Complementarities across multiple industries will require finding superharmonics for ambidextrous timing (O'Reilly III and Tushman, 2013; Gibson and Birkinshaw, 2004; He and Wong, 2004). There will be times when multiple business units are exploring at once, and synergies can be found to lower costs; at other times, temporal synergies can be found with related diversification across similarly timed, exploiting business units. At the corporate level of analysis, diversifying firms vacillate internally to maximize use of co-specialized assets (Teece, 1986). The focal firm's costs of holding or acquiring resources best suited for exploration or exploitation activities are mitigated by temporal economies of scope from convenient sequencing of related activities.

Sub-harmonics: Integrating value chain subsystems. A deeper examination of industrial trajectories must consider that timing of subsystems (Murmann and Frenken, 2006) happens within complex value networks. Little "local temporal realities" emerge like eddies in water. Vendors have a tradeoff between innovativeness and ability to capitalize (Patriotta and Hirsch, 2015). Each industry finds its own internal tempo of innovation to achieve harmonic fit, balancing interfirm efforts between exploring and exploiting technology (new/existing capabilities) (Gupta, Smith, and Shalley, 2006). Some architectural activities move on a slow cycle, whereas some component activities cycle at a proportional factor (say, twice as fast). Upstream/downstream innovations can differ across industries in terms of power asymmetries (Adner and Kapoor, 2010), including temporal power asymmetries.

Multiple firms will lead to multiple equilibria. Of course, most real-world industries have more than two firms taking actions in more than one category of goods at once. The simple graphics herein presumes two equal-sized firms dominating an industry with a single product category: a scenario for minimal incentive for firms to attack each other aggressively (Chen, 1996). Firms who can generate niche categories – as Marvel Studios did (Kim, Mauborgne, and Olenick, 2016) are likely to seek Blue Oceans as soon as possible! The theory presented here is an analytical basis point: three or more firms, or asymmetrically powerful firms, will create multiple equilibria. Some firms might have capabilities to play out *equifinal* strategic alternatives – creating complex timing patterns for managing low cost (follower), differentiation (leader), or focus niche (market-splitting) timing patterns.

Making and breaking lock-in. Future work should examine in detail how firms can lock-in (mutually entrain) and lock-out (prevent rival entry). Shocks – unexpected entrant and exit events – could disrupt short run timing equilibria, causing turbulence in a STS (Geels, 2002).

Specifying empirical models in future research. It is not difficult to incorporate cyclical timing effects into a variety of methodologies and research contexts. Product replacement rates, technology trajectories (Dosi, 1982) and seasonal demand cycles (Johnson, 2001; Krider and Weinberg, 1998) powerfully constrain patterns of industrial competition, but we still teach students one-size-fits-all models. This essay provides general concepts for developing a wide variety of industry-specific models of timing, with model parameters – such as k, r, amplitude, zeitgeber/zeitmacher periodicity, shape of spillover benefits, super-/sub-harmonics, and so on. HOT provides a new temporal view of the firm; still, HOT uses widely accepted constructs. Thus, it remains compatible with the fields' most-used "views": resources (Peteraf, 1993), knowledge (Grant, 1996), attention (Ocasio, 1997), and dynamic capabilities (Teece, 2007).

2.0 Radical Exaptation and Incumbent-Challenger Dynamics

"Invention occurs in three patterns not two, which are conventionally summarized as demand-pull and supply-push. These two are augmented by exaptation, in which invention flows from the emergence of new functions for old forms. Owing to its pivotal role as a third force in invention, exaptation may kick-start the founding of new market niches, thereby producing novel (and largely unplanned) elements within the market process." (Garud, et al., 2016)

Ever Since Joseph Schumpeter (1934) popularized the concept of creative destruction, scholars have studied whether challengers or incumbents have the advantage for radical innovation (landmark reviews include: Dewar and Dutton, 1986; Henderson and Clark, 1990; Garcia and Calantone, 2002; Hill and Rothaermel, 2003; Ansari and Krop, 2012; Norman and Verganti, 2014). Older literature referred to 2 main scenarios to encompass all radical challenge scenarios – Schumpeter Mark 1 and Mark 2. This sorting needs updating, to take into consideration the dominant contemporary strategies that firms practice to win challenge scenarios. There remains much confusion over how to sort new industry formation events according to innovation type.

Schumpeter Mark 1. The classic assumption is that challengers have the advantage. In Schumpeter Mark 1, an incumbent defends its current technology and current user base against a challenging entrepreneur who is attacking with a discontinuous technology (Schumpeter, 1934; Henderson, 1993; Arrow, 1962; Ansari and Krop, 2012). The contemporary strategy literature tends to follow Clay Christiansen's (1997) theory of Disruptive Innovation for an explanation of how firms accomplish this. The challenging entrepreneur starts with a niche but discontinuous technology, but rapidly that niche technology overtakes and replaces the prior industry.

Schumpeter Mark 2. But sometimes, incumbents have the advantage by going on the attack. Incumbents already have technology that can be adapted to new architectures, and in rare occasions, to new architectures that cannibalize its own user base (Chandy and Tellis, 1998; Chandy and Tellis, 2000;

Christensen and Rosenbloom, 1995). The most popular approach to Mark 2 strategy is Kim and Mauborgne's (2014) Blue Ocean Strategy. They argue that incumbents should focus energies on reusing their technology to spawn niches in new, "uncontested" spaces, thereby finding new uses for existing technology. Alternatively, scholars have referred to construction of a niche via existing technology as *radical exaptation* (Andriani and Carignani, 2014), *market breakthrough* (Chandy and Tellis, 1998), or *architectural innovation* (Henderson and Clark, 1990; Henderson, 1993). We focus here on extending recent theory on radical exaptation, as the other terms do not provide a mechanism for change.

Defining Radical Exaptation. Gould and Vrba (1982) coined the term, exaptation, to refer to a biological structure that evolved for a debut function yet emerged as suitable for another. Their classic example is bird's feather. Feathers evolved for cooling but became useful for flight. In technology, incremental exaptation only creates a new product feature set, usually by way of varying use of minor components. For example, Kimberly-Clark created "Easy to carry" packaging for their toilet paper by imitating the handles on heavier products. However, some exaptations are radical enough to found entirely new industries – such as personal computers and microwaves. Andriani and Carignani (2014) provided a typology of exaptation types, and identified radical exaptation to be industry-defining exaptations. They discussed how microwave ovens use magnetrons as their central heating element –a technology exapted from military radars. Even though the underlying technology was quite similar, the new use constituted a new industry.

Incomplete Sorting of Challenge Types. The reader will note that the innovation mechanisms for Mark 1 (discontinuous technology, rival to the incumbent user base) and Mark 2 (radical exaptation technology, nonrival to the incumbent user base) are not an analytically complete set. Axis one is radicality of innovation: radical exaptation vs. discontinuity. Axis two is radicality of user base i.e., whether the new technology creates a directly rival user base (creative destruction) or a nonrival user base (creation of markets with minimal impact on existing markets). To date, this complete sorting has not been explained. See Table 3 for the fully expressed 2x2 matrix (pg. 41).

Discontinuous innovation quadrants. Discontinuous innovation has been given heavy attention for decades. Challengers have the clear advantage for rival, *Disruptive Innovations*, unless the incumbent can leverage its locked in control of the pertinent research/market channels (Christiansen and Rosenbloom, 1995), so as to force an acquisition of a key challenger. But national innovation systems are dominated by organizations that are charged with seeking, classifying, and institutionalizing technical breakthroughs (Baba and Walsh, 2010). These cases are non-destructive discontinuous innovations, herein called *Moonshots.* National innovation systems enable both new and old firms to be winners through selected consortia. For Moonshots, the national innovation system prioritizes its desired goals, and "pulls" demand, inviting all pertinent parties. Thus, push comes from rivalry, and pull comes from nonrivalry.

Radical exaptation quadrants. Radical exaptation situations have barely been addressed in the literature, and this essay focuses on clearing up these two quadrants. An argument will be advanced that challengers tend to have the advantage when radical exaptations challenge rival incumbent user bases. Upstart challengers must cooperate to establish the technology standards for the rival value chain, resulting in what is labeled a *Rebel Alliance Strategy*. Challengers target lead users by organizing a niche for their unmet demands (Von Hippel, 2005). Demand pull requires coordinated effort on the part of challengers to create alternative infrastructures for highly related, yet territorially challenging, technologies. In contrast, incumbents, rich in knowledge, have the attacker's advantage for creating radical *Blue Oceans*. Blue Ocean Strategy (Kim and Mauborgne, 2014) involves radically exapting technology, but into a nonrival space. This approach of leveraging existing capabilities puts large incumbents at the advantage.

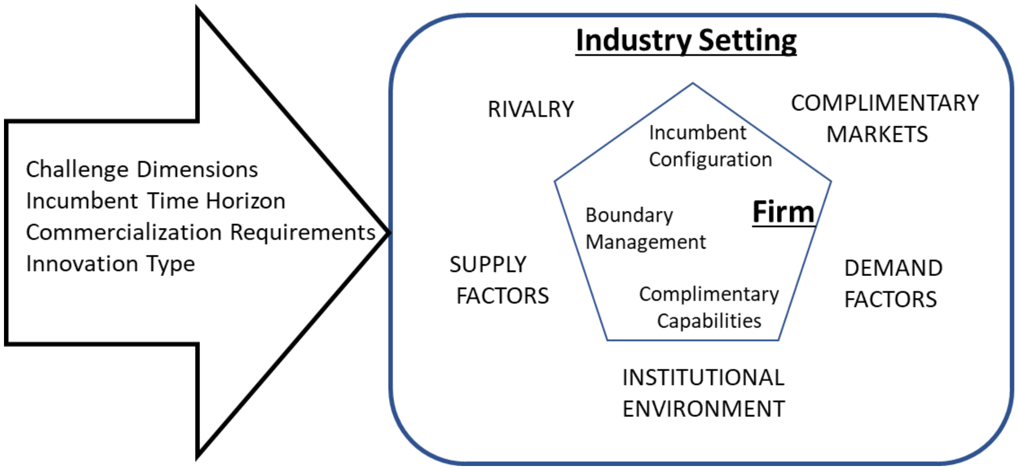
Essay Outline. This essay shall examine which factors tend to facilitate or impede radical exaptation strategy for challengers/incumbents. Extending previous work on the Exaptation-Adaptation Cycle (Andriani and Carignani, 2014), this essay introduces the concepts of *insight lag, bottleneck lag, and regulatory lag* as an explanatory logic of why some firms strategically underperform at radical exaptation. Innovation proceeds over rather lengthy time intervals, and thus good policy and strategy might accelerate these lags, closing the lead that incumbents or challengers possess. Furthermore, it is shown that exaptation lags align neatly with Agarwal and Bayus (2002)'s "commercialization" and "sales takeoff" product launch windows, and therefore integrates into much industry lifecycle research. This essay proceeds in six more sections, to sculpt the basis of a general taxonomy for new industry formation. First, I theorize the four Innovation Challenge Types as briefly discussed. Second, I focus attention on classifying the most likely respective outcomes for Rival Exaptations (Rebel Alliance Strategy) and Nonrival Exaptations (Blue Ocean Strategy), based on closer examination. I extend Andriani and Carignani's (2014) Exaptation-Adaptation Model to sort victory scenarios according to our identified exaptation lag types: insight, bottleneck, and regulatory. Third, I review the literature to propose five scenarios for Rebel Alliances, and five scenarios for Blue Oceans. In section four, I present a qualitative case method for confirming the empirical validity of the ten radical exaptation scenarios. In section five, I offer tables of the confirmatory case study, covering twelve industry formation cases across a variety of sectors. In section six, I discuss implications, limitations of this study, and future directions.

2.1 Theoretical Background: Categorizing the Four Challenge Types

"…commercialization strategy for start-up innovators often presents a tradeoff between establishing a novel value chain and competing against established firms versus leveraging an existing value chain and earning returns through the market for ideas." (Gans and Stern, 2003, pg. 335).

In the classic view, it is assumed that all radical innovations are technological discontinuities threatening incumbent firms' user base (Tushman and Anderson, 1986; Kaplan and Tripsas, 2008). Incumbents are faced with the dramatic replacement of the entire technical system (Hughes, 1987), and a completely different set of capabilities is necessary for future competition (Helfat and Pateraf, 2003). However, these classic disruptive innovations (Christiansen, 1997), with a radical pattern of creative destruction, (Schumpeter, 1934) may be much less common than once believed. Indeed, scholars increasingly focus on several alternative situations: Moonshots, where discontinuities create new industries without destruction; Blue Oceans, where incumbents create new industries with capabilities it already possesses; or, Rebel Alliances, where a wave of small firms create a spinoff industry, splitting the incumbent market.

Figure 4: Reproduction of Ansari And Krop's (2012) ICD Model



Sorting Four Challenge Types. Figure 4 is a reprint of Ansari and Krop's ICD Model (2012). They presented a review of the literature, but did not sort their propositions by challenge type – implying no clear difference for incumbent advantages for, say, Blue Oceans as opposed to Disruptive Innovations. This essay extends and clarifies their ICD Model by presenting a 2x2 matrix of challenges. Precedent also comes from Hill and Rothaermel (2003, pg. 258):

"An incremental innovation builds squarely on the established knowledge base used by incumbent firms, and it steadily improves the methods or materials used to achieving the firm's objective of profitably satisfying customer needs. In contrast, a radical innovation involved methods and materials novel to incumbents. These novel methods and materials are derived from either an entirely different knowledge base or from the recombination of parts of the incumbents' established knowledge base with a new stream of knowledge".

Radical exaptation or discontinuity? Radical innovations stem from two types of knowledge: 1) entirely new knowledge bases, known as discontinuities; and, 2) partially new ones, radical exaptations. Discontinuities are competence destroying shifts in paradigmatic knowledge, as one technical domain and language directly supplants the other (Anderson and Tushman, 1986). Radical exaptation is the repurposing

Table 3: Four Types of Radical Innovation

	EXAPTED TECHNOLOGY New architecture, derived technology	DISCONTINUOUS TECHNOLOGY Competence-destroying technology
RIVAL RADICAL USER BASE Rivalrous use – competes with market incumbents' installed base ecosystem	RIVAL RADICAL EXAPTATION Rebel Alliance Strategy Challengers Favored Incumbent Advantages: • H10: Continuous innovation (de-radicalization) Challenger Advantages: • H2: Disruptive Foresight • H4: Lucky pre-adaptation • H6: Incumbent blown lead • H7: Double exaptation • H8: Institutional entrepreneurship Policy mechanism: Emerging exaptation pools/forums Examples: automobiles, motorcycles, personal computers, 3D desktop printers, social media, one-way radio, small modular reactors, cryptocurrency	RIVAL DISCONTINUITY Disruptive Innovation Strategy Challengers Favored Incumbent advantages: • Acquisition of smaller challengers • Control of key downstream commercialization capabilities Challenger advantages: • Unique technical capabilities • Understanding new users Policy Mechanism: Tech Push innovation Examples: Digital film, typesetting, cellphones
NON-RIVAL RADICAL USER BASE Non-Rivalrous use competes with non-consumption	NONRIVAL RADICAL EXAPTATION Blue Ocean Strategy Incumbents Favored Incumbent Advantages: • H1: Lucky discovery • H3: Dynamic capabilities • H9: Institutional defense (temporary advantage) Challenger advantages: • H5: Alertness (overlooked uses) • H7: Double exaptation Policy mechanism: Incumbent exaptation pools/forums Examples: microwave ovens, LEDs, phonograph jukeboxes, medical marijuana	NONRIVAL DISCONTINUITY Moonshot Strategy Public-Private Consortia Favored To commercialize high tech industries with a national innovation system, governments and universities work with firms to coordinate the long-term rollout of a high risk, high reward technology. Both challengers and incumbents might be invited to participate. Policy Mechanism: Demand Pull Innovation Examples: DARPA's internet, the Apollo program, Sun Microsystem's Javascript consortium, Japanese service robots

of a technology to a new use, as additional features of that technology suddenly become apparent (Dew et al, 2004; Dew, 2007; Garud et al, 2016). Thus, discontinuous innovation concerns the challenger's advantage for introducing a new knowledge base to create a new technical market, whereas radical exaptation concerns the ability to draw on an older knowledge base to create a new technical market. In both cases, firms must transition to new technical standards and new product architectures.

Rival or nonrival user bases. For the second axis of Challenge Type, we must distinguish between new user bases that are rivalrous with incumbent user bases, versus new user bases that are nonrival (Henderson, 1993; Arrow, 1962). A rivalrous technology is a direct substitute, sometimes referred to as a *drastic innovation* (Arrow, 1962; Henderson, 1993) that rapidly makes the prior technology obsolete. A nonrival technology has only trivial impacts on users in existing industries (Cornes and Sandler, 1996; Romer, 1990). For example, automobiles were exapted from locomotives/carriages, and are a direct substitute to locomotive travel; on the other hand, microwave oven technology was exapted from radar technology, but the use of microwaves obviously did not displace any users of radar (Voss, 1988; Cummings and Doh, 2000). Thus, we can sort innovation challenge types by both technology radicality, and user base radicality – prior scholars usually focus on one or the other viewpoint of incumbency. [1]

Synonyms for Exaptation. But we must also clear up the proliferation of synonyms for radical exaptation. Chandy and Tellis (1998) referred to *market breakthroughs*, when a technology is partially similar, but has a big impact on an existing market's value proposition. The same conditions are described by Amit and Zott (2012) as *business model innovations*; by Verganti (2008) as *design driven innovations;* and, by

[1] Scholars used to describe an incremental innovation as the only *competence sustaining* type of innovation (Tushman and Anderson, 1986). Indeed, incremental innovations will extend the incumbent knowledge base and user base. But radical innovations are not always competence destroying. Discontinuities can, in fact, be either competence sustaining (nonrival) or competence destroying (rival) for incumbents; and, radical exaptations are always competence sustaining, even when displacing rival user bases. Thus, the *only* major type of innovation that is competence destroying is a Disruptive Innovation. Henderson (1993) explored Arrow's interest in drastic innovations that destroy competences (1962); but little work has since clarified this issue. Further clarification is of high importance to work on multi-sided software platforms (Suarez and Kirtley, 2012).

Henderson (1993) as *architectural innovations*[2]. A commonly mentioned example for all three terms above is the iPod. The mp3 portable technology already existed, but Apple acted as a challenger to the incumbent music industry music formats, and winning the insight battle over more complicated and expensive mp3 players. Apple conducted the exaptation by launching iTunes to create a rival user base to dying music formats, whereas music incumbents failed to launch competitive mp3 marketplaces. To repeat: exaptation will be the preferred term in this essay.

Challenge One: Disruptive Innovation. The incumbent defender is disadvantaged, and must win control of channels to survive a Disruptive Innovation. Incumbents have a head start because of deep familiarity of existing markets (Teece, 2007; Sood and Tellis, 2005), but act slow to transition to emerging technologies. The niche challengers ride a new technology s-curve. The initially weaker niche technology rapidly overtakes the broader market.

A popular prototypical example is Kodak's failed defense of film against digital film (Wu et al, 2004). Despite some very pleasing features of classic film, digital film rose to take over nearly all the camera market. Due to overly conservative projections of the rate that the new technology was disrupting the old (Wu, Wan, and Levinthal, 2014), Kodak fell into a competency trap (Levitt and March, 1988). Another classic case is typesetting (Tripsas, 1997). Most typesetter incumbents failed. This industry underwent waves of discontinuous innovation, dating back to Gutenberg's original press, and has experienced rapid s-curves of disruption from dot matrix, inkjet, and laser technology. Incumbent failures are high when facing discontinuous technologies, except for those who dominate downstream markets and successfully transition those channels to the new technology (Rothaermel, 2001). So, for example, pharmaceutical incumbents, the dominant controllers of the drug trial process, survived by absorbing biotechnology startups into the

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[2] Additional relevant observations were made by Rothaermel, 2001; Katila and Ahuja, 2002; King and Tucci, 2002; Markides, 2006; Christensen, 2001; however, they did not use any of the terms discussed in this paragraph. In addition, Taalbi (2017) recently proposed an alternative matrix of inducements to innovation: institutional, market opportunity, technical opportunity, and problematic; but, while it is empirically useful, this is a passive "inducement" approach to innovation, which assumes new markets and technologies happen "out there" before the firm reacts to it, when in fact the firms use innovation processes to create these opportunities. The passive inducement approach to innovation obscures both the incumbent-challenger rivalries and the innovation processes responsible for it.

same trial process. Big pharma simply acquired many biotech startups. Thus, the typical story is that incumbents can only survive discontinuous innovation by enticing smaller challengers to sell themselves to incumbents and give up on establishing a rival platform (Gans and Stern, 2003). For most challengers, this is the lowest risk strategy to accept.

Challenge Two: Moonshots. Discontinuous and nonrival, Moonshots are uncontested markets driven by large scale, risky investments. An example is the Apollo space program, which had no true user or technology precedent, and did not displace any incumbent user base. The Apollo program necessitated the creation of a host of new technologies. Other common examples include breakthrough medical devices, such as artificial hearts; and, research and diagnostic equipment, such as new categories of scientific instruments like particle accelerators. There is little reason to distinguish between incumbents or challengers in such a space: whether the participating firm is new or old, it gains immense advantage by participating in the earliest consortia of projects. Survival depends on inclusion in the consortium. Cases such as Javascript software, Bell Labs' telecommunications monopoly, and more recently, Japanese service robots (Kattel and Mazzucato, 2018; Lechevalier, Nishimura, and Storz, 2014) demonstrate the power of consortia to create radical technologies and markets, conjointly.[3]

Challenge Three: Blue Oceans. In this essay, sustaining innovations that create new product subcategories are not treated as radical enough to be a technical exaptation. For example, Kim and Mauborgne's (2014) website talks about how Kimberly-Clark used Blue Ocean strategic methodology to make one brands' toilet paper packages easier to carry and store. But such designs, although valuable, have a very short competitive advantage – the technology protections on alternative toilet paper packaging are, unfortunately, easy to work around rapidly. Radically exapted technologies – such as microwave ovens, light emitting diodes (LEDs), and phonograph jukeboxes – established new markets nonrival to existing technology user bases,

[3] Earlier research used the term "greenfield competition" (Gans and Stern, 2003) when incumbents have no capability advantages for commercialization; however, it is unclear if they really meant to refer to Moonshots, or were talking about Blue Oceans.

but also provide sustained advantages to first movers. The respective incumbent technologies for those three technologies aforementioned – radars, semiconductor diodes, and dictation phonographs – were virtually undisturbed by the new markets. Sometimes powerful incumbents, such as high tech software giants, have such a wide technology platform that they can repeatedly innovate nonrival technologies that serve the same platform ecosystem.

The incumbent has advantages for three approaches: 1) lucky early discovery leading to technical protections (Cattani, 2005) and superior component knowledge, such as in the case of microwaves; 2) dynamic capability advantages in starting new markets repeatedly (Teece, 2007; Gawer and Cusumano, 2002) 3) institutional advantages, especially leveraging of first-to-market brand power (Farquhar, 1989; Kerin et al, 1992; D'Aveni, 2002). The challenger can still win if the incumbent fails to treat the new market as "serious", and due to biases, passes up lucrative opportunities on purpose (Basalla, 1988). The classic example of such an attention failure: Thomas Edison lost out on the phonograph jukebox market because of his preoccupation with a "more important" phonograph dictation machine.

Challenge Four: Rebel alliances. Here we come to the underexplained quadrant in the literature. Because this quadrant of innovation is not mentioned in prior literature, it is herein logically derived by contrasting it to the other three quadrants. The label itself is a play on words, derive from the D'Aveni (2002) essay on incumbent advantages, entitled "The Empire Strikes Back". Rebel alliances arise when lead users are desperate to get their hands on an incumbent technology, and so they rise up together as challengers to create a new form factor and infrastructure for them. Demand is thus pulled by lead users, not powerful institutions.

First, let us contrast Rebel Alliances to Blue Oceans. Exaptations are driven by the frustrated demands of lead users (von Hippel, 2005), or preference discontinuities (Tripsas, 2008) when downstream customers of a technology have an immense shift in wants. Such technologies are repurposed into alternative form factors that slowly draw users away from its parent technology form factor, but they leave some incumbent activity intact for a long time. Automobiles, motorcycles, personal computers, 3D desktop printers, and small modular nuclear reactors are all examples of exapted technology that directly competed with installed user bases. This pattern of market creation is obviously inverse of a blue ocean, where incumbents are favored and no market exists; and yet, both blue oceans and rebel alliances are fashioned from radically exapted incumbent technology.

Second, let us compare Rebel Alliances versus Moonshots. Market development is a mirror image of Moonshots: based on a wave of new entrants that must create an industry that stands on different institutional grounds – technology standards, trade associations, value chains, etc. – which requires the collective, cooperative effort of challengers, with very little institutional help from existing authorities in society. Moonshots are intended to orchestrate large technical systems across public and private interests. For example, Henry Ford had to leave his senior engineering post at Edison Labs to pursue combustion-based automobiles, as Edison would rather see electric trains and busses have their heyday. Edison fought for centralized moonshot projects with the government to jointly, massively electrify urban America.

Third, consider Rebel Alliances versus Disruption. A Rebel Alliance merely destroys incumbents' sunk investments into a value chain, whereas Disruptive Innovation is truly competence-destroying. Disruptive technical discontinuities cause abrupt technical obsolescence of incumbents past a certain inflection point (Adner, 2002), but Rebel Alliances can only rely on better understanding of user wants as the technology evolves. Therefore, incumbents might eventually catch up as "fast followers" (Sanchez, 1995). Rebel Alliance challengers cannot rely on technical obsolescence, and so must create institutional arrangements that favor the new industry. For example, automobile firms did not overtake locomotive firms by the destruction of technical competences; rather, challengers invested in roads, gas stations, and aftermarket mechanics as an alternative infrastructure to railroads, train stations, and central planning. These scenarios usually favor challengers, as incumbents typically oppose the very existence of an alternative form factor or infrastructure. The incumbents often grossly underestimate the ability for challengers to rapidly displace incumbent technical systems (Christensen, 2013). Exaptation challengers reinterpret the existing technologies with new narratives, business models, architectures, and design motifs (Garud et al, 2016; Christensen and Rosenbloom, 1995).

Can Incumbents substantially delay failure? Yes, the incumbent can use regulation so that the "Empire Strikes Back" (D'Aveni, 2002), while preparing to enter the new market themselves. But this tends to be a very short-lived solution in internationally open markets. The incumbents often understand the exapted technology, but typically do not understand the perspective of the new market users (Christensen and Rosenbloom, 1995; Kogut and Zander, 1992).

The Rebel Alliance challenger has five advantages, whereas the incumbent has one. First, the challenger could win by foresight into the enormity of the untapped market, commercializing an early insight based on what McCray (2013) calls *visioneers:* inventors exploring science fiction descriptions of user wants (Turner, 2005). Second, the challenger could win by a lucky pre-adaptation to the new user base – both in terms of pre-existing relationships and resources, and in terms of know-how to complete the innovation for sales takeoff (Cattani, 2005). Third, the challenger can practice *double exaptation* and instantly deploy an insightful new product category – rapidly repurposing two incumbent exaptations into a different form factor. A prominent example is the simultaneous inventions of automobiles and safety bicycles, double-exapted in nearly the same year to become motorcycles. Fourth, challengers can win via institutional entrepreneurship and challenge the incumbent-friendly regime. A pure example of institutional challenger victory is the rapid deployment of medical marijuana. Fifth and finally, an alert challenger can still win if the incumbent somehow takes all the right initiatives to win but fails to launch a would-be blockbuster product (Hiltzik, 2000). An incumbent must overcome all challenger conditions to win, while defeating their former selves: a rare feat. However, companies that innovate early – and identify as creators – can win later market battles too. Cases exist where *continuous innovation* by the incumbent was able to de-radicalize the challenge (Ries, 2011; Verona and Ravasi, 2003; Wood and Brown, 1998).

2.2 Tech-Push and Demand-Pull Policies

Tech-push and demand-pull were the earliest mechanisms discussed in the literature on discontinuous innovation. Several recent studies have reviewed these policy perspectives (Di Stefano, Gambardella, and Verona, 2012). These policies are useful for discontinuous innovation, but not for radical exaptation.

Tech-push is a theory that top-down basic research programs enable new means of innovation. According to tech-push, science expenditures in a national innovation system would accelerate technological breakthroughs (Mowery and Rosenberg, 1979; Dosi, 1982; Cohen and Levin, 1989). Planners can reduce incumbent inertia, increasing likelihood of Disruptive Innovations; or can create policy incentives to help incumbents generate Blue Oceans.

Demand-pull. Alternatively, consider how a demand-pull dynamic characterizes Moonshots (Kleinknecht and Verspagen, 1990; Schmookler, 1966; Di Stefano, et al, 2012; Baumol and Strom, 2007). In radical demand-pull situations, policy makers or lead users fund innovation of unmet ends (Agarwal, Moeen, and Shah, 2017). Once new ends are identified, basic research can hone in on a technology roadmap toward those ends. Planners use incentives to guide entrepreneurs toward new ends. Moonshots benefit from government procurement in the national interest, or basic research budgeting. Rebel Alliances are aided by small firm incubation policy.

Policies to pursue exaptations. To date, scholars have said little about how radical exaptation strategy fits into ICD or policy literature, so this essay focuses on that investigation.[4] An entrepreneurs' creation of an *opportunity* (Shane, 2003; Dyer, Gregersen, and Christensen, 2008). *The individual-opportunity nexus* is where the entrepreneur constructs variants of existing technology for a new *mean-ends model* (Eckhardt and Shane, 2003; Shane and Venkataraman, 2000). While prior researchers have explored how

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[4] This section does not rely on the work for Kim and Mauborgne, as their methods and approaches do not focus on radical exaptation only; indeed, their approach does not distinguish between the type of technical innovations employed in the creation of new markets. Yet, there is theoretical reason to believe that radically exapted new markets are different than sustaining innovations, especially in terms of sustainable advantage.

entrepreneurial personality impacts missed opportunities (Arora, Haynie and Laurence, 2013; Baron, 1998), there are no empirical studies on how to make entrepreneurs more effective at creating new markets. But, there is new theory to that purpose. It is well known that firms tend to "Farm out" related patent classes (Jaffe, 2000), to stake claim to all intellectual property; but innovation is a bit different. Innovation requires the ability to make and market the product – and a full commitment.

Exaptation pools and forums. Garud, Gehman, and Guiliani (2016;2018) have argued that exaptation can be accelerated by crafting "pools" of technology that have been underapplied, and "forums" where new applications are discussed, looking ahead of existing prototypes. Corporate venture capital is such a pooling approach – incumbents willing to fund employee entrepreneurship are more likely to form new markets (Drover, et al., 2017). Industry conferences and business incubators provide places of discussion for startup challengers to congeal into emerging clusters for future applications. For example, several microcomputer trade shows took place in the inaugural year of the category: 1976 (Veit, 1993). At shows, challenger firms collaborated on value chains, alliances, and innovation roadmaps for the fledgling industry.

2.3 Extending the Exaptation-Adaptation Model: Exaptation Lags

This section provides a deeper explanation of the two radical exaptation quadrants, by fitting it to the recent literature on radical exaptation. Exaptation opportunities are subject to substantial *time lags*. These lags provide the possibility for any one focal firm to improve their innovation strategy enough to overcome the "Typical" outcome for such a scenario; or, for policymakers to improve the economy. Exaptation is boundedly rational (Garud et al, 2014; Cattani, 2005), so lag times always exist between a technical possibility and its implementation. For example, the first microwave prototype appeared in 1947, but *technology bottlenecks* slowed the development of a viable commercial hit, a commercially complete set of features, for twenty more years. Exaptation markets are thus inefficient search landscapes, and benefit from explicit policies intended to link technological means to new ends (Garud, et al, 2016; Villani et al, 2007). Consider the following observation: "The production of an exaptation requires linking an existing body of knowledge to its possible new application. The emergence of this link requires a close interaction between producer and user of that knowledge." (Ganzaroli and Pilotti, 2011, pg. 4).

Lead users need to experiment extensively with the technology, develop the new user culture, and iteratively improve components to the satisfaction of future users (Sedita, 2012; Bonifati and Villani, 2013). For example, insight into microwave oven technology began in 1946, but a suitable adaptation for home users took 21 additional years to develop. The lags are derived from Adriani and Cannani (2014)'s Exaptation-Adaptation Cycle.

The Gradual Exaptation-Adaptation Cycle, and Exaptation Lags. The most thorough definition of the technology exaptation process, to date, is the Exaptation-Adaptation Cycle (Dew et al, 2004; Andriani and Carignani, 2014). They identify three basic steps: First, *functionality emergence,* when the exaptation possibility is discovered, often accidentally, by taking note of features emergent from improvements to an existing technology; Second, *deliberate selection* of a new use for the features, whereby prototypes of new uses are made; and Third, *secondary adaptation* – a synonym for the term, technology bottleneck – is the step whereby prototypes are improved on secondary characteristics to be fully viable commercially. These improvements do not require dramatic breakthroughs. Instead, technology bottlenecks are solved with repeated trials with lead users, and the subsequent identification of a scalable manufacturing process. Drawing on this theory, I posit three major time lags that can be reduced by policy effort: insight, bottleneck, and regulatory lag.[5]

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[5] There exists a fourth lag, prior to the time of first feature emergence. But the fourth lag, "pre-adaptation" (Cattani, 2005; Dew, 2007) during pre-emergence, cannot be *deliberately managed* by the very definition of exaptation. Firms cannot influence the ex ante luckiness of feature emergence (Cattani, 2005; Andriani and Carignani, 2014). Past stage one, future success depends on insight and secondary technology innovations (Cattani, 2005; Dew et al, 2004) which can indeed be deliberately managed.

Stage Two: Deliberate Selection is vulnerable to *insight lag.* Insight is how the entrepreneurship literature explains the cognitive search for opportunities. Entrepreneurs typically stumble upon insight of a means-ends model (Shane and Venkataraman, 2000; Eckhardt and Shane, 2003). By deliberately investing in the search for new uses of a technology, insight lag can be reduced.

Stage Three: Secondary Adaptation is vulnerable to *bottleneck lag*. After insight, the entrepreneur still must commit time and resources to additional innovation steps. The proof of concept must be fashioned into a viable state – such as the lag between the first proof of the primary functions of microwave ovens (1946) versus the first commercially successful microwave oven, which had a number of added features (1967). The microwave required more than a useful heating element: it required a safe, reliable architecture, which required further development of new features (Henderson and Clark, 1990; Levinthal, 1999). To convert the original commercial launch into a sales takeoff success (Agarwal and Bayus, 2002), the entrepreneur must come to understand the minimum viable product (Ries, 2011) for each scalar increase in sales. For example, the new users of microwaves were highly concerned about the safety of the device; it needed adequate new controls, a turntable for even heating, and recommended settings for a wide variety of food items.

Regulations Post-Insight. Once the exaptation has been prototyped, regulations can be interpreted to favor or oppose it. Some new uses of technologies are discouraged by *regulatory lag*. Specific regulations tend to favor investment and innovation for incumbent uses, delaying and discouraging investment and innovation for new uses (Malerba et al, 2008; Jacobides, Knudsen and Augier, 2006). Research policy must take consideration of how to reduce legal lags to clear the space for new markets[6] – for example,

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[6] The Exaptation-Adaption Model aligns well with other literature on the industry lifecycle timing of innovation, which connects it firmly to related literatures on innovation and research policy. For example, it roughly corresponds to Saviotti and Metcalfe's (1984) model of *main services*: the emergent feature provides the main services, or functions, of the new use category; but, the secondary adaptation step cannot be completed until bottlenecks are resolved, to amply provide *secondary services* for commercial success. It also aligns with the research on the stages of industry emergence. Stage two aligns with the "commercialization phase" identified by Agarwal and Bayus (2002), and stage three aligns with the "firm takeoff".

many states chose to overlook existing taxi laws to clear space for the ridesharing firms, Lyft and Über. But most industries experience more difficult regulatory hurdles. Society would have benefitted from accelerating the development of automobile laws and regulations, but the train companies - and the stakeholders which promoted train technology - resisted the alternative infrastructure with legal roadblocks (D'Aveni, 2002; Jones, 2001). Incumbents have lobbied or exerted influence to shape industry rules, in favor of the debut use of the technology (Ansari and Krop, 2012; Lawrence, 1999).
For example, Agarwal and Bayus (2004) posited that creator firms who commercialized the first version of a new technology have been found to have, on average, the longest survival horizon. Challengers or incumbents who invent early (stage two) can survive product innovation battles and can extend that advantage to victory with the funds to scale up (Echambadi, Bayus, and Agarwal, 2008). But some challengers can enter during firm takeoff (stage three) –known as "first followers", these firms who can completely bypass short-lived first generations of product markets, and can aim to produce a value chain with true staying power (Querbes and Frenken, 2017). Thus, this model maintains backwards compatibility with research on emergent strategy.

2.4 Lag Measurement and Scenario Hypotheses.

"Yet it is diffusion rather than invention or innovation that ultimately determines the pace of economic growth and the rate of change of productivity. Until many users adopt a new technology, it may contribute little to our well-being. As Nathan Rosenberg said in 1972, 'in the history of diffusion of many innovations, one cannot help being struck by two characteristics of the diffusion process: its apparent overall slowness on the one hand, and the wide variations in the rates of acceptance of different inventions, on the other.'" (Hall and Kahn, 2003)

Measuring Insight, Bottleneck, and Regulatory Lag. So how do we measure an exaptation opportunity? We follow Agarwal and Bayus (2002), and look for time intervals for waves of new product introductions. Insight lag is measured as the time between feature emergence and the "commercialization wave". There may be several near-simultaneous firsts, so it is best to aim for accuracy rather than precision; this essay uses the year of first saleable products. Bottleneck lag is measured as gap between commercialization and "sales takeoff"– a stable growth trajectory (Dosi, 1982; Agarwal and Bayus, 2002). For regulatory lag, we can measure the first year of a legal change or major government procurement action to facilitate the new industry.

Ten Hypotheses of Radical Exaptation Lag Scenarios. Below is a list of ten lag-based hypotheses, based on a review of the literature most relevant to radical exaptation challenges. Most Rebel Alliance advantages favor challengers, and most Blue Ocean advantages favor incumbents: however, some incumbents choose to act "like a challenger", and vice versa, therefore overcoming substantial hurdles. But this essay goes further than just leaving these in a list format; instead, I provide a theoretical mapping to show that the hypotheses are collectively exhaustive. In other words, I first rule out all "null hypotheses" for lags that would be merely irrational for the respective Challenge Types. See Table 4 for the alignment of hypotheses with phases.

Null conditions. Null 1 is regulation prior to insight lag period. Such regulation doesn't impact the challenge outcomes. Null 2 is a situation where feature emergence is sufficient for producing exaptation. By definition, such exaptations are not radical. Null 3 is the absence of incumbent participation, and doesn't add any additional impact to outcomes. Null 4 is a nonrival incumbent practicing double exaptation. On closer examination, two lucky exaptation discoveries arriving at once are still limited by the insight lag period of the first exapted use, and thus this hypothesis is the same as two simultaneous H1 hypotheses in the same firm. Null 5 is a contradictory situation. Skipping bottleneck lag is a privilege only challengers can have, by alertly noticing an incumbents' missed opportunity: H3. It is not possible that an incumbent would overlook its own exaptation use and still take advantage of its own bottleneck technology. Null 6 is an incumbent committing regulatory suicide, by blocking its own innovation. This cannot happen, since incumbents never intentionally develop regulations against itself; at least, assuming no extraordinary societal concerns emerge that could challenge incumbent viability if left uncommunicated (e.g. Freon, where regulations favored any incumbent with a suitable replacement).

Table 4: Lags for 12 Cases of Radical Exaptation

EXAPTATION CATEGORY HYPOTHESES FOR ADAPTATION-EXAPTATION LIFECYCLE	CONFIRMED CASES (challenger win in italics)	INSIGHT LAG	BOTTLENECK LAG	REGULATORY LAG
HYPOTHESIS ONE: FIRST TO INSIGHT NONRIVAL INCUMBENT SECOND STAGE ADVANTAGE CAUSED BY A LUCKY DISCOVERY	LEDS MICROWAVE OVEN PHONOGRAPH JUKEBOX CRYPTOCURRENCY	1927-1951 (24) 1940-1947 (7) 1877-1890 (13) 1982-1988 (6)		
HYPOTHESIS TWO: FIRST TO INSIGHT RIVAL NEW ENTRANT SECOND STAGE ADVANTAGE FROM **FORESIGHT**: INNOVATIVE USERS SEEKING TO DISRUPT THE DEBUT USE	*AUTOMOBILES* *PERSONAL COMPUTERS* *3D DESKTOP PRINTING* *SOCIAL MEDIA* *ONE-WAY RADIO* *MODULAR REACTORS*	1789-1885 (96) 1945-1968 (23) 1984-2005 (21) 1984-1997 (13) 1888-1894 (6) 1942-1974 (23)		
HYPOTHESIS THREE: DYNAMIC CAPABILTIES NONRIVAL FINAL WAVE INCUMBENT ADVANTAGE BASED ON **DYNAMIC CAPABILITIES**	LEDS MICROWAVE OVEN		1951-1963 (12) 1947-1967 (20)	
HYPOTHESIS FOUR: PRE-ADAPTATION RIVAL THIRD STAGE NEW ENTRANT ADVANTAGE, IF NEW ENTRANT HAS THE COMPLEMENTARY TECHNOLOGY	*AUTOMOBILES* *MOTORCYCLES* *3D DESKTOP PRINTING* *SOCIAL MEDIA* *ONE-WAY RADIO* *MODULAR REACTORS*		1885-1901 (16) 1884-1902 (18) 2005-2009 (4) 1997-2003 (6) 1894-1920 (26) 1974-2017 (43)	
HYPOTHESIS FIVE: ATTENTION NONRIVAL INCUMBENT ATTENTION FAILURE FOR WRONG UNDERSTANDING OF EXAPTATION INISGHT LAG BUT NO BOTTLENECK LAG – CHALLENGERS' KIRZNERIAN ADVANTAGE	*CRYPTOCURRENCY* *PHONOGRAPH JUKEBOX*	1988-2009 (21) 1877-1897 (20)	2009 (0) 1897 (0)	
HYPOTHESIS SIX: FAILURE TO LAUNCH RIVAL INCUMBENT BIAS (INERTIA) INSIGHT AND BOTTLENECK INCUMBENT ADVANTAGE BLOWN	*PERSONAL COMPUTERS*	1945-1968 (23)	1968- 1976 (8)	
HYPOTHESIS SEVEN: DOUBLE EXAPTATION, RIVAL CHALLENGER DEVELOPS A SECOND MARKET DIRECTION FOR A BOTTLENECK TECHNOLOGY, WITH NO INSIGHT LAG	*MOTORCYCLES*	1884 (0)	1884-1902 (18)	
HYPOTHESIS EIGHT: INSTITUTIONAL ENTREPRENER WINS JUSTICE RIVAL CHALLENGER PIONEERING ADVANTAGE	*MEDICAL MARIJUANA*			California is first state allowing medical use (1996).
HYPOTHESIS NINE: REGULATORY DEFENSE RIVAL REGULATORY LAG BEYOND FEATURE EMERGENCE: INCUMBENTS LOSE ADVANTAGE WHEN REGULATION EXPIRES	*ONE-WAY RADIO* *AUTOMOBILES* *MODULAR REACTORS*			1914-1918 (4) 1860-1890 (30) 1951-2017 (66)

H1: Lucky absorption, insight, incumbent wins. The lucky incumbent inherits the exaptation in their own research settings. By observing Stage One Feature Emergence, they developed the Stage Two Insight secretly. Sometimes multiple incumbents discover simultaneously, and race each other; but for now, we can simply approximate the first deliberate prototype in a year-wide interval. Incumbent second stage advantage caused by a lucky stage one advantage: incumbents have more R&D budget and are more likely to first hit an experimental discovery of emergent features (Schumpeter, 1934). They can also lean on their large absorptive capacity (Cohen and Levinthal, 1990). A typical example is the development of Light Emitting Diodes (LEDs). In the 1950s, incumbents working on semiconductors stumbled onto technologies that were structurally similar to electronic diodes (used in computer chips) but were efficiently electroluminescent Zheludev, 2007), and which became very popular in the form of small lasers in various colors. These were exapted to make infrared indicators and calculator displays, which did not previously exist- a nonrival user base (Schubert, Gessmann, and Kim, 2005). Let us not get confused by the fact that LEDs were used as discontinuous innovations in the 2000s: Illumination sources and LED TVs displaced some of the largest incumbents, including GE and Phillips, as a disruptive innovation. The same technical trajectory can sometimes be exapted or a discontinuity.

Another H1 example is the radar magnetron, which became suddenly relevant for microwave. The focal firm's to-date knowledge and possession of magnetrons confers a first-mover advantage (Kerin, Varadarajan, and Peterson, 1992). The incumbent repeats use of its capabilities in a familiar market (Christensen and Rosenbloom, 1995). For example, the first microwave oven, the Radarange, was launched in a familiar market for Raytheon: nuclear submarines. This was a commercialization advantage but not enough to provide the incumbent the means for a subsequent, sales takeoff to achieve leadership in the more lucrative user base.

H2: Foresight insight, challenger wins. When uses are rivalrous, a technological head start may not always be enough incentive for pursuing exapted uses. Sometimes incumbents sink resources into developing the debut use, with little left to expend on rival uses. This is observed especially when the radical innovation requires an *asset specific investment* but has no established market yet (Ansari and Krop, 2012;

Riordan and Williamson, 1985). Whereas incumbents think in terms of conserving profit streams, challengers dream of science futures (Turner, 2010). Challengers notice the radical nature of a technology more readily than incumbents. Thus, we expect stage two challengers to create the first insight, and for them to gain advantage in the race for a sales takeoff hit. Examples include personal computers and 3D desktop printing, both of which started from radical open source movements. Certainly, if entrepreneurs had earlier insight into form factors, innovation could have proceeded with less hesitation, but uncertainty slowed development (Dimov, 2007; Busenitz, 1996).

H3: Dynamic capabilities, bottleneck, incumbent wins. Nonrivial technology appears in this case within a firm having the oldest experience with the technology. Firms with *dynamic capabilities* (Teece, Pisano, and Shuen, 1997; Helfat and Peteraf, 2003) can bridge across capability lifecycles and renew competitive advantage. For instance, the user base of a microwave oven doesn't compete with radar, so all relatedness is on the supply side. Incumbents tend to act as a related diversifying firm to sustain their supply side advantage in such cases when the new user base is not cannibalistic. Thus, the incumbent will try to leverage its dynamic capabilities to gain economies of scope (Teece, 2007) – alternatively described as absorptive capacity (Cohen and Levinthal, 1990), transformative capabilities (Garud and Nayyar, 1994), or combinative capability (Zogut and Zander, 1992). Such incumbents have often launched a series of hit products and leading technologies, excelling with radical innovation. They are frequently first movers to commit to commercial growth (Eisenmann et al, 2006; Liberman and Montgomery, 1988) and to the breaching of bottlenecks (Langlois, 2002) at the third stage of the Exaptation-Adaptation Cycle. Once an insight is presented, they can race to push the original prototype through costly bottlenecks well before challengers (Tripsas, 1997). In the classic example of the microwave, a Raytheon engineer discovered that radar magnetrons could also make a microwave oven and made a successful stage two prototype. Capitalizing on their dynamic capabilities, Raytheon bought Amana in 1965 to successfully commercialize the stage three microwave in 1967.

H4: Lucky pre-adaptation, bottleneck, challenger wins: Some challengers just happen to have the secondary capabilities for the final exaptation stage. The challenger's possession of bottleneck know-how is a lucky pre-adaptation. They aren't skilled at radical innovation in general, but they are fortuitously skilled in the right stuff to adapt that technology to a commercially successful form (Cattani, 2005; Dew, 2007; Dew et al, 2004). These lucky experiences seem to come from individuals working within the debut industry, who then leave incumbent firms to focus on adapting the exapted use. For example, the original automobile engine makers, such as Gottlieb Daimler and Wilhelm Maybach, learned their skills while working for industrial engine makers in previous engine categories, like locomotives and steamships. They were pre-adapted, possessing complementary capabilities (Moorman and Slotegraaf, 1999).

H5: Alert to missed opportunities, Kirznerian bottleneck, challenger wins. Incumbents sometimes have many commitments and cannot properly assess each new opportunity (Macher and Richman, 2004). They might also fail to capitalize on exaptation insights owing to technical or personal prejudice, like Thomas Edison's failure to launch the phonographic jukebox because, even though he had the insight of that use, he was embarrassed by jukeboxes as "non-serious". After years of inaction, rivals picked up on the idea and beat him to market. For exaptation, an emerging opportunity sometimes predates a winning new combination by a large interval (Levinthal, 1998). The Kirznerian entrepreneur (1973; 1999) could be watching and waiting for the moment to strike. For exaptation, the critical step is, from a Kirznerian perspective, alertness: to be the first to notice emergent features in an existing technology (Andriani and Carignani, 2014; Dew et al, 2004). However, alert incumbents might also survive a pioneering phase of entry, presenting a mixed result (Chandy and Tellis, 2000).

H6: Failure to launch from inertia, blown bottleneck lead, challenger wins. Chesbrough and Rosenbloom (2002) imply that new business models favor challengers because incumbents don't understand them yet. Inertia can bring any incumbent down, clutching defeat from the jaws of victory (Tripsas and Gavetti, 2000). The most famous blown lead is Xerox PARC's failure to launch the first personal computer, the Xerox Alto (Hiltzik, 2000). The PARC program produced a whole suite of radical innovations. Most of its leadership came from the Advanced Research Projects Agency that developed the internet (Isaacson, 2014). Extremely eager inventive lead users took raw components, mostly for calculators, and repurposed them for "microcomputers". Incumbents could have done this even better but didn't consider the market "serious". This allowed companies like Apple to initiate the industry: they used some spillovers from Xerox's PARC technology. Incumbents like Xerox were more committed to centralized mainframe computing, with masses of office users. Yet, the exapted home technology evolved faster than imagined, and the Xerox Palo Alto Research Center (PARC) failed to commercialize its already invented and functional personal computer technology. With the failure of PARC, incumbents like IBM and Texas Instruments to scrambled to the defense of the user base, but only after giving up critical market share to pioneering challengers like Apple, Tandy, and Commodore. Personal computers enabled a new value chain with a rival ecosystem: decentralized routing and personal networks. Incumbents are often unlikely to resist the fear of cannibalizing products (Hill and Rothaermel, 2003; Ansari and Krop, 2012).

H7: Schumpeterian double-exaptation, without insight lag, rapid prototype, challenger wins. A Blue Ocean/Rebel Alliance Hybrid is possible; by fragmenting the Rebel Alliance into multiple form factors, multiple markets are created. Most of the research cites the Schumpeterian theory of economic development (1934). The Schumpeterian entrepreneur uses creativity and is responsible for a new combination (and bottleneck solution) of production means or product. Kogut and Zander (1992) explain how capabilities arise to make new combinations, and how sometimes complementary features emerge in two separate industries and can still be recombined instantly. Motorcycles involved the repurposing of both emerging car engines and emerging bicycles. This double exaptation makes Stage One and Stage Two virtually simultaneous. The motorcycle industry is a case of a challenging firm creating a new industry out of convenience, and a wave of challengers hunting for their first big commercial success.

H8: Institutional entrepreneurship, regulation-only gap, challenger wins. Removing a regulation could potentially cause a near-instant exaptation with very large social impact. A rival situation may present a regulation-only gap, which is one that acts on something that has long since been available but is illegal in exapted form. One instance is recreational marijuana, which has long been illegal, but which regulations also made the medical exapted uses illegal (Dioun, 2014; Wicks, 2016). Pharmaceutical and medical incumbents are conditioned to avoid medical marijuana, which presents substantial risks during the awkward transitionary phases. Incumbents also will resist marijuana being used to replace existing medications, such as analgesics and opiates. Only unusually aggressive incumbents will catch up to the rebels, due to risk aversion (Levy and Scully, 2007; Suddaby and Greenwood, 2005). **H9: Defensive regulatory lag, extends past insight lag, challenger wins. Incumbent Survival Advantage for Rivalry**. A debut use for a technology can, under some conditions, be powerful enough to hinder the arrival of rival exaptation uses, thereby creating systemic delays in such innovation throughout society. These systemic delays grant incumbents a longer tenure without adopting the new use (Klepper and Simmons, 2000), but also increase the odds that new entrants after that extended tenure will eventually thrive, especially when the technology is complex (Rosenbloom, 2000; Ansari and Krop, 2012; Querbes and Frenken, 2017). In this rival situation, regulations go into place after the earliest prototype experiments. The cause of regulation is defensive, and in the interests of the incumbents who want to protect the debut use (Mitnick, 1980). The railroad barons were not fans of the automotive industry and lobbied for a number of "Red flag" laws**-** automobiles required attendants in front of the vehicle, waving a red flag. Incumbents may even commit market manipulations defensively, such as in the case of railroads employing a host of anticompetitive practices (Mitnick, 1980).

England had many powerful interests that were opposed to automobiles or road locomotives. Incumbent investors, often aristocratic or politically connected, pressured Parliament to favor horse-based transportation and railways. In the Act of 1865, locomotives were restricted to 10m mph country, 5 mph city, with strict rules about tolls. These rules were tightened – and partially implemented in the USA as well **-** with no relief until the 1890s. Thus, these regulations held up the investments into automobile exaptation.

H10: Incumbent continuous innovation (challenge de-escalated to incremental type). De-escalating the radical challenge into continuous challenges can sometimes work, if incumbents have the right strategies (Anand et al, 2009)**.** De-escalation is the key to successful cannibal products (Conner, 1989; Foster, 1985), as the willing cannibal can plan transitionary steps to the new technology, whereas the unwilling cannibal resists until it is forced to make a quantum leap. An example from Verona and Ravasi (2003)'s study of continuous innovation: an incumbent analog hearing aid company survived the transition to digital hearing aids, by thinking ahead and splitting the would-be radical innovation transition into several continuous product steps. They commercialized the minimum viable product (Ries, 2011) for each digital feature, spreading out the transition on a component level. Thus, incumbents might survive with sufficient foresight to “de-radicalize” the transition (Benner and Tushman, 2003).

2.5 Qualitative Methods for Case Analysis

In this essay, the goal is to confirm lag phenomena as qualitatively useful categories for use in future causal modeling and deeper case analysis. If some of the theorized historical cases do not exist, then no generalization can be made about that kind of exaptation. Therefore, it is important for each theorized exaptation condition to exist in at least some major cases (Eisenhardt, 1989), and so constitute an analytically interesting subfield of study. Thus, this essay will examine case studies as evidence that the phenomena in question have occurred in some historical pattern; and, this procedure shall confirm the presence of the theorized outcomes. Confirmatory studies are a first step towards empirical validity (Tsoukas, 1989; Perry, 1998). Methodologically, we follow the recommendation of Miles and Huberman (1994), and target 12 cases: no more cases than necessary for theoretical saturation but enough for confirmation of some common scenarios.

Case Representativeness. This paper uses a convenience sample of popularly researched and well known radical exaptations, and targets typical, “classic” cases, not outliers. Studies on radical innovation can be reliable, but cannot be representative. I follow Agarwal and Gort (2001, pg. 167) on how to handle the representativeness problem:

“Indeed, since the population of all product innovations has never been defined (let alone measured by anyone), there is no method available for drawing a representative sample. Our sample of innovations, however, does encompass a broad spectrum of important innovations in the past century.”

Sample Selection. The cases reviewed here are chosen for their popular use in the ICD and exaptation literature to create theoretical continuity with the literature, and are conveniently selected for the general reader's knowledge. Theoretical saturation (Bowen, 2008) of the sample was reached on confirming that each category has multiple cases, and each category has unique membership. I drew twenty of the most cited cases from the innovation literature, and randomly sampled twelve of the twenty for full illustration, due to journal space limitations. I did not need to redraw the sample, as the twelve cases were sufficient to empirically confirm each of the ten hypotheses.

Table 5: Table of 12 Confirmed Cases of Radical Exaptation

HISTORICAL CASES	FEATURE EMERGENCE	SELECTION (INSIGHT)	POST-ADAPTATION (BOTTLENECK)	MECHANISMS (HYPOTHESES)
AUTOMOBILES from locomotives, rivals all personal and industrial transportation methods	French steam wagon, commissioned by the army for hauling cannons. Concept worked, but wasn't cost effective for military use (1789)	Daimler and Maybach (1885) and Karl Benz (1885) both develop the first automobiles: lightweight, small, and quick form factors for the Berlin market.	The Oldsmobile Curved Dash becomes the first successful, mass-production car – the first to employ a reliable, scalable process, and also satisfy most users. Several competitors followed. (1901)	**REBEL ALLIANCE** Challenger: foresight (H2) Challenger: pre-adaptation (H4) Challenger: regulatory lag(H9)
CRYPTOCURRENCY MINING From online payments, creates a nonrival market	In 1982, David Chaum exapted crypto-graphic algorithms: "blind payments" for existing bank transactions. Anonymous "Wallets" compete with banks.	In 1988, Chaum launches Digicash: a system for anonymous bank account and bank transactions through the internet. Major banks and software companies fail to launch.	In 2008, an anonymous hacker, "Satoshi Nakamoto", launches an open source blockchain system for implementing a cryptocurrency. Several rebels for coin exchanges online; some also mine coin on a p2p network.	**REBEL ALLIANCE** Incumbent: discovery (H1) Challenger: alertness (H5)
LIGHT EMITTING DIODES (LEDs) From semiconductor diodes, creates a nonrival lighting technology	In 1907, Henry Round was working for Marconi Labs- the leading Radio communication firm. He discovered that radio crystal diodes emit light.	By roughly 1952, nearly all major incumbent firms in the semiconductor industry re-discovered the properties of light emitting semiconductor diodes, and began development of process technologies.	Texas Instruments becomes the first company to sell LEDs as indicator lights. Subsequently, a host of other incumbents enter the business.	**BLUE OCEAN** Incumbent: discovery (H1) Incumbent: dynamic capabilities (H3)
MEDICAL MARIJUANA From recreational marijuana, rivals traditional medicine	Folk medicine employed weak strains of natural cannabis for a very long time. Prohibitions began in the 20th century.	No insight lag – recreational users were already "self medicating".	No insight lag – as prohibition continued, recreational users were already developing greatly enhanced strains with medicinal qualities. By the 1970s, California activists distributed "brownies" for terminal patients.	**REBEL ALLIANCE** Challenger: Regulatory only (H8)
MICROWAVE OVEN From radar, creates a nonrival cooking technology	Invention of the Radar Magnetron John Randall and Harry Boot (1940). Raytheon becomes the first leading manufacturer.	Discovery by Percy Spencer at the military contractor, Raytheon. While experimenting with the magnetron, he noticed it melted a candy bar in his pocket. He developed the Radarange (1956)	After years of very slow launches in commercial kitchens, Raytheon finally acquires Amana in 1965, to help commercialize its microwave oven. The first Amana oven is a big hit (1967), but does not displace traditional cooking technologies.	**BLUE OCEAN** Incumbent: discovery (H1) Incumbent: dynamic capabilities (H3)
MOTORCYCLES From automobiles and bicycles, rivals all personal	"Safety" bicycles, automobiles, and motorcycles appear nearly simultaneously,	Edward Butler produced the Butler Petrol cycle in England. It had many technological	Two English bicycle startups pivoted (1902) to rally other firms and create the motorcycle industry's mass production	**BLUE OCEAN/REBEL ALLIANCE HYBRID** Challenger:

transportation methods	but motorcycles take the longest to sell.	advancements that helped define the industry, but no sales(1884).	designs and methods: Triumph and Indian Motorcycle Manufacturing Co.	Pre-adaptation (H4); double exaptation (H7)
ONE-WAY RADIO From laboratory electronic test equipment, rivals wired telegraphs and telephones	Radio is often conceived of as a discontinuity, but radio emitter features emerged from Hertz's electromagnetic sensors (1888).	Marconi starts a company to commercialize one-way radio communications, in 1897. After years of prototyping, he develops emitters and invents radio receivers for mass use.	Radio stations are the final technology bottleneck. The United States bans civilian radio during World War I. After the war, commercial radio stations are established (1920), and sell advertising to fund programs.	**REBEL ALLIANCE** Challenger: foresight (H2) Challenger: pre-adaptation (H4) Challenger: regulatory lag(H9)
HISTORICAL CASES	**FEATURE EMERGENCE**	**SELECTION (INSIGHT)**	**POST-ADAPTATION (BOTTLENECK)**	**MECHANISMS (HYPOTHESES)**
PERSONAL COMPUTERS From mainframe computers and personal calculators, rivals all computing devices	First description of a device adapted for personal management called a Memex. Vannevar Bush, As We May Think (1945)	The Mother of All Demos: The first simulated demo of a Personal Computer, including the invention of e-mail, the mouse, and the contemporary keyboard and screen combination – Doug Englebart, Stanford Research Institute (1968)	Bob Taylor assembled an elite team of researchers for Xerox Palo Alto Research Center (PARC). PARC invented many commercial standards for personal computing, but could not convince their bosses to launch. PARC eventually reveals prototypes to Steve Jobs for the Apple II (1976)	**REBEL ALLIANCE** Exapted from Mainframe Computing Challenger: foresight (H2) Challenger: pre-adaptation (H4)
PHONOGRAPH JUKEBOX From phonograph, creates a nonrival music device for public spaces	Thomas Edison develops the first phonograph in 1877 while looking for a way to record speech. His patent notes 10 uses for it, including to record and play music.	Edison spends years developing dictation machines, even selling 600 units to the United States Congress. He continually refuses to develop music devices, claiming they aren't "serious" technology.	Edison's challenger competition makes two minor adaptations: improving the quality of the recording media, and adding a coin operated feature. They launch the first jukeboxes in 1897.	**BLUE OCEAN** Exapted from dictation phonograph. Incumbent: discovery (H1) Challenger: alertness (H5)
SMALL MODULAR REACTORS From heavy nuclear reactors, rivals those reactors and other power sources	First nuclear power plant at University of Chicago: Chicago Pile 1 (CP-1). Enrico Fermi developed a test reactor (1942).	First true small form factor nuclear reactor developed-EGP-6, in Russia. Although some of the reactor's technology was rapidly obsolete. (1974)	Several Small Modular Reactor projects have been recently funded, in the United States and the United Kingdom. Only challengers have active projects, but incumbents are threatening to enter (2020 projected date of first commercial reactors).	**REBEL ALLIANCE** Challenger: foresight (H1) Challenger: pre-adaptation (H4) Regulatory lag past insight (H9)
SOCIAL MEDIA From bulletin board systems (BBSes) and e-mail technology, rivals traditional media	The concept of multidirectional distribution of semi-anonymous, semi-filtered media appears in Whole Earth 'Lectronic Link, or WELL system. This avatar-based bulletin board system was conceived by Stewart Brand and Larry Brilliant. (1984)	A very limited number of expert users can tolerate the bulletin board systems. But once the graphical version of the World Wide Web launches, entrepreneurs blend the concept of the "home page" with a social messaging board. The first commercial product is called Six Degrees (1997). It begins to pull customers away from platforms like America Online.	After several short-lived experiments, the first truly commercially successful social media website, Myspace, integrates the RSS feed (2003). The RSS feed is the last major technology bottleneck to a smooth social media experience. Facebook and Twitter enters soon thereafter. A large number of media and software companies miss the opportunity-such as America Online, Microsoft, etc.	**REBEL ALLIANCE** Exapted from Bulletin Board Systems Challenger: foresight (H2) Challenger: pre-adaptation (H4)
3D DESKTOP PRINTING From industrial 3D printers, rivals	The first additive tools for heavy industry, stereolithography, are prototyped in 1984 by	In 2005, University of Bath professor Adrien Bowyer develops an open source project for a small printer	In 2009, Bre Pettis and his partners launch the Makerbot cupcake, the world's first commercial desktop extruder.	**REBEL ALLIANCE** Exapted from Additive Manufacturing

some alternative methods of prototyping and small lot manufacturing	Charles Hull. However, 3d printing is treated as a niche industrial technology, so there is no attempt to make a mass market for low cost prototyping or home manufacturing.	than can make itself, and is ideal for rapid prototyping. The first style to be improved on by an engineering graduate student is called the Prusa, and becomes the most popular form factor. Most importantly, Bowyer makes the plastic extruder technology open source.	They complete the bottleneck by making an online hub for sharing digital designs and work loads. have continually improved the design, and have spawned an entire industry of copycats and rivals. Adrien Bowyer helps the company and invests in it. A wave of other challengers enter the market in 2010-2012.	Challenger: foresight (H2) Challenger: pre-adaptation (H4)

The twelve cases are: Automobiles, Crypto-Currency, LEDs, Medical Marijuana, Microwave Oven, Motorcycles, Phonograph Jukeboxes, Personal Computers, Wireless Radio Communication, Small Modular Reactors, Social Media, and 3D Desktop Printers. Since the reader is burdened with appreciating each case, Table 4 provides *minimum sufficient evidence*. Table 5 contains qualitative evidence of strong lags. Most of the lags here also appear in Agarwal and Gort (2002).

2.6 Confirmatory Case Results

All hypotheses match at least one confirmed case in Table 5. Every case reviewed provides some distinguishing characteristic from other cases, but none contradict the presented ICD model. Thus, this basic model presented here seems valid for integration into the Exaptation-Adaptation Cycle, and the ICD literature. However, the number of lags and scenarios is not analytically exhaustive, and could be expanded at multiple levels of analysis. In fact, a great number of the paradigmatic technologies addressed in the literature on *techno-economic paradigms* are radical exaptations, not discontinuous (Freeman and Perez, 1988). Future literature could examine how exaptations might form a series of rival and nonrival cascades (Lane, 2016); or family trees of and branches of exaptation tactics (Garud and Nayyar, 1994).

Economies of Scope and Exaptation Strategy. Let us consider how exaptation flows from economies of scope (Teece, 1980; Helfat and Eisenhardt, 2004; Faems et al, 2010). I contend that *exaptation opportunities of scope* provide a powerful mechanism for related diversification. But it is a mistake for a firm to only consider a safe quadrant –say, Blue Oceans – when any possible Rebel Alliance that might employ the technology will inevitably be found out. Thus, firms must always be prepared to displace its own installed base as well as its own technical standards and form factors – in the long run, nothing is sacred. Simply having scenario planning can help incumbents find the ideal moment to execute a “plan B, C, or D”.

2.7 Limitations and Future Directions

We shall touch on some of the ways this model can be expanded in future research. First, I must clarify two historical idiosyncrasies in this study that don’t alter the hypotheses but are important to consider. 1) Cryptocurrency and small modular reactors are cases in progress, so it may be possible that new variants of these technologies employ breakthroughs that prove to be disruptive. 2) War, and other such political externalities, often favor incumbents in an already incumbent-favored environment, such as for microwaves and one-way radio. In other words, such regulations could incidentally favor incumbents.

The biggest limitation of this study is a lack of conclusion about the case frequency, or true quantitative impact, of the Four Challenge Types or the Ten Hypotheses. For example, most of the sampled cases explored fell into rival, challenger winning scenarios. While it may be tempting scenarios like H:2 and H:4 more common that nonrival ones, the sampling method used does not permit such a conclusion to be drawn. This small case study methodology is insufficient for a frequency or breadth study, only for theoretical validation and saturation. Measuring relative frequencies of each case in history would require an extensive database – an excellent next step for future research.

Future work should consider how innovation challenges differ at different levels of the design hierarchy (Clark, 1985; Andriani and Carignani, 2014) might be different. Many additional scenarios could subdivide the detailed innovation tactics specific to stages of exaptation. Finer grained analyses could explore how open innovation and curation (Laursen and Salter, 2006; Mitnick and Ryan, 2015) positively accelerates radical innovation.

This paper assumes that user base rivalry is an exogenously determined phenomenon. But alternative methods, such as simulation models, can use endogenous mechanisms to generate rivalry. *Industry convergence*, whereby user bases of multiple industries converge, is a common phenomenon for both exaptation and non-exaptation innovation scenarios – and, convergence appears to be increasingly common over time (Kim et al, 2015). Indeed, the biological concept of *structural degeneracy* is analogous to the way exapted technology can evolve to also meet the requirements of the old user base (Bonifati and Villani, 2013; Geels, 2005).

Conclusion. This new matrix of Challenge Types clears up confusion about which historical industries were born of what strategic process; and, how two of the four quadrants evolve in a multi-phase, time-lagged, Exaptation-Adaption cycle. In both rivalrous and nonrivalrous cases, incumbents might miss opportunities for reasons of attention (Ocasio, 1997). If any true advantage comes from the first access to the debut technology, then incumbents clearly have it in exaptation situations; but, if any true advantage can come from dissatisfied users, then challengers are likely to satisfy their wants with a new user base. Moonshots are up for grabs for consortium members.

3.0 Promethean Cliques, Mercurian Communities: A Configuration Approach to Industry Emergence

One of the classic elusive problems in the strategy literature is the identification of a consistent *configuration of strategic behaviors* (Miller, 1986; Ordanini, Parasuraman, and Rubera, 2014) by which firms attain market leadership in emerging industries. We know that successful early entrants find and capture first-mover advantages (Lieberman and Montgomery, 1998; Agarwal and Bayus, 2004; Agarwal and Gort, 2001; Romanelli, E., 1989) – herein referred to as FMAs, for short. This extensive literature has focused how entry timing correlates to firm survival. Scholars are in broad agreement that FMAs *can* be established, and are closing in on a timing model of *when* to enter an industry to maximize chances of locking in market leadership. But, the literature has not settled on a strategic theory and/or practical method of *how*.

Founder capabilities are not enough. The interest in entry timing was an attempt to expand beyond the capabilities-based view of founding team success. Many recent studies looked at firm founder's personal capabilities prior to market entry (Colombo and Grilli, 2005; Davidsson and Honig, 2003). They found that founder capabilities, including social ties and talent, have a weak relationship to firm success, and the interaction variables are often the strongest. Exceptional personal capabilities are not necessarily translated into market-leading firm capabilities in some *ceteris paribus* fashion, just as a talented driver cannot race an automobile missing one wheel.

Theorizing proofpoints as necessary conditions. New firms must seek venture capital to produce a resource base, and the founders must convince investors of their total preparedness for capturing value (Brush, Greene, and Hart, 2001). Managers must produce *social proof* (Petkova, Rindova, and Gupta, 2013; Pollock and Rindova, 2003; Rao, Greve, and Davis, 2001; Rao, 1994) of their readiness for sales takeoff in an emerging industry – they need to win product/quality awards, win relationships, and win the overall industry narrative. Hallen and Eisenhardt (2012 p. 46) called these conjoint sets of social certifications:

"…*proofpoints* [emphasis added] as positive signals of substantial venture accomplishment of a critical milestone that is confirmed by key external (not internal) actors." While no two venture capital firms agree on the specific proofpoints a firm must satisfy to secure venturing, this essay argues that some set of conditions may, in fact, be overwhelmingly necessary for attaining a leading market share. Obviously, some proofpoints signal technical success, and others signal social legitimacy (Plummer, Allison, and Connelly, 2016), but theory should predict the best set of signals to use.

Why Processor Technology failed and Apple succeeded. Consider the unlikely success of Apple as compared to 1976's other "golden child" of microcomputing, Processor Technology. While they each had "good enough", or satisficing proofpoints to commercialize 8-bit computers for the lead user market, Apple showed the proofpoints for sales takeoff.

On the technical side of the business: Apple's genius product designer, Steve Wozniak, contributed several groundbreaking innovations to the product; and, Wozniak's connections to Homebrew Computing Club put them in an elite club of insider community knowledge about the future of microcomputing technology (Freiberger and Swaine, 2000; Furnari, 2014). But consider that Processor Technology's design guru, Lee Felsenstein, was the leader of the club, and every bit as talented as a designer. Overall, Felsenstein could bring at least as many capabilities necessary for founding a leading microcomputer firm, if not more.

On the market-facing, "social" side of the business: Apple had the young but fanatical Steve Jobs driving the company strategy. Jobs' relentless drive to convert the microcomputer into a personal computer led him to fearlessly build necessary relationships. He drew on youthful experiences with the incumbent and the startup side of the computer industry, respectively at Hewlett-Packard and Atari. Jobs also had a good understanding of the wants of the early majority consumer across "the chasm" (Moore, 1999; Rogers, 2010). Jobs honed-in on a category-defining design for the Apple II by imitating design aspects of the blockbuster appliance, the Cuisinart. However, most experts of the moment predicted that Felsenstein, Gary Ingram, and Bob Marsh had all the same advantages for extending Processor Technology's sales leadership of late 1976 (Freiberger and Swaine, 2000; Issacson, 2014). They had enviable social connections, elite design, and access to lead users. In short, both firms had all capabilities necessary to launch a pioneering product for the first customers.

Apple's scalability. But Apple stood above the earliest entrants because they put together the next set of necessary capabilities to scale the business for early adopters. Apple pulled every string in Silicon Valley to leapfrog Processor Technology's production capabilities in 1977. Their benefactor, Mike Makkula, staffed the company with experienced directors and executives (Veit, 1993). Meanwhile, Felsenstein and company struggled to establish a suitable supply chain, resulting in disastrous product recalls, and a failed attempt at *quality leadership*. No customer felt safe ordering a second-generation Sol computer because of high disk drive and motherboard failures. Interestingly, Felsenstein continued his own illustrious product development career after the Sol's demise: he designed the highly celebrated Osborne 1 (1981), the #1 portable computer during sales takeoff. According to Felsenstein's boss, Adam Osborne:

> "Technology had nothing to do with Apple Computer Corporation's success; nor was the company an aggressive price leader. Rather, this company was the first to offer real customer support and to behave like a genuine business back in 1976 when other manufacturers were amateur shoe-string operations."(Osborne and Dvorak, 1984, pg. 11).

The necessary conditions approach. As demonstrated in this example, first mover firms cannot ride out a single competitive advantage: they must complete *a full set of necessary conditions*. Shane and Venkatraman (2000) pointed out that discovering a timely opportunity is, of course, necessary; but, knowing is only half the battle, at best. A few studies have used a "necessary condition" approach to industry evolution (Bol and Luppi, 2013; for dominant designs, see Lee, O'Neal, Pruett, and Thomas, 1995; for international business startups, see Phelan, Dalgic, Li, and Sethi, 2006). However, prior work has neither tested for a "necessary conditions" model of market leadership, nor has used proofpoints as their necessary conditions.

Explaining the first two leadership cohorts. Literature has identified four early waves of participation in emerging durable goods industries: pre-commercialization, pioneering commercialization, firm takeoff, and sales takeoff (Golder and Tellis, 1993; 1997; 2004; Chandy and Tellis, 1998; 2000; Agarwal and Bayus, 2002; 2004). Most timing papers focus on how pioneers and firm takeoff participants impact market leadership across the longer, and extremely profitable, sales takeoff wave. This paper takes the historical perspective of Langlois's (1992) classic breakdown of all the successive product waves for a new industry – i.e., microcomputers. The industry founders must develop the institutions and relationships that a mere product category innovator does not, including making the new industry cluster. Evidence suggests firms entering during firm takeoff are more likely to sustain category dominance than the earliest wave of pioneers, or later entrants (Markides and Sosa, 2013; Suarez et al., 2015); and, that the pioneering wave has a very high fatality rate.

Pioneering commercialization: the Promethean Phase. During pioneering – what I call the Promethean Phase – a startup must complete a full configuration of six *Promethean proofpoints* to launch an early leading product. I argue that a *Promethean Clique* – PQ for short – is a cohort of socially connected firms responsible for collective invention (Cowan and Jonard, 2003; Allen, 1983) of the new industry. I propose that clique members must have six minimum necessary conditions to be among the leaders in market share during the Promethean Phase. Firms lacking any of the six Promethean proofpoints will not have a significant share of the dominant product category sales and must use a niche strategy instead. Furthermore, PQ firms usually fail to create leading second-generation products because early focus on lead users is an *identity trap* (Bouchikhi and Kimberly, 2003).

Firm Takeoff: the Mercurian Phase. I refer to the firm takeoff window for sustainable FMAs as the Mercurian Phase. The name of the Mercurian Phase reflects the fleet-footed race among entrepreneurs to build a firm worthy of producing a multi-generational product line, and perhaps a future dominant design (Suarez and Utterback, 1995). I call this period's market leaders a *Mercurian Community* – or, MC for short. This cohort of firms locks in FMAs by achieving a full configuration of *Mercurian Proofpoints*.

Thesis: **Two sequential configurations**. In summary: the task of this essay is to theoretically and empirically distinguish the Promethean from Mercurian market leaders. I confirm two propositions: 1) Promethean leaders typically are stuck meeting the conditions for lead user market leadership; 2) Mercurians meet the conditions necessary to lead at a mass scale – and they are usually different firms but contain actors with Promethean experience.

Methods. This essay employs Crisp-Set Qualitative Comparative Analysis (CQ-QCA) to test a recurring pattern of demarcation between two cohorts. I draw boundaries on this initial model by focusing on a subset of Schumpeter Type I industries – particularly, those formed by commercialized new consumer durable versions of incumbent technology. I do not generalize this strategy to Mark II industries or nondurables/cultural goods. To show that the strategic sequence is not a historically specific occurrence, I test across three different eras of paradigmatic innovation: automobiles, microcomputers, and 3d desktop printers.

The paper proceeds as follows: Section One covers key definitions for Promethean and Mercurian Phase analysis, derived from prior literature. Section Two is a synthesis of six three-stage emergence models in the literature, pointing to Six Promethean and Six Mercurian proofpoints that certify market leadership. In Section Three I discuss each of the proofpoints, using examples from the three industries. Section Four covers the CS-QCA methodology and sampling method. Section Five reports the results of a confirmatory test for the necessary configurations of Promethean and Mercurian market leadership. I confirm this *Rebel Alliance Model* fits for the three Schumpeter Type I industries. Finally, in Section Six discusses limitations to the model, and directions for future research, such as "sufficient" proofpoints for equifinal strategic paths (Fiss, 2007; 2011; Rihoux and Ragin, 2008).

3.1 Definitions and Boundary Conditions

This section covers key definitions, boundary conditions, and illustrative examples of how some industries evolve according to a canonical sequence of phases. Refer to Table 6 for how the proposed proofpoints line up with classic literature on first mover advantages and network externalities. Refer to Figure 5 on page 77 for the list of leadership cohorts used in this study.

Four Emergence Phases. The entry timing literature has placed emphasis on four successive waves of actor participation during emergence (Agarwal and Bayus, 2002;2004; Chandy and Tellis, 1998; 2000).

First, entrepreneurs begin their inventive search during pre-commercialization. Research on this period can help explain how individual entrepreneurs find the initial starting conditions for enabling Promethean entry. Second, scholars have repeatedly identified pioneering commercialization (Agarwal and Bayus, 2002) as

Table 6: First Mover Advantages and Proofpoints

THEORY	**"TRIPARTITE INVESTMENTS" IN PIONEERING CAPABILITIES** (Chandler, 1992; Mowery and Nelson, 1999)	**FIRST-MOVER ADVANTAGES** (Lieberman and Montgomery, 1988; Kerin, Varadarajan, and Peterson, 1992)	**CONSUMPTION AND PRODUCTION NETWORK EXTERNALITIES** (Katz and Shapiro, 1985; 1994; Farrell and Saloner, 1985; Economides, 1996; Arthur, 1989)	**PROOFPOINTS** (based on the prior columns and a fuller review of the literature in this essay)
MECHANISM	(Social) management	Reputational Advantages	Path dependent imprint of brand and industry practices	**Institutional leadership**
MECHANISM	(Technical) management	Switching cost advantages	Installed user bases and loyalty advantages in business models	**Business model leadership**
MECHANISM	(Social) marketing	Preemptive locations and factor market relationships	Network economies, especially spillovers from cluster location	**Network leadership**
MECHANISM	(Technical) marketing	Product differentiation	Superior bundles of features backed with clever sourcing	**Product category leadership**
MECHANISM	(Social) manufacturing	Process management and learning curve	Lower manufacturing costs and higher product reliability	**Process quality leadership**
MECHANISM	(Technical) manufacturing	Technical standardization	Industry lock-in to intellectual property and expertise	**Standards leadership**
UNIT OF ANALYSIS	INVESTMENT Entrepreneurs invest in capabilities in the hopes of FMAs	FIRST MOVER ECONOMIC BENEFIT If investments are successful, they result in early FMAs	NETWORK ECONOMIC BENEFIT FMAs are a special case of generic network externalities; some followers attempt to imitate first mover advantages	**CERTIFIED STATUS** **Firms who can achieve a *full configuration of statuses* at sales takeoff can "lock in" leadership for the long run. Proofpoints are "Social proof" of capabilities.**

the phase when an initial wave of "barely functional" products are targeted and sold to the most fanatical and risk-taking lead technology users. Some industries form a Promethean Clique (PQ) of market leaders in this Promethean Phase. Third, scholars define firm takeoff as the window when a wave of firms aggressively compete for lock-in advantages and proprietary standard setting (Lieberman and Montgomery, 1998; Langlois and Robertson, 1992). The fourth wave, sales takeoff, has been identified as the beginning of a product standards battle between top firms, and usually ends with one or more dominant designs. Alternatively, some models identify this period as the early growth phase which competes for the early majority, and the dominant design period as the late growth phase that attracts the late majority into the industry (Langlois, 1992). Mature competition thus deals with managing the interests of all users, including drawing in the remaining resistors, and reaching full global penetration into developing markets. Evidence suggests that market share remains very stable after sales takeoff, with only a couple of later large challengers upsetting the balance of power (Chandler, 1992); therefore, the primary research question for emergence has been to identify how early entrants sustain advantages throughout sales takeoff (early growth) when category standards are set (Suarez et al., 2015) – and even perhaps into the dominant design, which frequently incurs a firm shakeout and a last-minute shift towards a cost war that decimates the "middle" (late growth). This essay surveys the literature on the structural break between the Promethean Clique (PQ) and the Mercurian Community (MC), and checks evidence.

Boundary conditions: Rebel Alliance Strategy (RAS). The three cases herein focus on one typical sequence for Schumpeter Mark I industry birth (Malerba and Orsenigo, 1995). In Mark I, industry birth is frequently driven by individuals working for incumbents. These entrepreneurs see an opportunity to commercialize technology. The incumbents themselves resist rather than encourage these markets. For example, nearly all microcomputer founders began as young, disgruntled employees of major tech firms, or entrepreneurs from elite university settings (Freiburger and Swaine, 2000). The industries used to illustrate the RAS are all consumer durable goods. Future work can check if other sectors (media, software, etc.) imitate the RAS.

Radical Exaptation and the RAS. In the industries addressed herein, leading startups captured an opportunity for *radical exaptation* of underapplied technology to a new purpose (Andriani and Carignani, 2014). Andriani and Carignani defined radical exaptation as the lateral adaptation of an existing technology to the purpose of creating a new industry of products. A popular example is the magnetron, a device that began as a radar component but became the heating element of microwave ovens. Their Three-Phase model of radical exaptation aligns exactly with this author's proposed Athenian, Promethean, and Mercurian phases.[7]

Radical exaptation as a group practice. Radical exaptation has also been described by Henderson and Clark as (1990) *architectural innovation* – an industry-defining innovation driven by market opportunities underserved by all the existing technical possibilities. The combined result is both an architectural product/process innovation – i.e., the new dominant product category – and a new industry value chain (Henderson, 1993; Levinthal, 1998).

Of course, needs are underserved when incumbents resist serving them. So, the RAS model doesn't quite work for incumbent-driven industries like the microwave. Raytheon, a military contractor, practiced Schumpeter Mark II invention by pioneering the microwave itself and building the market for it. The necessary conditions presented in this paper thus can only apply where a wave of Promethean new entrants cooperate and practice some extent of collective invention (Allen, 1983) to jointly set industry standards and institutions.

Value creation versus value capture. Promethean strategies focus on *value creation* to bypass the conservative forces of large organizations; but open sharing is not an ideal strategy for *value capture* (Amit and Zott, 2012). Mercurian startups "cross the chasm" (Moore, 1999) by developing a value capture strategy. I refer to this emergence sequence as the Rebel Alliance Strategy, or RAS for short. The name of the strategy is in reference to D'Aveni's (2002) article about incumbent defense strategies, entitled "The Empire Strikes Back". The RAS is a strategy for overcoming incumbent resistance to the very existence of the new industry.

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[7] Athena and Prometheus were Greek gods, but Mercury is a Romanization of Apollo. This changeover in myths is on purpose: the first two periods were motivated by knowledge and innovation for its own sake, and are primal fields of activity. But from that point forward, all business activities across the lifecycle are directed towards capitalist competition; thus, I recommend using Romanized terms from Mercury onward. I would also suggest using the term Marsian for firm takeoff, as it is a period characterized by aggressive "battles" for standards and stakeholders. For the later growth period associated with the struggle against one firm's dominance, I would label the period, Jupiterian; for oligarchic maturity, Ceresian; and, for decline, Plutonian. This nomenclature encourages a proliferation of mythic Greco-Roman terms for the convenience of educators and practitioners of capitalism, but I encourage scholars to adapt these concepts into any world system of mythology desirable for local audiences.

RAS industries. Personal computers were based on components from the existing calculator and mainframe computer markets (Issacson, 2014). Experienced entrepreneurs created the automobile industry with architectural innovations derived from many existing technologies: carriages, bicycles, machine tools, mechanical engineering theory, and engine niche markets for small locomotives, boats, and custom industrial devices (Carrol, Bigelow, Seidel, and Tsai, 1996). 3D desktop printer tinkers employed off-patent additive manufacturing parts and simple mechanical parts (West and Kuk, 2016). Automobiles, personal computers, and desktop 3D printers were thus all exapted from other industries by ambitious "hackers" (Issacson, 2014) – the most inventive lead users of incumbent technology.

The challenger's motive in radical exaptation. The literature sometimes assumes a challenger is a wholly new venture in direct contrast with an incumbent; however, this is an inaccurate assessment of the dynamic. Most challengers who succeed at a sales takeoff rely on employees, investors, and/or board members with powerful incumbent experience with managing large scale operations (Klepper, 2003; 2007; Agarwal et al, 2016; Echambadi, Bayus, and Agarwal, 2008; Baum and Silverman, 2004). Such managerial knowledge is developed in secretive settings. So the legal firm entity may be new, but if it is sizeable (a large startup) in a short period of time, the capabilities driving it must be old. This paradox helps explain Mercurian market leaders.

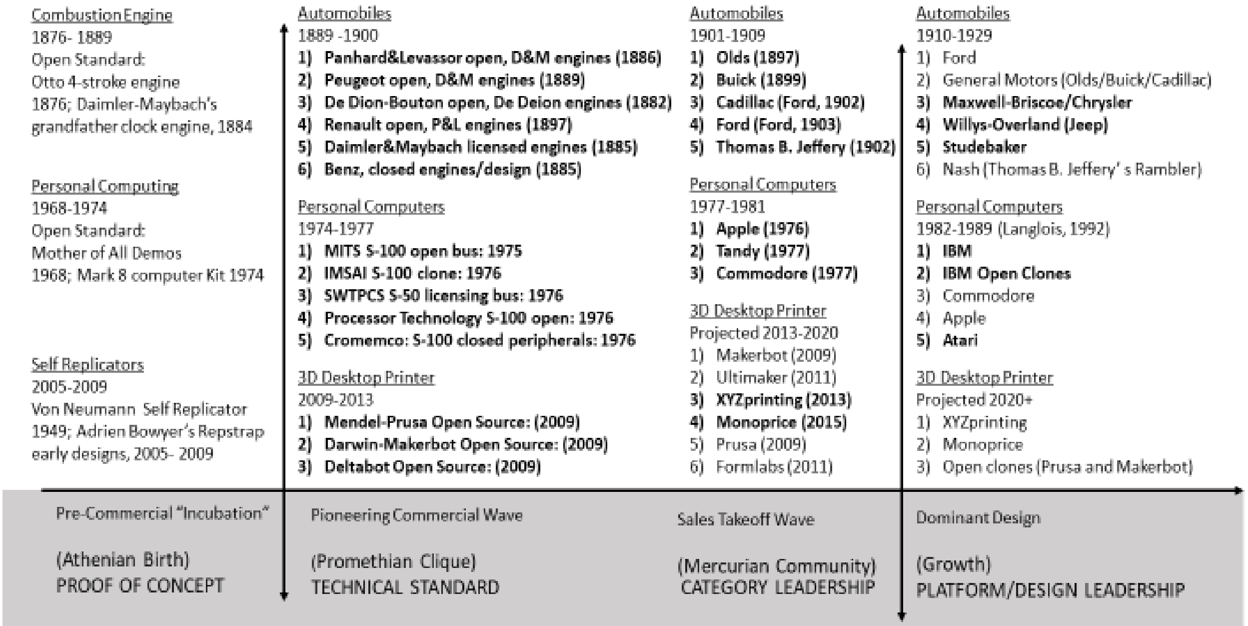
Buick: a story of several starts. For example, in the United States, all the leading Mercurian automotive startups, such as Buick, made use of knowledge, resources, and talent from related incumbent industries. David Dunbar Buick first ran an industrial engineering company, Buick Auto-Vim and Power Company. One of his engineers, Walter Marr, created his first automobile prototype in 1899. D.D. Buick resisted entering the new market at first. After a few false starts, D.D. Buick finally started the new Buick Motor Company in 1904. He used elite engineering talent from machine tools and carriage industries to create high quality vehicle designs (Dunham, 1987). Still, his first version of the firm wasn't competent to scale up. Buick's fortune really took off when they went into business with the wealthy William Durant (Miller, 2015; Flink, 1990).

The world's largest carriage maker at the time, Durant saw that the carriage market was likely to permanently crash. Believing the "horseless age" was nigh, Durant redeployed his old carriage-making facilities to convert Buick from a fledgling engineering shop to a large-scale automotive operation. By combining his manufacturing know-how with Buick's engineering talent, they were able to make a superior, "instantly large" startup.

Realizing the huge importance of scale economies, Durant didn't stop there. In late 1908, he went "all in" to the automotive business and abandoned carriages. He formed General Motors by consolidating 20 parts and auto assemblers, including three of the five leaders: Olds, Buick, and Cadillac. In this light, we can see that a "defending incumbent" is merely an organization that stays fully committed to the old regime (Chandy and Tellis, 1998). An "experienced new entrant" like Buick brings resources and capabilities to a Mercurian phase of competition to prepare for a sales takeoff (Klepper, 2007). All the Mercurian firms in Figure 5 have similar stories of combining "new" with "old".

Pre-emergence: Athena's Birth. The earliest phase of analysis is when tinkering inventors try out the first pre-commercial technologies for a nascent industry – before any product is sold. Agarwal, Moeen, and Shah (2017) refer to this period as Athena's Birth. In many high-tech industries, incumbents develop the first technologies for a new industry; thus, they act in accordance with Schumpeter Mark II predictions, and largely shut out small challengers from achieving market leadership. Mark II examples of radical exaptation include: the microwave; videocassettes (VHS); smartphones; and, light emitting diodes, aka LEDS, which sprang from semiconductor diodes, aka printed circuits.

Schumpeter Mark I conditions occur when incumbents suffer from inertia and/or resist cannibalization (Chandy and Tellis, 1998; 2000). Founding teams of small firms overcome barriers by tinkering in the pre-emergence phase, and participating in lead user innovation (Von Hippel, 2005). This essay shall make no new predictions about how pre-emergence impacts the subsequent two phases; but the period shall be explained to distinguish it from later periods.



Bold Text denotes new entrant during that wave. Date of entry is listed next to each early entrant.

Figure 5: Market Leader Cohorts by Phase of Emergence

Moving from Athena to Prometheus. Let us consider how automobiles were commercialized. Nikolaus Otto's 1876 4-stroke cylinder engine was made famous at the Paris World Fair. Otto's design was intended for industrial usage, but proved to be the critical Athenian technology that inspired his former employees and associates to attempt a commercial combustion engine that would enable an automobile prototype. Gottlieb Daimler and Wilhelm Maybach left his firm to commercialize the first such engine, in 1885; Karl Benz and other rivals attempted the same stunt. Furthermore, all would-be entrepreneurs in that time and place were impacted by the ideas of Franz Reuleaux, the father of kinematic mechanical engineering theory (Moon, 2014). Reuleaux enabled the rapid development of standardized mechanical parts for any industry. The Paris-Berlin auto cluster was a hotspot of Reuleaux-inspired engineers. Thus, the race for leadership begins with connections to central figures in sociotechnical movements (Hess, 2005).

Commercialization is a contest for glory among the lead user market, more than profit. In Schumpeter Mark I industries, firms must collaborate to construct the new industrial community (Van de Ven, 1993). Many small, resource-poor startups are motivated by their personal interests in the technology. Participants rapidly build their own language to describe the technology and exapt meanings, materials, and actors from related incumbent industries to construct the new technological frame (Kaplan and Tripsas, 2008). Therefore, the first leadership cohort focuses heavily on a cooperative strategy of creating shareable institutions – meaning-making activities (Furnari, 2014; Mitnick and Ryan, 2015), technology standards, product categories, trade organizations, etc., designed to attract lead users and informal/formal interfirm alliances. Pioneers in such a lead-user-oriented environment rely on personal networks and open standard-setting to establish initial supply chains, rather than attempting vertical integration (Langlois, 1992). The first wave products are short-lived and come in small batches; thus, the first product is merely a way to organically raise funds (Aldrich and Fiol, 1994; Zimmerman and Zeitz, 2002).

Promethean horseless carriage makers in Europe took advantage of the first generation of "kinematic engineers" –experts of modular and standardization designs in machining – already locally employed by machine tool makers, bicycle makers, and engine makers (Moon, 2014; Carroll et al, 1996). Some scholars claimed the later Detroit automobile cluster did not use university networks (Klepper, 2007), and instead drew on the expertise of many private engineering firms. But other scholars stress how the earlier Paris-Berlin cluster sprang from elite tech schools (Flink, 1990; Moon, 2014), and private carriage and bicycle makers worldwide improved their skills with kinematic theory. Sociological scholarship has explicated an extensive lead user involvement for early automobiles (Franz, K., 2011; Kline and Pinch, 1996).

The Promethean microcomputer makers took advantage of the first generation of university-trained computer engineers interested in personalizing machine-human interface and useful hacking. Most microcomputer engineers initially trained themselves on consumer electronics, telecommunications, mainframe computers, and calculators (Freiburger and Swaine, 2000; Levy, 1984; Frenken, Saviotti, and Trommetter, 1999). Promethean firms had an extensive lead user market they could target with their initial designs, such as the Homebrew Computer Club.

Promethean 3D desktop printer makers took advantage of the first generation of university-trained additive manufacturing engineers with interest in open source and peer-to-peer innovation ideas, on the heel of digital CNCs, industrial lithography, and laser printer technology (Kostakis and Papachristou, 2014; Rifkin, 2014). The epicenter of the action was Adrien Bowyer, engineering professor at University of Bath. Bowyer created an open source project and community, reprap.org, for developing the world's first desktop sized 3D printers. The documentation of that activity is preserved online at *reprap.org*. As much today as in the 19th century, universities are key interorganizational networks (Kauffeld-Monz and Fritsch, 2013).

A Promethean Clique (PQ) is defined herein as a Small World (Watts, 2004) network of leading challengers who co-create the institutions necessary to complete a pioneering wave of commercialization. In other words, only those firms who make it into this PQ will be the (short-lived) Promethean market leaders. These pioneering actors dominate the social certification process of each other and any would-be pioneering entrants. They are called Prometheans because, as aforementioned, they use radical exaptation (Andriani and Carignani, 2014) to "steal fire" from the incumbent "gods"; but, they do so in a sacrificial manner, since their firms are unlikely to survive. The commercialization wave is predominantly a matter of creating the opportunity for Mercurians to exist (Alvarez, Young, and Wooley, 2015; Alvarez and Barney, 2007; Durand and Khaire, 2017). Ultimately, nearly all Promethean firms are among those "first to fail" (Tellis and Golder, 1996) from the emerging dominant category.

Prometheans surviving as niches or rebirths. Prometheans may survive in small niches even though they lose the contest for market leadership. Consider how early auto firms like Panhard & Levassor survived by focusing on luxury and racing vehicles (Flink, 1990). In the United States, the pioneering Promethean, Charles Duryea, was forced to start new firms three times and never captured a significant market share. However, Henry Ford dabbled with two Promethean firm failures. Like Duryea, Ford's first two firms failed quite rapidly. But, his third (Mercurian) firm, Ford Motor Company, developed a car that was to become the dominant design, the Model T.

Failed Promethean Cliques. Some cliques fail for committing to the wrong technology. For example, Albert Pope was central to an 1890s attempt at a New England electric car clique. Pope focused on promoting his electric cars as ideal for short-distance leisure travel. But dominant status emanated from the Paris-Berlin gas combustion clique, dating back further to 1885 (Geels, 2005). Some early American tinkerers, such as Charles Duryea (1896), re-imagined American cars as a long-distance technology and began importing Daimler-Maybach combustion engines for that purpose. As the center of action shifted from Europe to the United States, the imported combustion clique rapidly overtook the early New England electric car clique. By 1909, the global market leaders were all American Mercurian firms producing combustion vehicles.

Firm takeoff: The Mercurian Period. Firm takeoff is a competition to attract resources and overall dominance (D'Aveni, 1999). In stark contrast to the cooperative spirit of the Prometheans, the second wave of product introductions is competitive and takes place in a very compressed amount of time. Firms jockey for top position by defining the competitive strategy and truly wowing skeptical audiences, just in time to raise funding for exponential growth and more extreme economies of scale/scope (Chandler, 1992). Since sales takeoff is a mass production phase, firm takeoff is the dress rehearsal for mass production. In preparation firms attempt to establish all the necessary institutional statuses for lock-in (Aldrich and Fiol, 1994; Lieberman and Montgomery, 1998) and platform leadership (Gawer and Cusumano, 2002).

A Mercurian Community (MC) is a group of leading firms embedded in the expanding network of dedicated trade and media institutions, seeking all market proofpoints for winning firm takeoff. Nearly the instant the PQ constructs industry institutions and open technology standards, the MC converts these advances into proprietary advantages, for profit and revenue. This dynamic of Mercurian "piracy" of the publicly accessible PQ knowledge was the topic of the film: "*The Pirates of Silicon Valley*" (1993). Candidate leaders of an MC attempt to establish proprietary industry standards and practices for FMAs (Aldrich and Fiol, 1994). Byrd (1992) encouraged the use of Mercury as a metaphor for the growth entrepreneur. According to Byrd (1992, Abstract):"…[A Mercurian] focuses on appetite, vision, changeableness, fast action, and networks at the individual level and on economic chaos at the social level." It is also noteworthy that niche entrants during the Mercurian period do well on the high end of the market

– such as H.H. Franklin's line of Franklin luxury cars (Early, 1956). The luxury/high-end market often sustains regional niches for years, such as Franklin at Syracuse, NY and surrounding cities.

A note on dominant designs and sales takeoff. The IBM PC, debuted in 1982. The PC architecture is usually used as the example of the dominant design for personal computers, and the inflection point for sales takeoff into the mainstream. Langlois (1992) discussed how Apple, Tandy, and Commodore established their personal computer leadership of the dominant category in 1977, five years *prior* to sales takeoff. Interestingly, these three MC firms subsequently held on to leading positions for some years *after* IBM introduced its dominant PC architecture. Not only that, but the PC architecture borrowed so heavily from the MC firms, helping to legitimate them as rivals. Thus, even though sometimes the dominant design is created by a firm that enters after the Mercurian Period, the MC is expected to stay among the oligarchs.

Why enter early? Some scholars have fretted to explain why anyone bothers to start a Promethean firm. Simple: people don't die when companies do. While firms might not survive, individual pioneering participants have strong personal incentives to participate as entrepreneurial lead users (Lakhani and Wolf, 2003; Von Hippel and Von Krogh, 2003). Inventive lead users benefit greatly by participating in shaping the first rules, technologies, and relationships (Von Hippel, 2005; Lettl, 2007; Lettl, Herstatt, and Gemuenden, 2006; Srinivasan, Lillien, and Rangaswamy, 2004). First wave firms tend to lack business acumen for large-scale operations and make many severe business mistakes; but individuals gain invaluable experience. Incumbents with greater business acumen tend to wait, preferring to use a "fast second" business model (Markides and Geroski, 2004; Markides and Sosa, 2013).

3.2 Building the Rebel Alliance Model

This section will present a synthesis of prior work on FMAs and the temporal sequencing of industry emergence. To build the Rebel Alliance Model – a model for testing the theory of the RAS – Table Seven (p. 90) presents a literature review for the six parallel certification processes of the firm leadership cohorts from Figure 5 (p .75). I then propose six leadership proofpoints for the PQ, and six leadership proofpoints for the MC.

Alfred Chandler and early market leadership. Alfred Chandler (1992) has, perhaps, the most succinct explanation of why and how early market leadership has always been a goal to establish the right configurations ahead of competitors. From page 82:

“ The first firms to make the three-pronged investments in manufacturing, marketing, and management essential to exploit fully the economies of scale and scope quickly dominated their industries. Most continued to do so for decades. The tripartite investment by the "first movers," as I term them, provided a base upon which managers and workers learned the potential of the new technologies and the ways of improving processes of production and distribution. Challengers had to construct plants of comparable size and do so after the first movers had already begun to work out the bugs in the new production processes. The challengers had to create distribution and selling organizations to capture markets where first movers were already established. They had to recruit management teams to compete with those already well down the learning curve in their specialized activities of production, distribution, and (in technologically advanced industries) research and development. Such challengers did appear, but only a few of them.”

However succinct Chandler’s explanation, it does not provide for a set of measures for the subsequent attainment of market leadership. Since then, a great deal of work has explained each FMA independently. Therefore, I focus on summarizing the literature that fits with Chandlers’ insights (1992). But next, I address alternative models that are close but not quite fitting.

Alternative model #1: Five trust factors. Scarbrough et al. (2013) found a somewhat similar list of “trust factors” for early venture relationship. They argued for five dimensions: Institutional signals, position in social networks, credible (technical) competence, actor relationships, and information exchange. The terminology of this list is best suited for studies on the individual level of analysis, and thus is not best to explain the firm level of proofpoints. The list also misses out on the importance of separating product design, process quality, and technical standards. Other work can examine if a multifactor model on the individual level explains firm formation.

Alternative model #2: Four breakthroughs. Buisson and Silberzahn (2010) proposed a model of “four breakthroughs” for achieving market dominance: technical, business model, design, and process breakthroughs. However, this model neglects the network and cognitive leadership dimensions, and

Table 7: Literature Support for the Rebel Alliance Model

LITERATURE:	**ATHENA'S BIRTH (Agarwal et al. 2017)** **"Pre-Commercial" Prototyping**	**PROMETHEAN PHASE** **"Commercialization" First Entry Window**	**MERCURIAN PHASE** **"Firm Takeoff" Second Entry Window**
ENTRY TIMING THEORIES	Literature supports Mercurian entry for future market leadership in durable goods, and Promethean entry for individuals seeking long term notoriety and free expression.		
CONFIGURATION PROPOSITIONS		**SET PROPOSITION 1: A full PQ configuration confers a short-term leadership for the Mercurian Phase**	**SET PROPOSITION 2: A full MC configuration confers Mercurian leadership, but also sustained FMAs throughout sales takeoff**
SOURCES Lilien and Yoon, 1990; Agarwal and Bayus, 2002; Rao, 1994;2004; Santos and Eisenhardt, 2009; Suarez, Ghodal, and Gotsopoulos, 2015; Zachary et al. 2015; Golder and Tellis, 2001; Bayus, Jain, and Rao, 1997; Audia and Rider, 2005; Reid and De Brentani, 2010; Eckhardt and Shane, 2003	Invention: "Having the Dream" Actors invent technologies that enable a path towards a commercial product, thereby drawing the attention of other would-be entrepreneurs	Pioneering Commercialization: "Having the Vision" Firms cooperate to share ideas and set standards for the first product designs. A clique forms around the world's most engaged and talented inventors. Those projects "certified" as attractive by the small-world leaders are most trusted by lead users.	Firm Takeoff: "Having the Will" Several products explode into mass production, as frontrunners claim, demarcate, and control a "certified" dominant category by trade media; demand coalesces around a few superstar companies. Firms compete in certification contests.
SOCIAL EXAPTATION THEORIES	Social sequences for exaptation are specific to the Rebel Alliance Strategy; business model leaders capture public attention, becoming industry role models in social events.		
BUSINESS MODEL LEADERSHIP PROPOSITIONS		**PQ1: Promethean Leaders create industrywide events, stoking conversations with early stakeholders about best business model practices.**	**MC1: Mercurian Leaders dominate in trade show presence. These forums are ideal for conversing with all stakeholders about business models for capturing early adopters.**
SOURCES Zott and Amit, 2010; Garud, Gehman, and Guiliani, 2016; 2018; Jacobides, M.G., Knudsen, T. and Augier, M., 2006; Rinallo and Golfetto, 2011; Andriani and Carignani, 2014; Dew, Sarasvathy, and Venkatraman, 2004; Downes and Mui, 1998; Lawton, Rajwani, and Minto, A., 2017.	Exaptive Pools and Feature Emergence A core technology emerges from pools of knowledge in a related industry, showing necessary features for a new product. Business model is not yet known.	Exaptive Events and Deliberate Selection: Creating Paths Leading Prometheans create situations where lead users work across organizations to explore business models. They harvest best practices and identify key features for commercial design by steering the conversation.	Exaptive Forums and Secondary Adaptation: Capturing Bottlenecks A leader's ability to articulate the nature of the emerging industry, and draw all the attention, certifies their leadership for the early adopter business model. They use their social presence to capture and iteratively improve the value chain.
TECHNICAL EXAPTATION THEORIES	Technical sequences for exaptation are specific to the Rebel Alliance Strategy; Prometheans prefer open technology standards, whereas Mercurians "close the box".		
STANDARDS LEADERSHIP PROPOSITIONS		**PQ2: Promethean Leaders create open technical standards convenient for lead users.**	**MC2: Mercurian leaders create proprietary standards that outperform the open market.**

SOURCES Rindova and Petkova, 2007; Saviotti and Metcalfe, 1984. Christiansen, 1997; Adner and Levinthal, 2001; Arthur, 1989; Sydow et al, 2009; Stinchcombe, 1965; Chesbrough and Rosenbloom, 2002;; Pinch and Bijker, 1984)	Pre-Formation The first standards are shaped by idiosyncratic personal histories, chance encounters, and serendipity; personal circumstances might impact technical evolution.	Formation (AKA Closure) Community members hunt for open standards. Firms who attempt closed standards will deter lead users, and thus fail. The selection process begins, reducing options to a handful of paths, favoring path-dependent business models.	Lock-In Savvy market leaders attempt to make proprietary variants of popular standards, and lock in consumers to these superior versions. Niche strategies consist in a sustained fight for remaining users disgruntled by the prevailing order.
EGO NETWORK THEORY	Scholarship shows that industry networks begin as heavily overlapping personal networks but evolve into distinctive social clusters anchored around each leading firm.		
NETWORK LEADERSHIP PROPOSITIONS		**PQ3: Leading Promethean firms will have social ties to the star inventor, and thus also ties to other star firms**	**MC3: Leading Mercurian Firms will have presence at the center of the technical community cluster.**
SOURCES (Klepper, 2002;2007; Aldrich and Kim, 2007; Moon, 2014; Van Wijk et al, 2013; Gulati, Sytch, and Tatarynowicz, 2012; Baum, Shipilov, and Rowley, 2003; Furnari, 2014; Audretsch and Feldman, 1996).	Pre-Small World with Serendipitous Invention A few isolated instigators begin the process of technologically challenging incumbents	Small World Community A few brokers each unify a critical cultural pattern to create a complete clique of challenger firms and elite lead users. Star Networks need at least one "star creator" who provides assistance.	Post-Small World: Industry Clusters As homogenous standards and formal institutions replace informal bridging actors, social networks become organizational rather than interpersonal. Supporting firms are related to leaders by personal ties.
COMMUNITY KNOWLEDGE	Technological and social sequences for the development of community knowledge. Early communities center around tech enthusiasts, whereas later communities are brand-loyal.		
INSTITUTIONAL LEADERSHIP PROPOSITIONS		**PQ4: Leading Promethean Firms will have social ties to the "star curator" who fosters community knowledge basis for lead users.**	**MC4: Leading Mercurian Firms will maintain supporting institutions for their brand community, such as tech societies and aftermarkets.**
SOURCES (Aldrich and Fiol, 1994; Allen, 1983; Agarwal, Moeen, and Shah, 2017; Moon, 2014; Cool, 2008; Fjeldstad et al, 2012; McCray, 2013; Lakhani and Von Hippel, 2003; Muñiz Jr. and O'Guinn. 2001; Mitnick and Ryan, 2015).	Athenian Triggers Early waves of elite researchers and inventors solve major problems that posed by futurists. They describe the science future in a new linguistic terms.	Open Community Knowledge The first clique is dependent on periodicals and clubs that support existing community knowledge. Post-internet, cliques also communicate through leading virtual communities.	Knowledge Corporatization The early cliques break down as a few market leader firms create their own permanent industry institutions for promoting technical support and aftermarket activities. Product development now focuses on supporting a proprietary platform.
PRODUCT THEORIES	Literature supports expandable "minimum viable products" for lead users, and a switch towards reliability, attractiveness, and ease of use to "cross the chasm".		
PRODUCT CATEGORY PROPOSITIONS		**PQ5: Leading Promethean firms win design recognition for product categories based on lead user priorities.**	**MC5: Leading Mercurian firms win awards for product category features targeting the mainstream early adopter.**
SOURCES Suarez's (2004) Five Phases, where Phase Five is sales	Phase One and Two: R&D Race / Feasibility	Phase Three: Creating the Market	Phase Four: Decisive Battle

takeoff and dominant design. Anderson and Zeithaml, 1984; Ries, 2011; Markides and Geroski, 2004; Rogers, 2010.	Actors begin the search for a working technology, and end with a first prototype. Much of the essential knowledge is created by elite technical talent at incumbents.	Actors launch the first minimum viable products and communicate carefully to pick sufficient price/feature combinations. Firms try to prove themselves on lean budgets and "eat what you catch" employee mentality.	Market Leaders all show clear first-mover advantages and "Frontrunner" status, by fully establishing category price points and demand trajectories. Firms often go public (IPO) and seek maximum funds for scaling up.
PATH DEPENDENCY	Technological and social sequences for establishing reliable, affordable manufacturing processes. The first products are built to order, the second must be made continuously.		
QUALITY LEADERSHIP PROPOSITIONS		**PQ6: Promethean leaders must develop a reputation of delivering on preorders. Orders can ship late but must work as promised.**	**MC6: Mercurian leaders must win awards for on-time and working shipments to secure investors for mass scaling of production.**
SOURCES Bayus, Jain, and Rao, 2001; Chandler, 1992; Mowery and Nelson, 1999; Hendricks and Singhal, 1997; Fawcett, Jones, and Fawcett, 2012.)	"Vapor Market" Successful firm founders must develop an awareness of how all relevant parts are made.	"Vapor Product" Leading firms overcome resource problems by garnering advance commitments. Leaders must be able to deliver on "white papers" and "vaporware" on demand.	"Vapor Process" Successful market leaders must establish "Supply chain trust" to attract funds for new facilities to compete for market leadership.

overstates the "singularity" of each breakthrough as happening but once. Indeed, Apple, Tandy, and Commodore all achieved recognition for their proprietary standards, business model, category design, and quality leadership; but moreover, achieved network and cognitive proofpoints. Niche strategies might focus on as little as one leadership dimension.

Deriving the Rebel Alliance Strategy. RAS shall be derived by synthesizing existing literature on emergent dynamics, but interpreted in terms of radical exaptation and lead user innovation paradigms. The three phases of Andriani and Carignani's (2014) radical exaptation model are: feature emergence, deliberate selection, and secondary adaptation. Note this sequence aligns with pre-emergence, commercialization, and sales takeoff. Interestingly, the fitting process aligns with sequences proposed for each of the sub-literatures. In other words, scholars already have largely worked out the theories associated with each proofpoint and with the proposed innovation sequence. For example, the three-stage model of *industry path dependence* (Sydow, Schreyögg, and Koch, 2009; David, 1985; Arthur, 1989) indicates that multiple successive steps may be necessary to discourage followers from challenging arbitrary aspects of Promethean standards. Early cognitive and institutional advantages are locked-in by social construction – such as the famous case of the locked-in, but technically inferior, QWERTY keyboard. The third stage, as described by the authors, neatly aligns with the goals of the Mercurians: to innovate for the general consumer, avoiding perfection. Consider the famous lock-in case of the Model-T Fords' reverse gear being more powerful than both forward gears. Savvy drivers would exploit this feature to overcome the "Thin Lizzy's" weak engine, driving backwards on the steepest hills. Locking in advantage includes understanding which sacrifices can be made in design: most Ford drivers lived on "flat-ish" land, anyhow.

3.3 Explaining the Set Propositions

Six Statuses, Twelve Market Conditions. For this section, I cover the propositions in the table using examples. Instead of merely repeating the referenced literature on FMAs, this section focuses on case-based explanations. At the end of the section, Table 3 provides an automobiles illustration of the measures chosen for testing proofpoints with CS-QCA.

Set Proposition 1: A full PQ configuration confers short-term market leadership at the start of the Mercurian Period, but it is insufficient to sustain market leadership forward. A Promethean entrant competing in a dominant category must attain the full configuration of six PQ proofpoints to survive intact into the Mercurian Period. Firms who do not will fail. Success will grant the PQ leader enough status to launch a second generation of products during the Mercurian Period. Their strategy is likely too focused on lead user interests to appeal to the mass market, and therefore will not "cross the chasm" (Moore, 1999) into sales takeoff. Most PQ individuals and some niches do well, but this model does not track those units.

Set Proposition 2: A full MC configuration confers a firm a long-term market leadership advantage, lasting throughout the sales takeoff period. Firms must attain a full configuration of six MC proofpoints to sustain market leadership past the inflection point of sales takeoff. A Firm who falls shy of the full configuration might survive via a niche strategy, but will not maintain a top market share in the dominant category. Again, niche firm survival is not tracked in this study, although the data is available for future work. Surviving niche firms must always lack *MC5: Mass category leadership* as they purposefully abandon that product category.

Proofpoint #1: Business model leadership. Would-be leaders must demonstrate a superior command of the value creation and value capture challenges associated with a phase of competition (Morris, Schindehutte, and Allen, 2005; Amit, and Zott, 2012). Leadership involves selling the business model narrative to stakeholders, and getting buy-in. Bre Pettis's 3D desktop printer firm, Makerbot, was the only firm in this study who successfully transitioned from Promethean to Mercurian business model leadership role – so I use this example to cover both periods. Originally, the firm used open hardware and open software, and made strong promises to maintain both practices (West and Kuk, 2016). But by 2013, the firm was transitioning into a closed hardware design. They did leave their consumer design community, Thingiverse, free and open. However, this transition led to the loss of most original employees, including two of the three co-founders. A similar exodus happened at Apple when Steve Wozniak, the lead designer, protested the Macintosh computers becoming a desk appliance instead of an open system (Hertzfeld, 2004; Langlois, 1992). Automobile companies also initially were lax about patenting, until leading firms got tired of seeing their best design elements reappear in competitor's cars – often after employees were poached or left to start their own imitator firms.

Crossing the Chasm. A few firms make the transition to MC meanings and categories, but most abruptly perish due to inability to cross the chasm. MC firms curate meanings, such that consumers directly identify product value with proprietary designs – they become brand leaders that embody the specific new meanings of product categories (Aaker and Joachimsthaler, 2012).

Proofpoint #2: Standards leadership. Radical exaptation (Andriani and Carignani, 2016) and open lead user innovation (Hienerth and Lettl, 2011; Von Hippel and Von Krogh, 2003; Stieglitz and Heine, 2007; Bogers, Afuah, and Bastien, 2010) jointly constitute a collective approach to industry formation. PQ participants disrupt incumbents who overlook possible uses for existing technology. Small, new challengers struggle to amass the resources to unseat large, old firms, yet many industries are pioneered by a wave of new entrants – such as automobiles, personal computers, and 3D desktop printing.

Collective invention for RAS. Prometheans can pool efforts for the collective invention of new technology standards – a way to cheaply and quickly improve the technology to the point that it rapidly overtakes incumbents (Cowen and Jonard, 2003). For example, Nikolaus Otto's 4-Stroke engine patent was abruptly rejected by Germany as being too broad, opening up a floodgate of open engine innovation in Paris and Berlin. Gottlieb Daimler and Wilhelm Maybach left Otto's company to commercialize their vastly improved version of the open standard. In the 1890s, nearly everyone either used Daimler-Maybach engines or created rival variants of them. Being technically close to Daimler and Maybach, therefore, became a key determinant of early success. For microcomputers, MITS and Southwest Technical Products Corporation created alternative standard busses: the S-100 and SS-50. Firms who followed either of these standards sold well until 1978, but firms who neglected either standard failed to capture a large early market share. For 3D desktop printing, Adrien Bowyer set the first open standard for nozzles: Fused Filament Fabrication (FFF). This standard dominated until the Mercurian Period.

Closing the Box. Mercurians are tasked with making proprietary standards that stabilize platforms (Hill, 1997). To compete with trains, carriages, and steamboats, fledgling automobile firms first needed to collectively construct standards. Thus, standards innovation connects the knowledge of a host of experts to central leadership nodes. Many of the failed firms in this study focused on what they considered to be technically superior features, but violated the standards. Stan Veit (1993) explained that several microcomputer firms tried and failed in standard-setting, such as The Digital Group and Ohio Scientific. Some early 3D printer firms tried to use pellet plastics rather than filament plastics but didn't overturn the filament as the industry standard.

Proofpoint #3: Network leadership. Leading firms must forge superior ego networks and fight to preserve them as an advantage (Rosenkopf and Tushman, 1998; Tellis, 2010). Cool (2008) documented the birth of e-publishing as being one of close social ties. The firms who sprang forth from the Cyborganic community of San Francisco were early leaders: Wired magazine and ZDnet, for example. Being out of the central clique can be a serious detriment. Tim Berners-Lee, creator of the World Wide Web, documented a similar social effect (Berners-Lee and Fischetti, 2001), explaining just how hard it was to create the "installed base" of users, producers, and consumers. Opera was a documented browser of the Promethean wave that could have technically surpassed Netscape, but didn't have the right installed base. Thus, many other cases exist to explain why early entrepreneurs must "connect the dots" with budding technical communities (Baron, 2006). My chosen measurement method is to connect the leading firms to a single actor: a star curator who manages meaning-making (Mitnick and Ryan, 2015) for a clique. Francis Moon's (2014) book on inventor networks and kinematics is an excellent resource.

Promethean social networks. Prometheans must work with "star curators" that stir up public interest and encourage clubs to form. The Count de Dion-Bouton created a series of automobile events and contests in France to promote his own designs and those of his friends (Flink, 1990). Other Prometheans also did their best to hype up products; but social connection to De Deion-Bouton was not optional – everyone, including his most isolated rival, Karl Benz, eventually participated in his racing events (Moon, 2014). For microcomputers, the star curator was Lester Solomon, editor of *Popular Electronics* magazine. Everyone from Ed Roberts of MITS to Lee Felsenstein of Processor Technology was reading his magazine, and most of the leading firms either submitted projects to it or created proprietary upgrades to those published projects. Thus MITS's own events, and the Homebrew Computer Club, were both offshoot tendrils of Solomon's influence. Firms who operated with no awareness of the tastes of this budding clique produced weird designs and were quickly forgotten. In 3D printing, the first firms were personally tied to Adrien Bowyer, and subsequently participated in Maker Faire events. For 3D printing, Josef Prusa, creator of the most-cloned Prusa printer, worked with Bowyer – Makerbot also received his investment and support. All the top Promethean printers were of his lineage.

Becoming the heart of the industry. As the market begins to widen, connections to a star curator are no longer important (Baum, Shipilov, and Rowley, 2003). This is because firms are no longer dependent on the social interactions facilitated by the star curator. Instead, the industry develops permanent institutions such as trade organizations and trade shows where any potential firm can easily find another. Now the bigger limitation to social centrality is location: firms must find a location in a cluster where all the talent can be found, the small vendor firms congeal, and where industry spillovers are highest (Klepper, 2009;

Audretsch and Feldman, 1996) This shift form interpersonal ties to firm-level ties is dramatic, and Mercurians must claim, demarcate, and control their position in categories by being actively involved (Santos and Eisenhardt, 2009).

Proofpoint #4: Cognitive institutional leadership. The Promethean radical exaptation entrepreneur launches a social movement narrative for the new industry (Hess, 2005; Soule, 2012; Garud, Gehman, and Guiliani, 2014). Thus, it is not enough to be a business model leader or to be in the focal clique/community: a leading firm must also actively construct supporting institutions to proliferate communities of designers, consumers, aftermarket support, and so on.

The RAS Promethean narrative. Indeed, automobile, microcomputer, and 3d desktop leaders all masterfully told a story about revolutionary "Access to tools" – as Stewart Brand put it in his 1970s *Whole Earth Catalog* (Turner, 2010). Each of these birthing events involved making ideas fashionable in a very willful manner. Automobile enthusiasts resented railroad tracks, speed limits, and unreliable collective transportation conditions; and, following several speculative and corrupt railroad booms in every industrializing nation, they had enough of robber barons and monopolies. They were eager to share, experiment on uses and upgrades, and liberate each other to travel (Flink, 1972; Kline and Pinch, 1996). Microcomputer prophets like Ted Nelson wanted "computer power to the people" (Turner, 2010; Levy, 1984). Computer enthusiasts experimented with how to hack televisions, radios, phone lines, and mainframe computers. The 3D desktop printer was born of the "maker" movement (Rivkin, 2014), a global cosmopolitan enthusiasm for makerspaces that provide open access to manufacturing equipment. Adrien Bowyer at the University of Bath had started an open online project, reprap.org, in 2005. The goal was inspired by the von Neumann self-replicator theory, popular in the 1950s: to produce an open source "self-replicator" machine with the goal of printing near-copies of itself. Bowyer's belief was any machine capable of complex self-replication would be a globally liberating technology. Promethean leaders must sell an open-source narrative to the public, and contribute to events that support open institutions.

Mercurian institutions. MC leaders separate themselves from the star curators. They become their own "managers of meaning" (Mitnick and Ryan, 2015) and design brand identities that can support brand communities. As institutions congeal, Mercurians create cultural silos for their own proprietary technology. Automotive leaders created their own aftermarket industries, trained their own workers and revolutionized human resources processes, and established institutions such as the Society for Automotive Engineers. Microcomputer companies created their own periodicals and clubs to support their products and created social networks and tooolkits for software designers. 3D desktop printer companies competed to create their own exclusive online communities, such as Makerbot's Thingiverse design sharing community. These supporting institutions became channels whereby users become enculturated to one philosophy.

Proofpoint #5: category-defining product innovations. Early leaders must define the product categories for the industry (Suarez, Ghodal, and Gotsopoulos, 2015). Initial products please lead users and divide the industry in terms of only a couple of main production functions.

Promethean contests. For example, automobile makers quickly realized the tradeoff between lightweight urban leisure vehicles for conspicuous consumption, initially called runabouts; vehicles designed for speed and long distance, known as touring vehicles; and middle-of-the-road vehicles built for ease of modification and for suburban travel, known as sedans. The dominant Promethean categories are designed to win simple contests (Rao, 1994). Other niches focused on rural markets (high-wheelers), small business (trucks), luxury (limousines), and so forth; but the first three categories were much larger in sales. See Table 8 on page 93 for a more detailed explanation of these categories.

The design chasm. But the category sequence must change focus over time as a new, broader class of users enters the industry [see Table 8 again]. Runabouts gave way to phaetons, which dropped some of the old carriage parts and added such practical innovations as modern tires, hoods, and suspensions. Early touring models were designed to endure dirt-road conditions, but these gave way to modern touring and roadster designs for cruising at high speeds down paved highways and racetracks. The classic open sedan evolved into the coupe-sedan dominant design of the Ford Model T, after adding a closed body, safety features, and extremely easy operating controls.

Proofpoint #6: delivering quality. The best entrepreneurs seem to already know the power of institutions for certifying their firms and products (Rao, 1994), and the ultimate power of attaining a top status. Thus, to become an early quality leader, a firm must have a scalable process and not be buried by product recalls. Not just customers, but all stakeholders, need evidence of quality for supply chain trust (Fawcett, Jones, and Fawcett, 2012).

Promethean pre-order markets. For example, Stan Veit (1993), the owner-operator of the first computer store in New York City, explains in his memoirs on microcomputers that Ohio Scientific, an "almost leader" in personal computers, simply fell short of the whole recipe. History should recognize that their owner-operator, Mike Cheiky, was every bit the talent of Steve Wozniak, except he also made his own peripherals: the first printers, large hard disk drives, and even smoke detectors and security systems designed to ship with the Ohio Scientific computer system, all hardware innovations ahead of what Apple had! Cheiky and his wife Charity put together the best price/performance personal computer combinations in the industry, and were ahead of the competition with its range of features, upgrades, and peripherals. However, Veit noted they routinely failed to keep delivery promises, strayed from industry standards and institutions, and often changed product specifications on an ad hoc basis, thereby totally confusing and frustrating the user base. Lead users were willing to wait 60 days to have their computers built – additional short delays were shrugged off if the product worked.

Mercurian sales: on-time and working. A Mercurian firm cannot be saddled with recalls, as was the case with Processor Technology. However, customers begin to expect rapid delivery, and will no longer wait 60 days. It is difficult to maintain promises without social integration into a supply chain. Ohio Scientific's lack of social integration into the industry certainly doomed their chances to take on Apple, Radio Shack, and Commodore. As Zimmerman and Zeitz (2002) have noted, legitimacy is the key resource that leads to other resources, and there is no faster way to ruin your legitimacy than a product failure.

3.4 Defining the Sample and Crisp Set Hypotheses.

Using mostly historical sources, I identified 28 cases of leadership (firms) across 3 industries (automobiles, personal computers, 3d desktop printers) and across two phases (Promethean and Mercurian). For automobiles, I leaned heavily on the work of Klepper (2002;2007) and Flink (1990); but I double-checked their claims using *Frank Leslie's Popular Monthly* (Unknown Author, 1904), Georgano's (1973) *Encyclopaedia of Motorcars*, and some independent internet sources. For microcomputers, I used the works of Veit (1993), Langlois (1992), and Freiberger and Swaine (2000), *Byte*, and *Computer Shopper* to identify leaders and near-misses. For 3D desktop printers, I used online sources (3ders.org and reprap.org), *Make: Magazine*, the movie *Print: The Legend* (2014), Wohlers industry reports, and 20 semi-structured interviews in 2014 at Maker Faire and the 3D Print Show in London. Data appears in **Appendix A.**

Market Leadership Sets. Each predictor set (Table 5) includes six proofpoints, and the predicted set is the predefined group of sales leaders (Figure 4). I test all 28 firms against both the Promethean and Mercurian proofpoints, to demonstrate a structural break between the PQ and MC cohorts. Crisp sets are thus measured by the presence of all set-specific proofpoints.

Crisp Set QCA Method. The Crisp set method, or CS-QCA, (Rihoux and Ragin, 2008; Kan et al., 2016) was designed to confirm a specific relationship between cases in a social environment that has no fuzziness, no stochastic character, and no internal variability across the time period. Thus, I present only a raw table of all cases within the leadership cohort, and for the purposes of this study, I ignore the variability among all the non-leading firms who failed to make the cut.

Fuzzy Set QCA Method. In contrast, a fuzzy set QCA (FS-QCA) approach would accept some combination of *sufficient conditions* for multiple equifinal paths to sales leadership (Fiss, 2011). This method would be appropriate if only some of the proofpoints were necessary for market leadership- indeed, if I were to find counter-examples among the PQ and MC cohorts, it would force me to test the entire set of early entrants to the dominant categories for all three industries, which would exceed 300 total cases. *Therefore, I prepared for this possibility and gathered extensive data on all early entrants*. Note FS-QCA approach is more complex and requires a more formal approach, the analysis of variance, and the presentation of a full matrix of all cases.

Aligning Measures to Theory. To translate the RAS theory into a QCA table, I selected an industry-specific measure for each of the hypothesized proofpoints. To conserve space, I have only provided a detailed explanation of the measures used for automobiles. Additional details about the measures selected of the other two industries are largely covered in the examples given in the previous section, and full tables can also be obtained from the author.

Table 8: Aligning Automobile Measures to the Proofpoint Model

Dominant Categories (society of Automotive Engineers, 1916; Hyde, 1989; Carroll et al, 1996)	Athena's Birth (France and Germany) 1876-1893 Until the Maybach Carburetor	Promethean Clique Combustion (France and Germany) 1893-1900 Until Gas Engine Standard	Mercurian Community Combustion (USA) 1901-1909 Until the Model T Ford reaches full production
Tri-wheel, Runabouts and Phaetons (urban-only, lightweight horseless carriages)	Karl Benz Patent Motorwagen (1885 Germany); Daimler and Maybach 4 form factor models (1885); De Dion-Bouton Steam Quadricycle (1889 France)	Karl Benz Velo (1889 Germany); De Deion-Bouton Runabouts (1893 France); Peugeot First Series (1892 France). This is the first category to become "Standard" in design	Thomas B. Jeffery and Co.'s Rambler (1901); Oldsmobile Curved Dash (1901); Ford Model A (1903); Buick Model B (1904)
Roadsters and Touring (long distance, rugged, fast, suspension for rural roads)	Duryea (1893 United States); Panhard & Levassor (1891 France), creators of "Systeme Panhard", the first body design standard.	DMG Mercedes 35hp (1900 Germany); De Dion-Bouton Series vehicles (1892 France). These two companies were the most notorious engineering enthusiasts in their respective countries. They collaborated to stage many events, breaking many "firsts".	Buick Model 10 (1908); Engine Leadership; Cadillac Model F (1906). This category received all the media coverage for long distance road races. Large, rugged, and reliable.
Sedans and Coupes (closed body, safe, easy to use, slow)	Early mass transit buses: Amédée Bollée's steam busses (1875-1883)	Renault Voiturette Type B (1899 France); Automobile's first child prodigy. The world's first sedans and coupes were rare custom vehicles. Renault filled a small niche for decades, until partnering with rivals.	Cadillac Model M (1906); Ford Model T (1908); After being imitated by competitors for years, a little bit of everyone else's wisdom poured back into his megahit car. 34) DOMINANT DESIGN: FORD MODEL T
Star Evangelist / Forum Leader	Armand Peugeot (France's Leading Bicycle manufacturer, 1886, was the critical curious incumbent for P&L); Gottleib Daimler	De Dion-Bouton (France). The French count was the biggest financial and social supporter of the Parisian auto industry. *Failed clique: Arthur Pope, Early Electric clique, bicycle industry titan, USA.*	1900 First New York Auto Show; other cities follow, and auto clubs exist in every major metro area. All leaders held center stage in these events and were skilled at making sales with dealers at auto shows.
Star Inventor / Cluster Leader	Nikolaus Otto, Inventor of the internal combustion engine, 1876, Germany)	Daimler-Maybach (Germany), and Panhard&Levasseur (France). All early road contests were won by cars using Daimler-Maybach engines	The best supply chains for parts and machine tool supply emerges in the greater Detroit area. Ford, Cadillac, Buick, Oldsmobile, and Thomas B. Jeffery take the lead by concentrating on this cluster, whereas luxury brands remain scattered throughout the country.

Quality leadership	Bertha Benz's first solo demonstration run of Karl Benz's prototype, 1888.	1894 First Paris-Rouen Race (1894, P&L). First American Chicago- Tribune Road Race (1895; Henry Ford was present; Duryea had only car that finished without disqualification)	The market leaders all won awards for quality based on superior production processes, thereby attracting capital investment for world's largest manufacturing facilities (1908-1909)
Community Knowledge	Berlin Technical School, Germany, and Ecole Centrale des Arts et Manufactures, France: Franz Reuleaux; Bicycle, engine, and carriage trade organizations.	Automobile Club of France: De Dion-Bouton (1895); The Horseless Age magazine (1895, USA). These periodicals and clubs created an auto user culture of lead users.	All market leaders create institutions, such as the Society of Automotive Engineers (1905), where Henry Ford was the first Vice- President. Ford wanted to be America's automotive version of Reuleaux and created "Fordism" for the Detroit community.
Engine Technical Standard	Otto 4-Stroke Engine (1976-1889); Daimler and Maybach first engine, pre-carburetor (1889-1893, inherited through marriage by Levasseur)	Daimler, Maybach, and P&L collaborated to make the Phenix Engine the global standard. Tens of thousands sold; Some patent protection, OEM licenses granted in most countries. Americans like Ford and Buick made their own Otto 4-stroke variants of the Phenix. (1894-1900)	De Dion-Bouton Engine – Full Patent Protection, Europe's most used engine lines, with over 200,000 sold worldwide, leapfrogging Daimler-Maybach. All American leaders make proprietary engines by 1909, but niche players still use standard engines.

Triangulating "market leadership". This study cannot directly analyze raw quantitative data on market share because it is famously unreliable during industry emergence: for example, the figures for 2013 factory assembled (non-kit form) 3d desktop printer global sales range from as low as 60,000 to as high as 100,000, and they don't take into consideration many firms who aren't big enough to bother reporting data to consultants. I simplify our task by being inclusive within a range of annual top 3 in sales: confirming any firm was mentioned among the top three in sales at least once for PQ or twice for MC across the stated time windows, numerically or qualitatively. I arrive at a range of up to six firms for each phase, discarding firms in sales takeoff who are one-hit wonders (for example, Texas Instruments I microcomputers, circa 1980; and, the 1981 Sinclair desktop as Sinclair's major subsequent successes came in niche products).

3.5 Results and Interpretation

Results: PQ and MC sets confirmed. Refer to Appendix A. The reader can clearly see that the PQ sales leaders all shared proofpoints that are mutually exclusive from those shared by all MC sales leaders. Only one PQ leader achieved crossover (Makerbot) although most Mercurians had some sort of firm experience during the Promethean period. The explanation as to why they achieved crossover is that they deliberately repeated the strategic case of microcomputers. Indeed, Bre Pettis makes clear in the movie, *Print the Legend* (2014), that Makerbot modeled itself on the rise of Apple. Paraphrased: “everyone wanted to be Wozniak but I had to be Steve Jobs because I was the only one who could do it”. Based on direct interviews with other companies in the industry at that time, this author found widespread awareness of the historical patterns associated with microcomputer strategy and a conscious attempt to do the same thing only better. In one particularly telling interview, Ethan Dicks, leader of Columbus Ohio’s 3D printing club, CORMUG emphasized that the social imitation of the microcomputer industry was quite deliberate. Not only were the lead user participants motivated by similar principles as aforementioned, but many of the organizers had experience in the microcomputer lead user groups. Dicks himself was at one time the teenaged ”alpha geek” of the Commodore Amiga user group – if anyone had a question about how to hack or improve the Amiga hardware, Dicks was the guy to ask. Dicks hoped to aid a generation of inspired young lead users.

Proofpoints, RAS, and the Chasm. Therefore, the model cleanly predicts both distinctive sets of leaders, and illustrates the strategic transition of the infamous “market chasm” for RAS industries. Furthermore, overall leaders entered early and sold very few of their PQ products, but successfully transitioned to an MC firm and proofpoints during MC period, while also retaining the most credit from the press for leading “the revolution” by the end of the MC period.

The geographic caveat. However, USA’s 3D desktop printer leader, Makerbot, is barely grasping onto leadership status as of 2018, for a non-hypothesized reason: because the geographic cluster for sales takeoff did not materialize in USA or Europe, but in East Asia – the highest demand market for the product! In fact, the only true difference between the three industry patterns seems to be due to global patterns of trade. The center of action for Automobiles shifted from Europe to USA because of the USA’s emerging proofpoints as the global automotive manufacturing powerhouse, because it had the greatest market demand (by 1910, American consumer sales and production was double that of Europe). For personal computers, both PQ and MC action takes place in the USA, with the Asian shift happening shortly after emergence. For 3D desktop printers, however, the emergence of the Asian cluster is happening at the tail end of emergence. Indeed, Asian firms are expecting to sell several times more printers to Asian households than to the rest of the world combined. Thus, even though Makerbot did everything else right to attain overall MC leadership, XYZprinting of Taiwan is taking that top spot in time for the Asian consumer explosion, predicted to happen by 2020 (3ders.org, 2017). Such predictions are extremely likely given China's explicit policy to be global leader in all additive manufacturing.

Interpreting the likelihood of achieving all proofpoints. Traditional Gaussian statistics assumes an inherently random, highly uncertain field of social activity, from whence emerges coorelative relationships. However, Claude Shannon's work on information theory assumes the opposite: a highly determined set of outcomes but a "scrambled" condition. Shannon developed his theory for use with cryptography to analyze the pure "signal" in a field of "noise. This same method has been famously applied to games of chance such as poker, where the winning hands are understood but the path to a winning hand is a scrambled, random dealing of resources, i.e. cards. The agents playing the game know the payoff structure, and that is what proofpoint theories do – they provide an accurate payoff structure (short term goals) to which players can aspire for locking in long term goals. Individual entrepreneurs are essentially trying to see through the scrambled conditions of initial resource allocations and find the clear signal in the noise –just like cryptologists and poker players. Thus, the configurational approach to industry emergence uses the underlying Boolean algebra of CS-QCA in the statistical family of information theory, and involves analyzing the likelihood of obtaining winning conditions.

The probability of leadership. When interpreting configuration proofpoints, one might make the error of assuming a 6-condition configuration as 6 times less likely than 1-condition condition; in fact, it is $\mathbf{n^6 = 64}$ times less likely, in the most simple allocation conditions. Proofpoints are assumed to be uniformly distributed because somebody MUST win leadership in each dimension, and so we can assume leadership to be a fixed condition that is necessarily distributed to a few firms. In a random, uniformly distributed field of, say, 256 new entrants, you would statistically expect 6 firms to have a complete market leadership configuration. In comparison, a resource-based approach would require lucky and Gaussian (normal) distributions of resources – the odds would be severely against any firm ever achieving six lucky allocations, each of which are at least 2 standard deviations from the norm.

Choosing to play the game. Suppose it is possible to believe you have some competitive advantage in any dimension, based on the other firms you have encountered. The firm with the most knowledge of other firms' capabilities has the surest ability to know if it is a leader in a nascent market. Firms who submit to social certification processes, and engage in the community, reduce their own uncertainty as well as that for the entire field. Leading firms show some ex ante knowledge of the RAS strategy, and can beat mere random odds. Increased firm visibility through trade shows, contests, etc. can resolve ambiguities to disavow false notions.

3.6 Limitations and Future Directions

Is six configurations enough? All three industries examined had an average annual pool of competitors aiming for a dominant category in the range of 100-300 worldwide players. Interestingly, if configurations are assumed to be uniformly and randomly distributed, between 3-6 market leaders would be best estimated by $n^5 = 32$ to $n^7 = 128$ configurations, of between 5 and 7 leadership conditions. Thus the use of 6 leadership conditions per window could predict a sales leader for RAS industries with high certainty, but still cannot uncover which actor has the best odds in advance of social proof. This institutional measure of PQ and MC leaders is therefore accurate for picking sales takeoff leaders, but not precise. Future work should detail the mathematics of configurational analysis, especially for losing and niche strategies.

The role of agency and microprocesses. Institutional agency theory (Mitnick, 1975) rears its head here: the principal (investor) sees uniform randomness and looks for signals (Shepherd, 1999), whereas the agent (venture) sees the true information, but doesn't know the investors' preferred signals. Future work on proofpoints is thus a way to resolve agency problems of certification (Hallen and Eisenhardt, 2012; Graffin and Ward, 2010) and to help close the principal-agent gap that exists in the venture capital industry.

Imitating prior RAS leaders. For example, according to West and Kuk (2016), the Netflix documentary *Print the Legend,* and expert interviews, Bre Pettis of Makerbot constantly compared himself and his enterprise to Steve Jobs and Apple. Pettis studied the facts of that scenario to walk in Job's shoes *in only the necessary ways*. The increased speed of identifying and funding early leaders also implies professional early stage investors pull the trigger faster.

The East Asian cluster leaders – XYZprinting and Monoprice – are currently winning the cost war. In a sense, they are copying "Fordism"; and are also the rightful heirs to Jack Tramiel's legendary price-war-winning product, the Commodore 64 – to this date, the best-selling single computer model of all time. Makerbot is still playing the role of Apple and betting that it can survive price wars with design and community in the long run. We shall see how this plays out.

Other industries, other strategies = other configurations. This study sets a baseline approach for future configuration studies in industry emergence. The next steps are: to study more emergence scenarios, such as intrapreneurship; to broaden the study of RAS configurations to market business models such as ridesharing and cryptocurrency industries; to deepen the study of equifinal strategies, possibly by drawing on Athena's Birth; to analyze the longitudinal affects; to simulate alternative outcomes; and to create multilevel models of the ideal actions, actors, and resources for attaining proofpoints. We need to examine the types of firms and whether they are truly determined by the industry technology or by broader forces (Langlois 2007). One final problem raised is the essential nature of information stewardship, and the unique community role of the lead users in creating and curating the future. There may be policy measures that can be employed to facilitate Promethean activity and accelerate new industry formation. The literature has identified very sizeable lags from pre-emergence to firm takeoff (Agarwal and Bayus, 2002).

Summary Conclusion.

I have demonstrated that leadership cohorts operate under a different logic than the rest of the firms in their period of entry, because of greater responsibility for creating market institutions; and, that the logic of a Promethean leader is quite distinctive from a Mercurian. Only a rare firm can reconfigure itself rapidly from the first logic to the second. Due to the extreme difficulty of reconfiguration, it is questionable that early Promethean leadership contributes to Mercurian success. Also, it has been demonstrated that proofpoints can be used to anticipate future leadership cohorts, via necessary condition analysis.

Appendix A : Truth Tables for Promethean and Mercurian Proofpoints

MERCURIAN MARKET LEADERS: AMERICAN AUTOMOBILES						
MERCURIAN (sustained sales leadership) 1901-1909	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (Great Lakes) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6
Ford***^^	YES	YES	YES	YES	YES	YES
Olds	YES	YES	YES	YES	YES	YES
Buick	YES	YES	YES	YES	YES	YES
Cadillac	YES	YES	YES	YES	YES	YES
Nash	YES	YES	YES	YES	YES	YES
PROMETHEAN (existed in some legal form) 1893-1900	Exaptation Event Host PQ1	Open Standards (Otto) PQ2	Ties to Detroit Clique (Olds) PQ3	Ties to Detroit Clique (Ford) PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
Ford	0	YES	YES	YES	YES	YES
Olds	YES	0	YES	YES	YES	YES
Buick	0	0	YES	YES	0	0
Cadillac	0	YES	YES	YES	YES	YES
Nash	0	0	0	0	YES	0

MERCURIAN MARKET LEADERS: AMERICAN MICROCOMPUTERS						
MERCURIAN (sustained sales leadership) 1977-1980	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (California) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6
Apple	YES	YES	YES	YES	YES	YES
Tandy***	YES	YES	YES	YES	YES	YES
Commodore	YES	YES	YES	YES	YES	YES
PROMETHEAN (existed in some legal form) 1974-1977	Exaptation Event Host PQ1	Open Standards (S100/SS-50) PQ2	Ties to Popular science: Les Solomon PQ3	Ties to MITS Altair Computer clubs PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
Apple	YES	0	YES	0	YES	YES
Tandy	0	0	0	0	0	0
Commodore	0	0	0	0	0	0

	MERCURIAN MARKET LEADERS: ASIAN MANUFACTURED 3D DESKTOP PRINTERS					
MERCURIAN (sustained sales leadership) 2013-2020	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (East Asia) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6
XYZPrinting***	YES	YES	YES	YES	YES	YES
Monoprice	YES	YES	YES	YES	YES	YES
Makerbot	YES	YES	YES	YES	YES	YES
Formlabs	YES	YES	YES	YES	YES	YES
Ultimaker	YES	YES	YES	0	YES	YES
Prusa3^^	YES	0	YES	0	YES	YES

PROMETHEAN (existed in some legal form) 2009-2013	Exaptation Event Host PQ1	Open Standards (FFF) PQ2	Ties to Major Hackerspaces, Maker Faire PQ3	Ties to Adrian Bowyer PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
XYZPrinting	0	0	0	0	0	0
Monoprice	0	0	0	0	0	0
Makerbot ^^	YES	0	YES	YES	YES	YES
Formlabs	0	0	YES	0	0	YES
Ultimaker	YES	0	YES	YES	0	YES
Prusa3	YES	YES	YES	YES	YES	YES

	PROMETHEAN MARKET LEADERS: AMERICAN MICROCOMPUTERS					
MERCURIAN (existed in some legal form) 1977-1980	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (California) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6
MITS^^	YES	0	YES	0	0	0
IMSAI	YES	0	YES	YES	0	0
SWTPC	YES	0	YES	YES	0	0
Processor Technology	YES	0	YES	YES	0	0
Cromemco	YES	YES	YES	YES	0	YES
PROMETHEAN (top 3 in overall sales for a year) 1974-1977	Exaptation Event Host PQ1	Open Standards (S-100 or SS-50) PQ2	Ties to Popular science: Les Solomon PQ3	Ties to MITS Altair computer clubs PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
MITS^^	YES	YES	YES	YES	YES	YES
IMSAI	YES	YES	YES	YES	YES	YES
SWTPC	YES	YES	YES	YES	YES	YES
Processor Technology***	YES	YES	YES	YES	YES	YES
Cromemco	YES	YES	YES	YES	YES	YES

	PROMETHEAN MARKET LEADERS: AMERICAN 3D DESKTOP PRINTERS					
PROMETHEAN (existed in some legal form) 2013-2020	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (East Asia) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6
Prusa^^	YES	YES	YES	0	YES	YES
Makerbot Cupcake	0	0	0	0	0	0
Deltabot	0	0	0	0	0	0
PROMETHEAN (top 3 in overall sales for a year) 2009-2013	Exaptation Event Host PQ1	Open Standards (FFF) PQ2	Ties to Major Hackerspaces, Maker Faire PQ3	Ties to Adrian Bowyer PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
Prusa***	YES	YES	YES	YES	YES	YES
Makerbot Cupcake	YES	YES	YES	YES	YES	YES
Deltabot^^	YES	YES	YES	YES	YES	YES
	PROMETHEAN MARKET LEADERS: FRENCH/GERMAN CLUSTER AUTOMOBILES					
MERCURIAN (existed in some legal form) 1901-1909	All major trade shows MC1	Proprietary Standard Leadership MC2	Supporting proprietary tech with institutions MC3	Geographic Cluster (Great Lakes) MC4	Mass Category Leadership MC5	Quality Execution (on-time, working shipments) MC6

DMG	YES	YES	YES	0	0	YES
De Dion-Bouton	YES	YES	YES	0	0	YES
Peugeot	YES	YES	YES	0	YES	YES
Panhard & Levassor ^^	YES	YES	YES	0	0	YES
Karl Benz	YES	0	YES	0	0	YES
Renault	YES	YES	YES	0	YES	YES
PROMETHEAN (top 3 in overall sales for a year) 1889-1900	Exaptation Event Host PQ1	Open Standards (Otto) PQ2	Ties to Paris-Berlin Clique (De Dion) PQ3	Ties to Paris-Berlin Clique (Daimler) PQ4	Lead User Category Leadership PQ5	Quality Execution (working shipments) PQ6
DMG (Daimler-Maybach)^^ ***	YES	YES	YES	YES	YES	YES
De Dion-Bouton	YES	YES	YES	YES	YES	YES
Peugeot	YES	YES	YES	YES	YES	YES
Panhard & Levassor	YES	YES	YES	YES	YES	YES
Karl Benz	YES	YES	YES	YES	YES	YES
Renault	YES	YES	YES	YES	YES	YES

Bibliography

Aaker, D.A. and Joachimsthaler, E., 2012. Brand leadership. Simon and Schuster.

Abernathy, WJ, Clark, KB. 1985. Innovation: Mapping the winds of creative destruction. *Research policy* **14**(1): 3-22.

Abernathy, WJ, Utterback, JM. 1978. Patterns of industrial innovation. *Technology review* **80**(7): 40-47.

Adner, R, Kapoor, R. 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic management journal* **31**(3): 306-333.

Adner, R. and Levinthal, D., 2001. Demand heterogeneity and technology evolution: implications for product and process innovation. Management science, 47(5), 611-628.

Adner, R., 2002. When are technologies disruptive? A demand-based view of the emergence of competition. *Strategic Management Journal*, *23*(8), pp.667-688.

Agarwal R, Bayus, BL. 2004. Creating and surviving in new industries. In *Business Strategy over the Industry Lifecycle*. Baum JC, McGahan AM (eds). Emerald Group Publishing Limited: 107-130.

Agarwal R, Bayus, BL. 2002. The market evolution and sales takeoff of product innovations. *Management Science* **48**(8): 1024-1041.

Agarwal R, Moeen M, Shah, SK. 2017. Athena's birth: Triggers, actors, and actions preceding industry inception. *Strategic Entrepreneurship Journal* **11**(3): 287-305.

Agarwal, R. and Gort, M., 2001. First-mover advantage and the speed of competitive entry, 1887–1986. *The Journal of Law and Economics*, *44*(1), pp.161-177.

Agarwal, R., Campbell, B.A., Franco, A.M. and Ganco, M., 2016. What do I take with me? The mediating effect of spin-out team size and tenure on the founder–firm performance relationship. Academy of Management Journal, 59(3), 1060-1087.

Aldrich, H.E. and Fiol, C.M., 1994. Fools rush in? The institutional context of industry creation. Academy of management review, 19(4), 645-670.

Aldrich, H.E. and Kim, P.H., 2007. Small worlds, infinite possibilities? How social networks affect entrepreneurial team formation and search. Strategic Entrepreneurship Journal, 1(1-2), 147-165.

Allen, R.C. 1983. Collective Invention, Journal of Economic Behavior and Organization, vol. 4, 1-24

Alpert FH, Kamins MA. 1995. An empirical investigation of consumer memory, attitude, and perceptions toward pioneer and follower brands. *The Journal of Marketing* **59**(4): 34-45.

Alvarez, J. L., Mazza, C., Strandgaard Pedersen, J., & Svejenova, S. (2005). Shielding idiosyncrasy from isomorphic pressures: Towards optimal distinctiveness in European filmmaking. Organization, 12, 863–888.

Alvarez, S.A. and Barney, J.B., 2007. Discovery and creation: Alternative theories of entrepreneurial action. Strategic entrepreneurship journal, 1(1-2), 11-26.

Alvarez, S.A., Young, S.L. and Woolley, J.L., 2015. Opportunities and institutions: A co-creation story of the king crab industry. Journal of Business Venturing, 30(1), 95-112.

Amit R, Schoemaker PJH. 1993. Strategic assets and organizational rent. *Strategic Management Journal* **14**(1): 33–46.

Amit, R. and Zott, C., 2012. Creating value through business model innovation. MIT Sloan Management Review, 53(3), 41.

Anand, G., Ward, P.T., Tatikonda, M.V. and Schilling, D.A., 2009. Dynamic capabilities through continuous improvement infrastructure. *Journal of operations management*, *27*(6), pp.444-461.

Ancona DG, Chong CL. 1992. Timing is everything: Entrainment and performance in organizational theory. *Academy of Management Proceedings* **1**: 166-169.

Ancona DG, Chong, CL, 1996. Entrainment: Pace, cycle, and rhythm in organizational behavior. *Research in Organizational Behavior* **18**: 251–284.
Anderson P, Tushman, ML, 1990. Technological discontinuities and dominant designs: A cyclical model of technological change. *Administrative science quarterly* **35**(4): 604-633.
Anderson, C.R. and Zeithaml, C.P., 1984. Window of the product life cycle, business strategy, and business performance. Academy of Management journal, 27(1),5-24.
Andriani, P. and Carignani, G., 2014. Modular exaptation: a missing link in the synthesis of artificial form. *Research Policy*, *43*(9), pp.1608-1620.
Ansari, S.S. and Krop, P., 2012. Incumbent performance in the face of a radical innovation: Towards a framework for incumbent challenger dynamics. *Research policy*, *41*(8), pp.1357-1374.
Arrow, K.J., 1962. The economic implications of learning by doing. *The review of economic studies*, *29*(3), pp.155-173.
Arthur, W.B., 1989. Competing technologies, increasing returns, and lock-in by historical events. The economic journal, 99(394), 116-131.
Audia, P.G. and Rider, C.I., 2005. A garage and an idea: what more does an entrepreneur need?. California Management Review, 48(1),6-28.
Audretsch, D.B. and Feldman, M.P., 1996. R&D spillovers and the geography of innovation and production. The American economic review, 86(3), 630-640.
Baba, Y. and Walsh, J.P., 2010. Embeddedness, social epistemology and breakthrough innovation: The case of the development of statins. *Research Policy*, *39*(4), pp.511-522.
Basalla, G., 1988. *The evolution of technology*. Cambridge University Press.
Baum, J.A. and Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. Journal of business venturing, 19(3), 411-436.
Baum, J.A., Shipilov, A.V. and Rowley, T.J., 2003. Where do small worlds come from? Industrial and Corporate change, 12(4),697-725.
Baumgarden P, Nickerson J, Zenger, T. 2012. Sailing into the wind: Exploring the relationships among ambidexterity, vacillation, and organizational performance. *Strategic Management Journal* **33**(6): 587–610.
Baumol, W.J. and Strom, R.J., 2007. Entrepreneurship and economic growth. *Strategic entrepreneurship journal*, *1*(3‐4), pp.233-237.
Bayus BL, Jain S, Rao AG. 1997. Too little, too early: Introduction timing and new product performance in the personal digital assistant industry. *Journal of Marketing Research* **34**(1): 50-63.
Bayus, B.L., Jain, S. and Rao, A.G., 2001. Truth or consequences: An analysis of vaporware and new product announcements. Journal of marketing research, 38(1), 3-13.
Beck J. 2007. The sales effect of word of mouth: a model for creative goods and estimates for novels. *Journal of Cultural Economics* **31**(1): 5-23.
Bell G. 2008. Bell's law for the birth and death of computer classes: A theory of the computer's evolution. *IEEE Solid-State Circuits Society Newsletter* **13**(4):8-19.
Benner MJ, Tushman, ML. 2003. Exploitation, exploration, and process management: The productivity dilemma revisited. *Academy of management review* **28**(2): 238-256.
Berchicci L, Tucci CL Zazzara C. 2013. The influence of industry downturns on the propensity of product versus process innovation. *industrial and Corporate Change* **23**(2): 429-465.
Bernard, L., Gevorkyan, A.V., Palley, T.I. and Semmler, W., 2014. Time scales and mechanisms of economic cycles: a review of theories of long waves. *Review of Keynesian Economics*, *2*(1), pp.87-107.
Berners-Lee, T. and Fischetti, M., 2001. *Weaving the Web: The original design and ultimate destiny of the World Wide Web by its inventor*. DIANE Publishing Company.
Bers, J.A., Dismukes, J.P., Miller, L.K. and Dubrovensky, A., 2009. Accelerated radical innovation: Theory and application. *Technological Forecasting and Social Change*, *76*(1), pp.165-177.

Bird, B.J., 1992. The Roman god Mercury: an entrepreneurial archetype. Journal of management inquiry, 1(3), 205-212.

Bogers, M., Afuah, A. and Bastian, B., 2010. Users as innovators: A review, critique, and future research directions. Journal of management, 36(4), 857-875.

Bol, D. and Luppi, F., 2013. Confronting theories based on necessary relations: Making the best of QCA possibilities. Political Research Quarterly, 205-210.

Bonifati, G. and Villani, M., 2013. 10. Exaptation in innovation processes: theory and models. *Handbook of economic organization: Integrating economic and organization theory*, p.172.

Bouchikhi, H. and Kimberly, J.R., 2003. Escaping the identity trap. MIT Sloan Management Review, 44(3), 20.

Boudreau, K.J., 2012. Let a thousand flowers bloom? An early look at large numbers of software app developers and patterns of innovation. *Organization Science*, *23*(5), pp.1409-1427.

Bourdieu P. 2013. *Distinction: A social critique of the judgement of taste*. Routledge.

Bourdieu P., 2011. The forms of capital. In *Cultural theory: An anthology*. Sceman I, Kapozy T (eds). 81-93.

Bower JL, Christensen C. 1995. Disruptive technologies: catching the next wave. *Harvard Business Review* **73**(1): 43–53.

Brezis ES, Krugman PR, Tsiddon, D. 1993. Leapfrogging in international competition: A theory of cycles in national technological leadership. *The American Economic Review* **83**(5): 1211-1219.

Brown SL, Eisenhardt KM. 1997. The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly* **42**(1): 1-34.

Brush, C.G., Greene, P.G. and Hart, M.M., 2001. From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base. Academy of Management Perspectives, 15(1), 64-78.

Buisson, B. and Silberzahn, P., 2010. Blue ocean or fast-second innovation? A four-breakthrough model to explain successful market domination. International Journal of Innovation Management, 14(03), 359-378.

Burgelman RA. 2002. Strategy as vector and the inertia of coevolutionary lock-in. *Administrative science quarterly* **47**(2): 325-357.

Busenitz, L.W., 1996. Research on entrepreneurial alertness. *Journal of Small Business Management*, *34*(4), p.35.

Calantone, R.J. and Di Benedetto, C.A., 2007. Clustering product launches by price and launch strategy. *Journal of Business & Industrial Marketing*, *22*(1), pp.4-19.

Camillus J, Venkatraman N. 1984. Exploring the concept of 'fit' in strategic management. *Academy of Management Review* **9**(3): 513–525.

Carroll, G.R., Bigelow, L.S., Seidel, M.D.L. and Tsai, L.B., 1996. The fates of de novo and de alio producers in the American automobile industry 1885–1981. Strategic Management Journal, 17(S1), 117

Casson M. 2005. Entrepreneurship and the theory of the firm. *Journal of Economic Behavior & Organization* **58**(2): 327-348.

Cattani, G., 2005. Preadaptation, firm heterogeneity, and technological performance: A study on the evolution of fiber optics, 1970–1995. *Organization Science*, *16*(6), pp.563-580.

Cattani, G., Porac, J.F. and Thomas, H., 2017. Categories and competition. *Strategic Management Journal*, *38*(1), pp.64-92.

Caves, R.E. and Porter, M.E., 1978. Market structure, oligopoly, and stability of market shares. *The Journal of Industrial Economics*, pp.289-313.

Chakravarthy, B., 1997. A new strategy framework for coping with turbulence. *MIT Sloan Management Review*, *38*(2), p.69.

Chamberlin, EH. 1949. *Theory of monopolistic competition: A re-orientation of the theory of value*. Oxford University Press, London.

Chandy, R.K. and Tellis, G.J., 1998. Organizing for radical product innovation: The overlooked role of willingness to cannibalize. Journal of marketing research, 474-487.

Chandy, R.K. and Tellis, G.J., 2000. The incumbent's curse? Incumbency, size, and radical product innovation. Journal of marketing, 64(3), 1-17.
Chao YC. 2011. Decision-making biases in the alliance life cycle: Implications for alliance failure. *Management decision* **49**(3): 350-364.
Chaum, D., 1983. Blind signatures for untraceable payments. In *Advances in cryptology* (pp. 199-203). Springer, Boston, MA.
Chaum, D., Fiat, A. and Naor, M., 1988, August. Untraceable electronic cash. In *Conference on the Theory and Application of Cryptography* (pp. 319-327). Springer, New York, NY.
Chen MJ., 1996. Competitor analysis and interfirm rivalry: Toward a theoretical integration. *Academy of management review* **21**(1): 100-134.
Chesbrough W. 2002. Making sense of corporate venture capital. *Harvard business review* **80**(3): 90-99.
Chesbrough, H. and Rosenbloom, R.S., 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Industrial and corporate change, 11(3), 529-555.
Christensen, C. M. (2013). *The innovator's dilemma: when new technologies cause great firms to fail*. Harvard Business School Press: Boston
Christensen, C.M. and Rosenbloom, R.S., (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research policy*, *24*(2), pp.233-257.
Christensen, C.M., 2001. The past and future of competitive advantage. *MIT Sloan Management Review*, *42*(2), p.105.
Clark, K.B., 1985. The interaction of design hierarchies and market concepts in technological evolution. *Research policy*, *14*(5), pp.235-251.
Cohen A, Harcourt, GC. 2003. Retrospectives: Whatever Happened to the Cambridge Capital Theory Controversies? *The Journal of Economic Perspectives* **17**(1): 199-214.
Cohen, W.M. and Levin, R.C., 1989. Empirical studies of innovation and market structure. *Handbook of industrial organization*, *2*, pp.1059-1107.
Cohen, W.M. and Levinthal, D.A., 2000. Absorptive capacity: A new perspective on learning and innovation. In *Strategic Learning in a Knowledge economy* (pp. 39-67).
Colombo, M.G. and Grilli, L., 2005. Founders' human capital and the growth of new technology-based firms: A competence-based view. Research policy, 34(6), 795-816.
Conner, K.R., 1988. Strategies for product cannibalism. *Strategic Management Journal*, *9*(S1), pp.9-26.
Cool, J.C., 2008. Communities of innovation: Cyborganic and the birth of networked social media. University of Southern California.
Cornes, R. and Sandler, T., 1996. *The theory of externalities, public goods, and club goods*. Cambridge University Press.
Cowan, R. and Jonard, N., 2003. The dynamics of collective invention. Journal of Economic Behavior & Organization, 52(4), 513-532.
Cummings, J.L. and Doh, J.P., 2000. Identifying who matters: mapping key players in multiple environments. *California Management Review*, *42*(2), pp.83-104.
D'Aveni, R., 2002. The Empire strikes back. Counterrevolutionary strategies for industry leaders. Harvard Business Review, 80(11), 66-74.
D'Aveni, R.A., 1999. Strategic supremacy through disruption and dominance. Sloan management review, 40(3), 127.
Davidsson, P. and Honig, B., 2003. The role of social and human capital among nascent entrepreneurs. Journal of business venturing, 18(3), 301-331.
Derfus PJ, Maggitti PG, Grimm CM, Smith KG. 2008. The Red Queen Effect: Competitive Actions and Firm Performance. *Academy of Management Journal*, **51**(1): 61-80.
Dew, N., 2007. Pre-adaptation, exaptation and technology speciation: a comment on Cattani (2006). *Industrial and Corporate Change*, *16*(1), pp.155-160.
Dew, N., Sarasvathy, S.D. and Venkataraman, S., 2004. The economic implications of exaptation. Journal of Evolutionary Economics, 14(1), 69-84.

Di Stefano, G., Gambardella, A. and Verona, G., 2012. Technology push and demand pull perspectives in innovation studies: Current findings and future research directions. *Research Policy*, *41*(8), pp.1283-1295.

Dimov, D., 2007. Beyond the single-person, single-insight attribution in understanding entrepreneurial opportunities. *Entrepreneurship Theory and Practice*, *31*(5), pp.713-731.

Dioun, C., 2014, January. From dealing to healing: Social movements and changing conceptions of marijuana in California. In *Academy of Management Proceedings* (Vol. 2014, No. 1, p. 15035). Academy of Management.

Dosi G, Malerba F, Orsenigo L. 1994. Evolutionary regimes and industrial dynamics. In *Evolutionary and neo-Schumpeterian approaches to economics* ,Magnusson L (eds). Recent Economic Thought **36,** Springer, Dordrecht: 203-229.

Dosi, G., 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. Research policy, 11(3), pp.147-162.

Drover, W., Busenitz, L., Matusik, S., Townsend, D., Anglin, A. and Dushnitsky, G., 2017. A review and road map of entrepreneurial equity financing research: venture capital, corporate venture capital, angel investment, crowdfunding, and accelerators. *Journal of Management*, *43*(6), pp.1820-1853.

Dunham, T.B., 1987. The Buick: a complete history. Automobile Quarterly Publications.

Durand, R. and Khaire, M., 2017. Where do market categories come from and how? Distinguishing category creation from category emergence. Journal of Management, 43(1), 87-110.

Dyer, J.H., Gregersen, H.B. and Christensen, C., 2008. Entrepreneur behaviors, opportunity recognition, and the origins of innovative ventures. *Strategic Entrepreneurship Journal*, *2*(4), pp.317-338.

Early, F. 1956. "The Story of Herbert H. Franklin", Air Cooled News, 10 July.

Echambadi, R., Bayus, B.L. and Agarwal, R., 2008. Entry timing and the survival of startup and incumbent firms in new industries. Working paper, University of Illinois, Champaign.

Eckhardt, J.T. and Shane, S.A., 2003. Opportunities and entrepreneurship. Journal of management, 29(3), 333-349.

Einav, L., 2007. Seasonality in the US motion picture industry. *The Rand journal of economics*, *38*(1), pp.127-145.

Eisenhardt, K.M., 1989. Building theories from case study research. *Academy of management review*, *14*(4), pp.532-550.

Eisenhardt, KM. Brown SL 1998. Time pacing: competing in markets that won't stand still. *Harvard business review*, **76**(2):59-69.

Eisenmann, T., Parker, G. and Van Alstyne, M.W., 2006. Strategies for two-sided markets. *Harvard business review*, *84*(10), p.92.

Eliashberg J., Elberse A, Leenders, MA. 2006. The motion picture industry: Critical issues in practice, current research, and new research directions. *Marketing science*, **25**(6): 638-661.

Faems, D., De Visser, M., Andries, P. and Van Looy, B., 2010. Technology alliance portfolios and financial performance: value-enhancing and cost-increasing effects of open innovation. *Journal of Product Innovation Management*, *27*(6), pp.785-796.

Farquhar, P.H., 1989. Managing brand equity. *Marketing research*, *1*(3).

Farrell, J. and Saloner, G., 1986. Installed base and compatibility: Innovation, product preannouncements, and predation. *The American economic review*, pp.940-955.

Fawcett, S.E., Jones, S.L. and Fawcett, A.M., 2012. Supply chain trust: The catalyst for collaborative innovation. Business Horizons, 55(2), 163-178.

Fine C. 1998. *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*. Perseus Books, Reading, MA.

Fishman A, Gandal N, Shy O. 1993. Planned obsolescence as an engine of technological progress. *The Journal of Industrial Economics* **41**(4): 361-370.

Fiss PC. 2007. A set-theoretic approach to organizational configurations. Academy of management review. 32(4):1180-98.

Fiss, P.C., 2011. Building better causal theories: A fuzzy set approach to typologies in organization research. Academy of Management Journal, 54(2), 393-420.
Fjeldstad, Ø.D., Snow, C.C., Miles, R.E. and Lettl, C., 2012. The architecture of collaboration. Strategic management journal, 33(6), 734-750.
Flink, J.J., 1990. The automobile age. MIT Press.
Fortune A, Mitchell W. 2012. Unpacking firm exit at the firm and industry levels: The adaptation and selection of firm capabilities. *Strategic Management Journal* **33**(7): 794-819.
Foster, R.N., 1985. Timing technological transitions. Technology in Society 7, 127–141.
Franke, N. and Von Hippel, E., 2003. Satisfying heterogeneous user needs via innovation toolkits: the case of Apache security software. Research policy, 32(7), 1199-1215.
Franz, K., 2011. Tinkering: Consumers reinvent the early automobile. University of Pennsylvania Press.
Freeman, C. and Perez, C., 1988. Structural crises of adjustment: business cycles. In Dosi, ed: *Technical change and economic theory. Londres: Pinter*.
Frenken, K., Saviotti, P.P. and Trommetter, M., 1999. Variety and niche creation in aircraft, helicopters, motorcycles and microcomputers. Research Policy, 28(5), 469-488.
Furnari, S., 2014. Interstitial spaces: Microinteraction settings and the genesis of new practices between institutional fields. Academy of management review, 39(4), 439-462.
Gans, J.S. and Stern, S., 2003. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. *Research policy*, *32*(2), pp.333-350.
Ganzaroli, A. and Pilotti, L., 2010. Exaptation as source of creativity and innovation. In *European academy of management: EURAM 2010*.
Garcia, R. and Calantone, R., 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of product innovation management*, *19*(2), pp.110-132.
Garud, R. and Nayyar, P.R., 1994. Transformative capacity: Continual structuring by intertemporal technology transfer. *Strategic management journal*, *15*(5), pp.365-385.
Garud, R., Gehman, J. and Giuliani, A.P., 2014. Contextualizing entrepreneurial innovation: A narrative perspective. Research Policy, 43(7), 1177-1188.
Garud, R., Gehman, J. and Giuliani, A.P., 2016. Technological exaptation: A narrative approach. *Industrial and Corporate Change*, *25*(1), pp.149-166.
Garud, R., Jain, S. and Kumaraswamy, A., 2002. Institutional entrepreneurship in the sponsorship of common technological standards: The case of Sun Microsystems and Java. Academy of management journal, 45(1), 196-214.
Gawer A, Cusumano, MA. 2008. Platform Leaders. *MIT Sloan management review*.
Gawer, A. and Cusumano, M.A., 2002. Platform leadership: How Intel, Microsoft, and Cisco drive industry innovation. Boston, MA: Harvard Business School Press.
Geels FW. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy* **31**(8-9): 1257-1274.
Geels FW. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research policy* **33**(6-7): 897-920.
Geels, F.W., 2005. The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technology analysis & strategic management, 17(4),445-476.
Gehman, J. and Soubliere, J.F., 2017. Cultural entrepreneurship: from making culture to cultural making. *Innovation*, *19*(1), pp.61-73.
Georgano, G. N. 1973. Encyclopaedia of Motorcars. London, UK: Grange-Universal.
George JM, Jones GR. (2000). The role of time in theory and theory building. *Journal of Management*, **26**(4): 657-684.
Gibson CB, Birkinshaw J. 2004. The antecedents, consequences, and mediating role of organizational ambidexterity. Academy of management journal **47**(2): 209-226.
Gnyawali DR, Park BJR. 2009. Co-opetition and technological innovation in small and medium-sized enterprises: A multilevel conceptual model. *Journal of small business management* **47**(3): 308-330.

Golder, P.N. and Tellis, G.J., 1993. Pioneer advantage: Marketing logic or marketing legend?. Journal of marketing Research, 158-170.
Golder, P.N. and Tellis, G.J., 1997. Will it ever fly? Modeling the takeoff of really new consumer durables. Marketing Science, 16(3), 256-270.
Golder, P.N. and Tellis, G.J., 2004. Growing, growing, gone: Cascades, diffusion, and turning points in the product life cycle. Marketing Science, 23(2), 207-218.
Gort M, Klepper S. 1982. Time paths in the diffusion of product innovations. *The economic journal*, **92**(367): 630-653.
Gould, S.J. and Vrba, E.S., 1982. Exaptation—a missing term in the science of form. *Paleobiology, 8*(1), pp.4-15.
Graffin, S.D. and Ward, A.J., 2010. Certifications and reputation: Determining the standard of desirability amidst uncertainty. Organization Science, 21(2), 331-346.
Grant RM. 1996. Toward a knowledge-based theory of the firm. *Strategic management journal*, **17**(S2): 109-122.
Griliches Z. 1992. The search for R&D spillovers. *Scandinavian Journal of Economics* **94**: 29–47.
Grodal S, Gotsopoulos A, Suarez FF. 2015. The coevolution of technologies and categories during industry emergence. *Academy of Management Review*, **40**(3): 23-445.
Gulati R, Puranam P. 2009. Renewal through reorganization: the value of inconsistencies between formal and informal organization. *Organization Science* **20**(2): 422–440.
Gulati, R., Sytch, M. and Tatarynowicz, A., 2012. The rise and fall of small worlds: Exploring the dynamics of social structure. Organization Science, 23(2), 449-471.
Gupta AK, Smith KG, Shalley CE. 2006. The interplay between exploration and exploitation. *Academy of management journal* **49**(4): 693-706.
Hallen BL, Eisenhardt KM 2012. Catalyzing strategies and efficient tie formation: How entrepreneurial firms obtain investment ties. Academy of Management Journal. 55(1),35-70.
Haltiwanger J, Harrington Jr JE. 1991. The impact of cyclical demand movements on collusive behavior. *The RAND Journal of Economics*, **22**(1): 89-106.
Helfat CE, Peteraf MA. 2003. The dynamic resource-based view: Capability lifecycles. *Strategic management journal*, **24**(10): 997-1010.
Helfat, C.E. and Eisenhardt, K.M., 2004. Inter‐temporal economies of scope, organizational modularity, and the dynamics of diversification. *Strategic Management Journal*, *25*(13), pp.1217-1232.
Helyar, J., 2011. *The Lords of the Realm: The Real History of Baseball*. Ballantine Books.
Henderson R, Clark, K. 1990 Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* **35**(1): 9-30.
Henderson, R., 1993. Underinvestment and incompetence as responses to radical innovation: Evidence from the photolithographic alignment equipment industry. *The RAND Journal of Economics*, pp.248-270.
Hendricks, K.B. and Singhal, V.R., 1997. Delays in new product introductions and the market value of the firm: The consequences of being late to the market. Management Science, 43(4), 422-436.
Hertzfeld, A., 2004. Revolution in The Valley [Paperback]: The Insanely Great Story of How the Mac Was Made. " O'Reilly Media, Inc.".
Hess, D.J., 2005. Technology-and product-oriented movements: Approximating social movement studies and science and technology studies. Science, Technology, & Human Values, 30(4), 515-535.
Hienerth, C. and Lettl, C., 2011. Exploring how peer communities enable lead user innovations to become standard equipment in the industry: Community pull effects. Journal of Product Innovation Management, 28(s1), 175-195.
Hill, C.W. and Rothaermel, F.T., 2003. The performance of incumbent firms in the face of radical technological innovation. *Academy of Management Review*, *28*(2), pp.257-274.
Hill, C.W., 1997. Establishing a standard: Competitive strategy and technological standards in winner-take-all industries. The Academy of Management Executive, 11(2), 7-25.
Hiltzik, M.A., 2000. *Dealers of lightning: Xerox PARC and the dawn of the computer age*. Harper Business.

Hirsch, P.M., 1972. Processing fads and fashions: An organization-set analysis of cultural industry systems. *American journal of sociology*, *77*(4), pp.639-659.

Hirsch, P.M., 2000. Cultural industries revisited. *Organization science*, *11*(3), pp.356-361.

Huang D, Markovitch DG, Strijnev A. 2015. Exploring the small movie profitability puzzle. *Marketing Letters* **26**(1): 43-55.

Hughes, T.P. 1987. The evolution of large technological systems. Ed. Hughes, T.P., Bijker, W.E. and Pinch, T.J. *The social construction of technological systems: new directions in the sociology and history of technology*. MIT Press.

Huy QN. 2001. Time, temporal capability, and planned change. *Academy of Management Review* **26**(4): 601-623.

Hwang YS, Park SH. 2007. The organizational life cycle as a determinant of strategic alliance tactics: Research propositions. *International journal of management* **24**(3): 427.

Hyde, C.K., 1989. " The Automobile in American Life," an Exhibit at Henry Ford Museum, Dearborn, Michigan.

Iansiti, M. and Levien, R., 2004. *The keystone advantage: what the new dynamics of business ecosystems mean for strategy, innovation, and sustainability*. Harvard Business Press.

Isaacson, W., 2014. *The Innovators: How a Group of Inventors, Hackers, Geniuses and Geeks Created the Digital Revolution*. Simon and Schuster.

Jacobides, M.G., Knudsen, T. and Augier, M., 2006. Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. Research policy, 35(8), 1200-1221.

Jaffe, A.B., 2000. The US patent system in transition: policy innovation and the innovation process. *Research policy*, *29*(4-5), pp.531-557.

Jansen K, Kristof-Brown AL. 2005. Marching to the beat of a different drummer: Examining the impact of pacing congruence. *Organizational Behavior and Human Decision Processes* **97**(2), 93–105.

Janssen MA, Jager W. 2001. Fashions, habits and changing preferences: Simulation of psychological factors affecting market dynamics. *Journal of economic psychology*, **22**(6): 745-772.

Johnson ME. 2001. Learning from toys: Lessons in managing supply chain risk from the toy industry. *California Management Review*, **43**(3): 106-124.

Kan, A.K.S., Adegbite, E., El Omari, S. and Abdellatif, M., 2016. On the use of qualitative comparative analysis in management. Journal of Business Research, 69(4), 1458-1463.

Kapferer JN. 2012. *The new strategic brand management: Advanced insights and strategic thinking*. Kogan page publishers.

Kaplan, S. and Tripsas, M., 2008. Thinking about technology: Applying a cognitive lens to technical change. Research Policy, 37(5), 790-805.

Katila R, Chen EL. 2008. Effects of search timing on innovation: the value of not being in sync with rivals. *Administrative Science Quarterly* **53**(4): 593-625.

Katila, R. and Ahuja, G., 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. *Academy of management journal*, *45*(6), pp.1183-1194.

Kattel, R. and Mazzucato, M., 2018. Mission-oriented innovation policy and dynamic capabilities in the public sector. *Industrial and Corporate Change*. 27(5), pp.787-801.

Katz, M.L. and Shapiro, C., 1985. Network externalities, competition, and compatibility. The American economic review, 75(3), 424-440.

Katz, M.L. and Shapiro, C., 1994. Systems competition and network effects. Journal of economic perspectives, 8(2), 93-115.

Kauffeld-Monz, M. and Fritsch, M., 2013. Who are the knowledge brokers in regional systems of innovation? A multi-actor network analysis. Regional Studies, 47(5), 669-685.

Kauffman S. 1995. Technology and Evolution: Escaping the Red Queen Effect. *McKinsey Quarterly* **1**: 118-129

Kerin, R.A., Varadarajan, P.R. and Peterson, R.A., 1992. First-mover advantage: A synthesis, conceptual framework, and research propositions. *The Journal of Marketing*, pp.33-52.

Kim WC. Mauborgne R Olenick M.2016. *The Marvel Way: Restoring a Blue Ocean. Case Study*. Harvard Business Publishing.1-18.

Kim, N., Lee, H., Kim, W., Lee, H. and Suh, J.H., 2015. Dynamic patterns of industry convergence: Evidence from a large amount of unstructured data. *Research Policy*, *44*(9), pp.1734-1748.

Kim, W.C. and Mauborgne, R.A., 2014. *Blue ocean strategy, expanded edition: How to create uncontested market space and make the competition irrelevant*. Harvard business review Press.

King, A.A. and Tucci, C.L., 2002. Incumbent entry into new market niches: The role of experience and managerial choice in the creation of dynamic capabilities. *Management science*, *48*(2), pp.171-186.

Kirzner, I.M., 1999. Creativity and/or alertness: A reconsideration of the Schumpeterian entrepreneur. *The Review of Austrian Economics*, *11*(1-2), pp.5-17.

Kirzner, I M., 1973. Competition and Entrepreneurship. Chicago: University of Chicago Press.

Klarner P, Raisch S. 2013. Move to the beat—Rhythms of change and firm performance. *Academy of Management Journal* **56**(1), 160-184.

Kleinknecht, A. and Verspagen, B., 1990. Demand and innovation: Schmookler re-examined. *Research policy*, *19*(4), pp.387-394.

Klepper S. 1996. Entry, exit, growth and innovation over the product life cycle. *American Economic Review* **86**(3): 562–583.

Klepper, S. 2002. The evolution of the U.S. automobile industry and Detroit as its capital. Paper presented at 9th Congress of the International Schumpeter Society, Gainesville, FL.

Klepper, S. 2007. Disagreements, spinoffs, and the evolution of Detroit as the capital of the US automobile industry. Management Science, 53(4), 616-631.

Klepper, S. 2009. "Silicon Valley—a chip off the old Detroit bloc." In Entrepreneurship, Growth, and Public Policy, David B. Audretsch and Robert Strom, eds., Cambridge University Press: Cambridge, England

Klepper, S. and Simons, K.L., 2000. Dominance by birthright: entry of prior radio producers and competitive ramifications in the US television receiver industry. *Strategic Management Journal*, pp.997-1016.

Kline, R. and Pinch, T., 1996. Users as agents of technological change: The social construction of the automobile in the rural United States. Technology and culture, 37(4), 763-795.

Kogut, B. and Zander, U., 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization science*, *3*(3), pp.383-397.

Kostakis, V. and Papachristou, M., 2014. Commons-based peer production and digital fabrication: The case of a RepRap-based, Lego-built 3D printing-milling machine. Telematics and Informatics, 31(3), 434-443.

Krider, RE, Weinberg CB. 1998. Competitive dynamics and the introduction of new products: The motion picture timing game. *Journal of Marketing Research*, 35(1): 1-15.

Kumar, N., Scheer, L. and Kotler, P., 2000. From market driven to market driving. European management journal, 18(2), 129-142.

Lakhani, K.R. and Von Hippel, E., 2003. How open source software works:"free" user-to-user assistance. Research policy, 32(6), 923-943.

Lakhani, K.R. and Wolf, R.G., 2003. Why hackers do what they do: Understanding motivation and effort in free/open source software projects.

Lampel J, Lant T, Shamsie J., 2000. Balancing act: Learning from organizing practices in cultural industries. *Organization science* **11**(3): 263-269.

Lane, D.A., 2016. Innovation cascades: artefacts, organization and attributions. *Phil. Trans. R. Soc. B*, *371*(1690), p.20150194.

Langlois, R.N. and Robertson, P.L., 1992. Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries. Research policy, 21(4), 297-313.

Langlois, R.N., 1992. External economies and economic progress: The case of the microcomputer industry. Business history review, 66(1), 1-50.

Langlois, R.N., 2002. Modularity in technology and organization. *Journal of economic behavior & organization*, *49*(1), pp.19-37.

Langlois, R.N., 2007. The entrepreneurial theory of the firm and the theory of the entrepreneurial firm. Journal of Management Studies, 44(7), 1107-1124.

Lavie, D., Stettner, U. and Tushman, M.L., 2010. Exploration and exploitation within and across organizations. *The Academy of Management Annals*, *4*(1), pp.109-155.

Lawrence, T.B., 1999. Institutional strategy. *Journal of management*, *25*(2), pp.161-187.

Lawton, T.C., Rajwani, T. and Minto, A., 2017. Why trade associations matter: Exploring function, meaning, and influence. Journal of Management Inquiry, 27(1), 5-9.

Lechevalier S., Nishimura J., and Storz C. "Diversity in patterns of industry evolution: how an intrapreneurial regime contributed to the emergence of the service robot industry." *Research Policy* 43, no. 10 (2014): 1716-1729.

Lee JR, O'Neal DE, Pruett MW, Thomas H. Planning for dominance: a strategic perspective on the emergence of a dominant design. R&D Management. 1995 25(1), 3-15.

Lettl, C., 2007. User involvement competence for radical innovation. Journal of engineering and technology management, 24(1-2), 53-75.

Lettl, C., Herstatt, C. and Gemuenden, H.G., 2006. Users' contributions to radical innovation: evidence from four cases in the field of medical equipment technology. R&D Management, 36(3), 251-272.

Levinthal D. 1998. The Slow Pace of Rapid Technological Change: Gradualism and Punctuation in Technological Change. *Industrial and Corporate Change* **7**(2): 217-247.

Levinthal, D.A., 1998. The slow pace of rapid technological change: gradualism and punctuation in technological change. *Industrial and corporate change*, *7*(2), pp.217-247.

Levitt, B. and March, J.G., 1988. Organizational learning. *Annual review of sociology*, *14*(1), pp.319-338.

Levy, D. and Scully, M., 2007. The institutional entrepreneur as modern prince: The strategic face of power in contested fields. *Organization Studies*, *28*(7), pp.971-991.

Levy, S., 1984. Hackers: Heroes of the computer revolution. Garden City, NY: Anchor Press/Doubleday.

Liao, S. and Seifert, R.W., 2015. On the optimal frequency of multiple generation product introductions. *European Journal of Operational Research*, *245*(3), pp.805-814.

Lieberman MB, Asaba S. 2006. Why do firms imitate each other? *Academy of Management Review* **31**(2): 366–385.

Lieberman, M.B. and Montgomery, D.B., 1998. First-mover (dis) advantages: retrospective and link with the resource-based view. Strategic management journal, 19(12), 1111-1125.

Lilien, G.L. and Yoon, E., 1990. The timing of competitive market entry: An exploratory study of new industrial products. Management science, 36(5), 568-585.

Macher, J.T. and Richman, B.D., 2004. Organisational responses to discontinuous innovation: a case study approach. *International Journal of Innovation Management*, *8*(01), pp.87-114.

Mahajan V, Eitan M, Bass FM. 1990 "New Product Diffusion Models in Marketing: A Review and Directions for Research." *Journal of Marketing* **54**(1): 1-26.

Mäkinen SJ Dedehayir O. 2014. Business Ecosystems' Evolution—An Ecosystem Clockspeed Perspective. In *Collaboration and competition in business ecosystems*. Adner R, Oxley J, Silverman B. **30**: 99-125. Emerald Group Publishing Limited.

Malerba, F. and Orsenigo, L., 1995. Schumpeterian patterns of innovation. Cambridge Journal of Economics, 19(1), 47-65.

Malerba, F. and Orsenigo, L., 1996. The dynamics and evolution of industries. Industrial and Corporate change, 5(1), 51-87.

Malerba, F., Nelson, R., Orsenigo, L. and Winter, S., 2008. Public policies and changing boundaries of firms in a "history-friendly" model of the co-evolution of the computer and semiconductor industries. *Journal of Economic Behavior & Organization*, *67*(2), pp.355-380.

March JG. 1991. Exploration and exploitation in organizational learning. Organization Science **2**(1): 71-87.

Markides, C. and Sosa, L., 2013. Pioneering and first mover advantages: the importance of business models. Long Range Planning, 46(4-5), 325-334.
Markides, C., 2006. Disruptive innovation: In need of better theory. *Journal of product innovation management*, *23*(1), pp.19-25.
Markides, C.C. and Geroski, P.A., 2004. Fast second: How smart companies bypass radical innovation to enter and dominate new markets. John Wiley & Sons.
McCray, W.P., 2013. The visioneers: how a group of elite scientists pursued space colonies, nanotechnologies, and a limitless future. Princeton University Press.
McGrath JE, Kelly JR. 1986. *Time and human interaction: Toward a social psychology of time*. Guilford Press.
McGuire, M. and Schneck, D., 2010. What if Hurricane Katrina hit in 2020? The need for strategic management of disasters. *Public Administration Review*, *70*, pp.s201-s207.
Miles, M.B. and Huberman, A.M. (1994). Qualitative Data Analysis – An Expanded Sourcebook, Sage, Newbury Park, CA
Miller D, Shamsie J. 1996. The resource-based view of the firm in two environments: The Hollywood film studios from 1936 to 1965. *Academy of management journal*, **39**(3): 519-543.
Miller D. 1992. Environmental fit versus internal fit. *Organization Science* **3**(2): 159–178.
Miller, D., 1986. Configurations of strategy and structure: Towards a synthesis. Strategic management journal, 7(3), pp.233-249.
Miller, G.W., 2015. Car Crazy: The Battle for Supremacy Between Ford and Olds and the Dawn of the Automobile Age. Public Affairs.
Miron, J.A., 1986. Financial panics, the seasonality of the nominal interest rate, and the founding of the Fed. *The American Economic Review*, *76*(1), pp.125-140.
Mitnick, B.M. and Ryan, R.C., 2015. On making meanings: Curators, social assembly, and mashups. *Strategic Organization*, *13*(2), pp.141-152.
Mitnick, B.M., 1975. The theory of agency. Public Choice, 24(1), 27-42.
Moore, G.A., 1999. Crossing the chasm (Rev. ed.). New York: HarperBusiness.
Moorman, C. and Slotegraaf, R.J., 1999. The contingency value of complementary capabilities in product development. *Journal of Marketing Research*, pp.239-257.
Morris, M., Schindehutte, M. and Allen, J., 2005. The entrepreneur's business model: toward a unified perspective. Journal of business research, 58(6), 726-735.
Mowery, D. and Rosenberg, N., 1979. The influence of market demand upon innovation: a critical review of some recent empirical studies. *Research policy*, *8*(2), pp.102-153.
Mowery, D.C. and Nelson, R.R. eds., 1999. Sources of industrial leadership: studies of seven industries. Cambridge University Press.
Muñiz, A. M. Jr., and T. C. O'Guinn. 2001. Brand community. Journal of Consumer Research 27 (4): 412–432.
Murmann JP, Frenken K. 2006. Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy* **35**(7): 925-952.
Negus, K., 1992. *Producing pop: Culture and conflict in the popular music industry*. London: E. Arnold.
Nickerson JA, Zenger TR. 2002. Being efficiently fickle: a dynamic theory of organizational choice. *Organization Science* **13**(5): 547–566.
Nickerson JA, Zenger TR. 2008. Envy, Comparison Costs, and the Economic Theory of the Firm. *Strategic Management Journal* **29**(13):1429-1449.
Norman, D.A. and Verganti, R., 2014. Incremental and radical innovation: Design research vs. technology and meaning change. *Design issues*, *30*(1), pp.78-96.
Ocasio W. 1997. Towards an attention-based view of the firm. *Strategic management journal* **18**(S1): 187-206.
Ordanini, A., Parasuraman, A. and Rubera, G., 2014. When the Recipe Is More Important Than the Ingredients: A Qualitative Comparative Analysis (QCA) of Service Innovation Configurations. Journal of Service Research, 17(2), 134-149.

O'Reilly III CA, Tushman ML. 2013. Organizational ambidexterity: Past, present, and future. *Academy of management Perspectives* **27**(4): 324-338.
Orlikowski, W.J. and Yates, J., 2002. It's about time: Temporal structuring in organizations. *Organization science*, *13*(6), pp.684-700.
Osborne, A. and Dvorak, J., 1984. Hypergrowth: the rise and fall of Osborne Computer Corporation. Idthekkethan Pub. Co..
Pacheco De Almeida, G, Zemsky P. 2008. Time-Consuming Technology Development: How Imitation and Spillovers Affect Competitive Dynamics. ***Working Paper: INSEAD.***
Patriotta, G. and Hirsch, P.M., 2016. Mainstreaming innovation in art worlds: Cooperative links, conventions and amphibious artists. Organization Studies, 37(6), pp.867-887.
Pavitt K. 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. *Research policy* **13**(6): 343-373.
Peltoniemi M. 2011. Reviewing Industry Life-cycle Theory: Avenues for Future Research. *International Journal of Management Reviews* **13**(4): 349-375.
Pérez-Nordtvedt L, Payne GT, Short C, Kedia BL. 2008. An entrainment-based model of temporal organizational fit, misfit, and performance. *Organization Science* **19**(5): 785-801.
Perry, C., 1998. Processes of a case study methodology for postgraduate research in marketing. *European journal of marketing*, *32*(9/10), pp.785-802.
Peteraf, M.A., 1993. The cornerstones of competitive advantage: a resource-based view. *Strategic management journal*, *14*(3), pp.179-191.
Pettus, Michael L., Yasemin Y. Kor, Joseph T. Mahoney, and Steven C. Michael. "Sequencing and timing of strategic responses after industry disruption: Evidence from post-deregulation competition in the US railroad industry." *Strategic Organization* (2017): 1476127017743502.
Phelan, S., Dalgic, T., Li, D. and Sethi, D., 2006. The Development of entrepreneurial networks: A necessary condition for international new ventures. Strategic Management Review, 1(1), 1-21.
Pianka ER. 1970. On r-and K-selection. *The American Naturalist* **104**(940): 592-597.
Plummer, L.A., Allison, T.H. and Connelly, B.L., 2016. Better together? Signaling interactions in new venture pursuit of initial external capital. Academy of Management Journal, 59(5), 1585-1604.
Polidoro F, Toh PK. 2011. Letting rivals come close or warding them off? The effects of substitution threat on imitation deterrence. *Academy of Management Journal*, **54**(2): 369-392.
Pollock, T.G. and Rindova, V.P., 2003. Media legitimation effects in the market for initial public offerings. Academy of Management Journal, 46(5), 631-642.
Price, R., 1993. *Steve Jobs & The NeXT Big Thing*. Atheneum.
Priem RL, Li S, Carr JC. 2012. Insights and new directions from demand-side approaches to technology innovation, entrepreneurship, and strategic management research. *Journal of management*, **38**(1): 346-374.
Querbes, A. and Frenken, K., 2017. Evolving user needs and late-mover advantage. *Strategic organization*, *15*(1), pp.67-90.
Radas S, Shugan S.1998. Seasonal marketing and timing new product introductions. *Journal of Marketing Research* **35**(3): 296-315.
Raisch S, Birkinshaw J, Probst G, Tushman ML. 2009.Organizational ambidexterity: balancing exploitation and exploration for sustained performance. *Organization Science* **20**(4): 685–695.
Rao H. 1994 .The social construction of reputation: Certification contests, legitimation, and the survival of organizations in the American automobile industry: 1895–1912. Strategic management journal.15(S1), 29-44.
Rao, H., 2004. Institutional activism in the early American automobile industry. Journal of Business Venturing, 19(3), 359-384.
Reger RK, Huff AS. 1993. Strategic groups: A cognitive perspective. *Strategic management journal*, **14**(2): 103-123.

Reid, S.E. and De Brentani, U., 2010. Market Vision and Market Visioning Competence: Impact on Early Performance for Radically New, High-Tech Products. Journal of Product Innovation Management, 27(4), 500-518.
Ries, E., 2011. *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. Crown Books.
Rifkin, J., 2014. The zero marginal cost society: The internet of things, the collaborative commons, and the eclipse of capitalism. St. Martin's Press.
Rihoux, B. and Ragin, C.C., 2008. Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques (Vol. 51). Sage Publications.
Rinallo, D. and Golfetto, F., 2011. Exploring the knowledge strategies of temporary cluster organizers: A longitudinal study of the EU fabric industry trade shows (1986–2006). Economic Geography, 87(4), 453-476.
Rindova, V.P. and Petkova, A.P., 2007. When is a new thing a good thing? Technological change, product form design, and perceptions of value for product innovations. Organization Science, 18(2), 217-232.
Rink DR, Swan JE. 1979. Product life cycle research: A literature review. Journal of business research, **7**(3): 219-242.
Riordan, M.H. and Williamson, O.E., 1985. Asset specificity and economic organization. *International Journal of Industrial Organization*, *3*(4), pp.365-378.
Robertson D, Ulrich K. 1998. Planning for product platforms. Sloan management review **39**(4): 19-31.
Robinson J. 1953. Imperfect Competition Revisited. *Economic Journal.* **63**(251): 579-93.
Robson A. 2003. The evolution of rationality and the Red Queen. *Journal of Economic Theory*; **111**(1): 1-22.
Rochet JC, Tirole J., 2003. Platform competition in two-sided markets. *Journal of the european economic association* **1**(4): 990-1029.
Rogers EM. 2010. *Diffusion of innovations*. Simon and Schuster.
Romanelli, E., 1989. Environments and strategies of organization start-up: Effects on early survival. Administrative Science Quarterly, 369-387.
Romer, P.M., 1990. Endogenous technological change. *Journal of political Economy*, *98*(5, Part 2), pp.S71-S102.
Rosen D. 1993. A Fresh Look at Movie Making. Presented at *American Marketing Association's Marketing Research Conference*, Chicago.
Rosenbloom, R.S., 2000. Leadership, capabilities, and technological change: The transformation of NCR in the electronic era. *Strategic Management Journal*, pp.1083-1103.
Rosenkopf, L. and Tushman, M.L., 1998. The coevolution of community networks and technology: Lessons from the flight simulation industry. Industrial and Corporate Change, 7(2), pp.311-346.
Rotemberg JJ, Saloner G. 1986. A supergame-theoretic model of price wars during booms. *The American Economic Review* **76**(3): 390-407.
Rothaermel, F.T., 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic management journal*, *22*(6-7), pp.687-699.
Ryan, R.C., 2014. Harmonic Oscillation Theory: Competitive and Cooperative Entrainment as a View of the Firm. In Academy of Management Proceedings 1, 17573-17578.
Sanchez, R., 1995. Strategic flexibility in product competition. *Strategic management journal*, *16*(S1), pp.135-159.
Santos, F.M. and Eisenhardt, K.M., 2009. Constructing markets and shaping boundaries: Entrepreneurial power in nascent fields. Academy of Management Journal, 52(4), 643-671.
Saviotti, P.P. and Metcalfe, J.S., 1984. A theoretical approach to the construction of technological output indicators. Research Policy, 13(3), 141-151.
Schilling MA. 1998. Technological lockout: An integrative model of the economic and strategic factors driving technology success and failure. *Academy of management review* **23**(2): 267-284.

Schilling MA. 2003. Technological leapfrogging: Lessons from the US video game console industry. *California management review* **45**(3): 6-32.
Schmookler, J. 1966. Invention and economic growth. Cam- bridge, MA: Harvard University Press.
Schubert, E.F., Gessmann, T. and Kim, J.K., 2005. *Light emitting diodes*. John Wiley & Sons, Inc..
Schumpeter J. 1934. *The Theory of Economic Development: An inquiry into profits, capital, credit, interest and the business cycle*. Harvard University Press: Cambridge, MA.
Scott, A.J., 2004. Cultural-products industries and urban economic development: prospects for growth and market contestation in global context. *Urban affairs review*, *39*(4), pp.461-490.
Sedita, S.R., 2012. Leveraging the intangible cultural heritage: Novelty and innovation through exaptation. *City, Culture and Society*, *3*(4), pp.251-259.
Segev, E., 1989. A systematic comparative analysis and synthesis of two business-level strategic typologies. *Strategic Management Journal*, *10*(5), pp.487-505.
Shane, S. and Venkataraman, S., 2000. The promise of entrepreneurship as a field of research. Academy of management review, 25(1), 217-226.
Shane, S.A., 2003. *A general theory of entrepreneurship: The individual-opportunity nexus*. Edward Elgar Publishing.
Shepherd, D.A., 1999. Venture capitalists' assessment of new venture survival. Management science, 45(5), 621-632.
Shi WS, Prescott JE. 2012. rhythm and entrainment of acquisition and alliance initiatives and firm performance: A temporal perspective. *Organization Studies* **33**(10): 1281-1310.
Shifman L. 2014. *Memes in digital culture*. MIT press.
Simonoff JS, Sparrow IR. 2000. Predicting movie grosses: Winners and losers, blockbusters and sleepers. *Chance* **13**(3): 15-24.
Sirmon DG Hitt MA, Ireland RD, Gilber BA. 2011. Resource orchestration to create competitive advantage breadth, depth, and life cycle effects. *Journal of Management* **37**(5): 1390-1412.
Slawinski, N. and Bansal, P., 2015. Short on time: Intertemporal tensions in business sustainability. *Organization Science*, *26*(2), pp.531-549.
Smith, T.G., 1986. *Industrial light and magic: The art of special effects*. Random House Digital, Inc..
Society of Automobile Engineers (SAE), Nomenclature Division (August 20, 1916). "What's What in Automobile Bodies Officially Determined". The New York Times. New York, NY USA. Nomenclature Division, Society of Automobile Engineers.
Solnick SJ, Hemenway D., 2005. Are positional concerns stronger in some domains than in others? *American Economic Review*, **95**(2):147-151.
Sood, A. and Tellis, G.J., 2005. Technological evolution and radical innovation. *Journal of Marketing*, *69*(3), pp.152-168.
Soule, S.A., 2012. Social movements and markets, industries, and firms. Organization Studies, 33(12), 1715-1733.
Spitzer F. 2013. *Principles of random walk*, Springer Science & Business Media.
Srinivasan, R., Lilien, G.L. and Rangaswamy, A., 2004. First in, first out? The effects of network externalities on pioneer survival. Journal of Marketing, 68(1), 41-58.
Starbuck, W.H., 1992. Learning by knowledge-intensive firms. *Journal of management Studies*, *29*(6), pp.713-740.
Stettner U, Lavie D. 2014. Ambidexterity under scrutiny: Exploration and exploitation via internal organization, alliances, and acquisitions. *Strategic management journal*, **35**(13):1903-1929.
Stieglitz, N. and Heine, K., 2007. Innovations and the role of complementarities in a strategic theory of the firm. Strategic management journal, 28(1), 1-15.
Stigler G.1964. A Theory of Oligopoly. *Journal of Political Economy* **72**:44-61.
Suarez FF. Grodal S, Gotsopoulos A. 2015. Perfect timing? Dominant category, dominant design, and the window of opportunity for firm entry. *Strategic Management Journal* **36**(3): 437-448.
Suarez, F.F. and Kirtley, J., 2012. Dethroning an established platform. *MIT Sloan Management Review*, *53*(4), p.35.

Suárez, F.F. and Utterback, J.M., 1995. Dominant designs and the survival of firms. Strategic management journal, 16(6), 415-430.

Suarez, F.F., 2004. Battles for technological dominance: an integrative framework. Research Policy, 33(2), 271-286.

Suddaby, R. and Greenwood, R., 2005. Rhetorical strategies of legitimacy. *Administrative science quarterly*, *50*(1), pp.35-67.

Sydow, J., Schreyögg, G. and Koch, J., 2009. Organizational path dependence: Opening the black box. Academy of management review, 34(4), 689-709.

Taylor A, Helfat CE. 2009. Organizational linkages for surviving technological change: complementary assets, middle management, and ambidexterity. ***Organization Science*** **20**(4): 718–739.

Teece DJ. 1986. Profiting from technological innovation'. *Research Policy* **15**: 285-305.

Teece, D.J., 1980. Economies of scope and the scope of the enterprise. *Journal of economic behavior & organization*, *1*(3), pp.223-247.

Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic management journal*, *28*(13), pp.1319-1350.

Teece, D.J., Pisano, G. and Shuen, A., 1997. Dynamic capabilities and strategic management. *Strategic management journal*, *18*(7), pp.509-533.

Tellis, G.J. and Golder, P.N., 1996. First to Market, First to Fail? Real Causes of Enduring Market Leadership. MIT Sloan Management Review, 37(2),65.

Tellis, Gerard J. 2010. Network Effects: Do They Warm or Chill A Budding Product? Available at SSRN.

Tellis, Gerard J. and Golder, Peter N. (2001). Will and Vision: How Latecomers Grow to Dominate Markets. New York: McGraw Hill.

Throsby D. 1999. Cultural capital. *Journal of cultural economics* **23**(1-2): 3-12.

Toffler, A., 1964. *The culture consumers: Art and affluence in America*. New York: St. Martin's Press.

Tripsas M. 2008. Customer preference discontinuities: A trigger for radical technological change. *Managerial and decision economics* **29**(2-3):79-97.

Tripsas, M. and Gavetti, G., 2000. Capabilities, cognition, and inertia: Evidence from digital imaging. *Strategic management journal*, pp.1147-1161.

Tripsas, M., 1997. Surviving Radical Technological Change through Dynamic Capability: Evidence from the Typesetter Industry. *Industrial & Corporate Change*, *6*(2).

Tsai, W., 2000. Social capital, strategic relatedness and the formation of intraorganizational linkages. *Strategic management journal*, pp.925-939.

Tsoukas, H., 1989. The validity of idiographic research explanations. *Academy of management review*, *14*(4), pp.551-561.

Turner, F., 2005. Where the counterculture met the new economy: The WELL and the origins of virtual community. *Technology and Culture*, *46*(3), pp.485-512.

Turner, F., 2010. From counterculture to cyberculture: Stewart Brand, the Whole Earth Network, and the rise of digital utopianism. University of Chicago Press.

Tushman, M.L. and Anderson, P., 1986. Technological discontinuities and organizational environments. *Administrative science quarterly*, pp.439-465.

Unknown Author, 1904. Frank Leslie's Popular Monthly. January 1904 List of Automotive Manufacturers.

Van de Ven, A.H., 1993. A community perspective on the emergence of innovations. Journal of Engineering and Technology Management, 10(1-2), 23-51.

Vandekerckhove J, De Bondt R., 2007. Asymmetric spillovers and sequential strategic investments. *Social Science Research Network* 1-31.

Veit, S., 1993. *Stan Veit's history of the personal computer*. Acheville, NC: WorldComm.

Verganti R. 2009. *Design driven innovation: changing the rules of competition by radically innovating what things mean*. Harvard Business Press.

Verona, G. and Ravasi, D., 2003. Unbundling dynamic capabilities: an exploratory study of continuous product innovation. *Industrial and corporate change*, *12*(3), pp.577-606.

Villani, M., Bonacini, S., Ferrari, D., Serra, R. and Lane, D., 2007. An agent-based model of exaptive processes. *European Management Review*, *4*(3), pp.141-151.

Von Hippel, E. and von Krogh, G., 2003. Open source software and the “private-collective” innovation model: Issues for organization science. Organization science, 14(2), 209-223.

Von Hippel, E., 2005. Democratizing innovation. MIT press.

Watts, D.J., 2004. *Small worlds: the dynamics of networks between order and randomness*. Princeton university press.

West, J. and Kuk, G., 2016. The complementarity of openness: How MakerBot leveraged Thingiverse in 3D printing. Technological Forecasting and Social Change, 102, 169-181.

Wicks, D., 2016.The Role of Sensemaking and Institutions in Regulatory Change: The Case of Medical Marijuana. In *Academy of Management Proceedings* (Vol. 2016, No. 1, p. 10552). Academy of Management.

Windrum P, Birchenhall C. 1998. Is product life cycle theory a special case? Dominant designs and the emergence of market niches through coevolutionary-learning. *Structural Change and Economic Dynamics* ***9***(1): 109-134.

Wood, S.C. and Brown, G.S., 1998. Commercializing nascent technology: The case of laser diodes at Sony. *Journal of Product Innovation Management*, *15*(2), pp.167-183.

Wu, B., Wan, Z. and Levinthal, D.A., 2014. Complementary assets as pipes and prisms: Innovation incentives and trajectory choices. *Strategic Management Journal*, *35*(9), pp.1257-1278.

Zachary MA, Gianiodis PT, Payne GT, Markman GD. 2015 Entry timing: Enduring lessons and future directions. Journal of Management. 41(5), 1388-1415.

Zheludev, N., 2007. The life and times of the LED—a 100-year history. *Nature Photonics*, *1*(4), p.189.

Zott, C. and Amit, R., 2010. Business model design: an activity system perspective. Long range planning, 43(2-3), 216-226.

Zott, C., 2003. Dynamic capabilities and the emergence of intraindustry differential firm performance: insights from a simulation study. Strategic management journal, 24(2), 97-125.