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Entrepreneurial tweaking

An empirical study of technology diffusion through secondary inventions and design modifications by start-ups

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Abstract

Purpose – Existing theories of innovation posit a split between incremental innovations produced by large incumbents and radical innovations produced by entrepreneurial start-ups. The purpose of this paper is to present empirical evidence challenging this foundational assumption by demonstrating that entrepreneurs play a leading role, not a subordinate role, in sourcing incremental innovations through secondary inventions and design modifications.

Design/methodology/approach – Applying the methods of historical econometrics, this study draws parallels between two dramatically different contexts: the mechanized reaper (1803-1884) and cloud computing services (1961-2011). Data for the reaper were drawn from 517 historical sources involving 348 modifications. Data for cloud computing services were drawn from 3,882 US patent filings and firm-level data drawn from the Dun & Bradstreet database.

Findings – Entrepreneurial tweaking plays a central role in commercializing dominant designs. Among the highest-ranked incremental innovations leading to the commercialization of the reaper and cloud computing, nearly 90 percent were attributable to entrepreneurs. And yet, an entrepreneur had only a one in fourteen chance of garnering returns from a reaper innovation and a one in nine chance of gains from a cloud computing improvement.

Practical implications – Incremental innovations by entrepreneurs are indispensable to the widespread commercial acceptance of new technologies. Yet, entrepreneurial tweakers rarely benefit from the significant value they have created.

Originality/value – This paper constitutes the first significant attempt to empirically address the central role of entrepreneurs in producing incremental innovations that result in the commercialization of radical breakthroughs.

Keywords Innovation, Diffusion, Value appropriation, Entrepreneurial tweaking, Entrepreneurialism, Start-ups, Technology

Paper type Research paper

1. Introduction

Much of the literature concerning innovation divides the universe into large-firm incrementalism and small-firm radicalism. Subject to some notable variations based on industry and environmental factors (Acs and Audretsch, 1987; Methe *et al.*, 1996; Ahuja and Lampert, 2001), this approach highlights the purported tendency of large firms to extract value from innovations through incremental improvements and efficient-scale replication of emergent technologies (Abernathy and Utterback, 1978; Utterback, 1994; Baumol, 2004). Entrepreneurial ventures, meanwhile, are widely believed to possess an advantage in engineering revolutionary breakthroughs

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(Acs and Audretsch, 1990; Banbury and Mitchell, 1995; Baumol, 2004; Acs *et al.*, 2009). Although this incumbent vs entrepreneur bifurcation has gained considerable support, this paper demonstrates that the dichotomy is problematic, because in addition to driving radical innovation, new ventures play a pronounced role in the commercialization of breakthrough technologies through entrepreneurial "tweaking."

In the broadest sense, tweaks are "small modifications intended to improve a system" (Oxford English Dictionary, 2012). In the context of innovation economics, Meisenzahl and Mokyr (2010) referred to tweaking as "the myriad of small and medium cumulative micro-inventions that improve and debug existing inventions," by adapting them to more effective uses, and by combining them in new applications (p. 5). The essence of tweaking is that it embodies incremental innovation, which Baumol (2004) termed "the increased reliability and enhanced user friendliness of products and the finding of new uses for those products" (p. 16). Entrepreneurial tweaking, as it has been defined for this paper, specifically involves the development by start-up firms of secondary inventions and design modifications that are essential to the commercialization and diffusion of new technologies. Secondary inventions are patented incremental innovations, while design modifications are unpatented, but nonetheless significant, incremental innovations. Long thought to be the domain of large firms (Nelson and Winter, 1982; Utterback, 1994; Methe *et al.*, 1996), scholarly conceptions of incremental innovations have resulted in two questionable assumptions: first, start-ups are primarily focussed on producing radical innovations; and second, large incumbent firms are superior to start-ups in producing incremental improvements.

In stress testing the efficacy of these two assumptions, it is necessary to ask: Is it possible that entrepreneurs not only excel at radical innovation but also incremental innovation? If so, then it is conceivable that entrepreneurs play a central role, perhaps even a dominant role, in "tweaking" breakthrough technologies. The implications of this finding would add considerably to the understanding of technology development and diffusion. It would also contribute new perspectives on the internalization of adopter information costs as well as the creation and appropriation of rents through commercializable innovations. Consistent with the insights advanced by Teece (1986) regarding the appropriation of innovation value, the findings of this paper are that entrepreneurial tweakers face extreme appropriation risks. Despite the central role entrepreneurs play in commercializing breakthrough technologies through incremental innovations, the evidence from mechanized reapers and cloud computing services suggests that incumbents are able to wrest control over the rents created by entrepreneurs through the use of "soft power" (Santos and Eisenhardt, 2009). Building on the Santos and Eisenhardt model of power in nascent industries, the new institutional theories related to myth building and perceived legitimacy (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Zucker, 1987), and Teece's (1986) framework for innovating firms, this study forcefully underscores a crucial paradox: entrepreneurial firms, having contributed to the commercialization of new technologies through incremental improvements, rarely participate in appropriating the rents associated with the very technologies that they helped to commercialize.

The following section outlines the theoretical gaps caused by the bifurcation of radically innovating entrepreneurs and incrementally innovating incumbents. Within this framework, I advance and then test a set of four hypotheses that predict extensive and commercially decisive incremental innovation by entrepreneurial tweakers. Following a presentation of the results, I discuss notable implications for scholars and practitioners.

2. Theory development and hypotheses

2.1 Technology diffusion – overcoming of overcoming adopter uncertainty

According to Rogers (2003), "Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system" (p. 35). Specifically relating to commercializable products and services, diffusion involves the acceptance and spread of new technology in a market or user community (Loch and Huberman, 1999). Diffusion dynamics have been shown to be highly sensitive to specific industries (Acs and Audretsch, 1987), the contextual environment (Banbury and Mitchell, 1995) and the degree of ambiguity stemming from the relative newness of nascent-stage markets (Weick, 1995; Santos and Eisenhardt, 2009). For these reasons, it is critical to assess the risks associated with new technologies, as potential adopters perceive them. Rogers (2003) casts this issue as an ongoing challenge by adopters to reduce uncertainty by obtaining information.

Individuals participating in nascent-stage industries have a strong incentive to take steps to alleviate the adopters' struggle for quality information. Often, a common set of metrics is developed to communicate relative performance on a standardized scale. For example, in the development of the mechanized reaper (1803-1884), inventor-entrepreneurs staged elaborate, well-attended field trials to demonstrate the relative performance of their respective design modifications (Olmstead, 1975; Olmstead and Rhode, 1995). A key barrier to the adoption of reapers from 1831 to the late 1850s was the tremendous force required to pull the mechanism through the fields, a force known as "draft" (Olmstead, 1975). Unacceptably high draft (i.e. the moment of force, also known as "torque") posed several serious liabilities: the tendency to exhaust or even injure harnessed horses; the prospect of destroying rather than harvesting the crop; and, the common occurrence of stressing the reaper to such a degree that it "collapsed into a heap of cutters and bolts" (New York State Agricultural Society, 1857). Diffusion of the reaper was, therefore, largely contingent upon a meaningful reduction in draft. Newspapers and agricultural magazines from the 1800s are filled with accounts of field trials, each of which meticulously recounted the all-important statistics regarding draft and provided detailed accounts about the inventors who achieved meaningful improvements.

Similarly, cloud-computing firms have sought to address adopter risk aversion through field trials, albeit in the form of seminars and trade shows (Kaplan, 2011). Like the reaper, risk aversion constrained the diffusion of commercializable cloud computing solutions for nearly 50 years. Unlike the reaper, there is no unitary metric for cloud computing that comprehensively captures performance and reliability. Nonetheless, seeking to address the barriers to adoption through the development of clear metrics has been a primary preoccupation of entrepreneurial tweakers. These metrics include: the probability of a system failure, the probability of a security breach, the return on IT investments, the capital expense to operating expense conversions and the time-to-full-deployment for updated software.

Major technological breakthroughs are rarely, if ever, immediately ready for commercialization (Hargadon and Douglas, 2001; Meisenzahl and Mokyr, 2010). Rather, early competition to develop a "dominant design" (Utterback, 1994) fuels competing conceptions of what constitutes a commercializable solution. A lengthy development process involving incremental improvements necessarily precedes commercialization and widespread diffusion of new technologies. Articulated more formally:

H1. The rate of diffusion for breakthrough technologies is positively related to secondary inventions and design modifications.

2.2 Entrepreneurial tweaking and the internalization of information costs

Adoption lags persist when risk-averse decision makers judge the uncertainties of alternative technologies to be too significant to warrant acquisition and use (Soete and Turner, 1984; Tushman and Murmann, 1998). Prior literature on diffusion theory (e.g. Rogers, 2003) addresses adopters' search for more and better information. Unless these external costs are internalized, there will be no technology diffusion because decision makers will perceive that they possess inadequate information to adopt the new technology. My assertion in this paper is that prior attempts to articulate the relationship between decision makers and dominant designers (Henderson and Clark, 1990; Utterback, 1994; Tushman and Murmann, 1998) underemphasize the role that entrepreneurial tweakers play in systematically internalizing the decision makers' information costs by steadily improving the capabilities and performance of the dominant design. Dominant incumbents may be unwilling or unable to internalize adopters' information costs. Therefore, either the dominant design will remain dormant, or entrepreneurial tweakers will produce sufficient incremental innovations to make the dominant design commercializable.

To an increasing degree, there has come to be a tendency to bifurcate innovation into two contrasting sources: revolutionary breakthroughs emanating from entrepreneurial firms and incremental enhancements emanating from large, established incumbents (Acs and Audretsch, 1990; Baumol, 2004; Acs *et al.*, 2009). Baumol (2004) hypothesized that a "disproportionate share of breakthrough inventions is contributed by independent inventors, entrepreneurs and small or startup firms, while the large firms specialize in incremental improvements" (p. 7). Acs *et al.* reference and then extend Baumol's conclusions, noting, "We can think of incumbent firms as reliant upon incremental innovation from the flow of knowledge, such as product improvements. Start-ups with access to entrepreneurial talent and intra-temporal spillovers from the stock of knowledge are more likely to engage in radical innovation leading to new industries or replacing existing products" (Acs *et al.*, 2009, p. 16). The essence of this argument rests upon the belief that innovation stemming from existing sources of knowledge will favor large incumbents. Meanwhile, nascent-stage firms are expected to excel under circumstances that neither require nor benefit from established organizational routines (Nelson and Winter, 1982). The problem with this line of reasoning is that there is no body of empirical evidence providing support for the claim. In reality, entrepreneurial firms are continuously engaged in incremental innovations (Meisenzahl and Mokyr, 2010). What is more, incumbents desperately need entrepreneurial tweakers to internalize the information costs of potential adopters through a series of improvements that make radical innovations commercializable (Meisenzahl and Mokyr, 2010). Accordingly, I predict that:

H2a. New market entrants will be responsible for the majority of secondary inventions and design modifications that lead to the commercialization of breakthrough technologies.

H2b. Technology diffusion is positively related to the ability and willingness of entrepreneurial tweakers to internalize the information costs of risk-averse consumers.

2.3 Institutions, incumbents and the use of soft power

In Teece's (1986) oft-cited treatment of economic returns to innovation, he wrote, "It is quite common for innovators – those firms which are first to commercialize a new product or process in the market – to lament the fact that competitors/imitators have profited more from the innovation than the firm first to commercialize it!" (p. 285). The focus of Teece's (1986) analysis was directed toward original creators of radical innovations, especially the predicament of innovators failing to possess the complementary assets that are necessary to obtain economic returns from their respective innovations. However, a focus on large, publicly traded survivors misses the enabling enhancements contributed by entrepreneurial tweakers. A more accurate conception of value creation and value capture must incorporate the secondary inventions and design modifications by start-ups (Meisenzahl and Mokyr, 2010). For this reason, Teece's model is a good starting point, but an insufficient descriptor of the value appropriation phenomenon, particularly in addressing new organizations competing in new markets with nascent-stage technology.

Teece's foundational argument concerning the conditions under which innovators witness the appropriation of the value by competitors can be tangibly enhanced by incorporating two theoretical frameworks that are closely related to the role of power and influence in technological diffusion. The first of these streams is grounded in new institutional theories on myth making (Meyer and Rowan, 1977), legitimacy (Suchman, 1995) and institutional survival (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Zucker, 1987). The second stream is grounded in the resource dependence framework (Pfeffer and Salancik, 1978; Pfeffer, 1982), which focusses on the ways in which an organization manages and manipulates its external dependencies.

New institutional theory has compelling relevance to the issue of value creation and appropriation, particularly in understanding the disadvantages faced by nascent-stage, entrepreneurial organizations. Hargadon and Douglas (2001) explored these challenges through their fascinating examination of Thomas Edison's lighting inventions. They concluded that in order for entrepreneurs to be accepted they "must locate their ideas within the set of existing understandings and actions that constitute the institutional environment" (p. 476). This is a difficult task for entrepreneurial tweakers, since they rarely possess an appreciation for the wider institutional environment; nor have they typically participated in its creation. As Aldrich and Fiol (1994) observed, "Without widespread knowledge and understanding of their activity, entrepreneurs may have difficulty maintaining the support of key constituencies" (p. 649). On the other hand, large-scale incumbents often excel at managing their respective constituencies, especially when "they reach a point where they can dominate their environments rather than just adjust to them" (Freeman, 1982, p. 14; DiMaggio and Powell, 1983).

Key to this transformation is the attainment of legitimacy, which conveys a "taken-for-grantedness" status (Aldrich and Fiol, 1994; Suchman, 1995) that is highly instrumental in projecting trustworthiness and in achieving broad-scale acceptance. Once attained, "legitimacy can be used by an organization to strengthen its support and secure its survival" (Meyer and Rowan, 1977, p. 349). Since this status is primarily the domain of established organizations (Freeman, 1982; DiMaggio and Powell, 1983; Zucker, 1987; Aldrich and Fiol, 1994), legitimacy can be used to both create and control "market conditions, the characteristics of input and outputs, and technological procedures" (Meyer and Rowan, 1977, p. 351). For entrepreneurial tweakers, the relative lack of legitimacy is a consequence of newness, size and unclear institutional status (Aldrich and Fiol, 1994), making them easy targets for value appropriation by large-scale incumbents.

In similar fashion, resource dependence theory (Pfeffer and Salancik, 1978) finds strong relevance to manipulation in the context of small and large firm innovation. This dynamic is particularly evident in the model of entrepreneurial power logics developed by Santos and Eisenhardt (2009). This framework stems from their observation that many successful entrepreneurs "wield power by relying on a strategy of using soft power," by which they mean the "subtle influence mechanisms that cause others to willingly behave in ways that benefit the focal agent" (Santos and Eisenhardt, 2009, p. 663). Soft power is manifested in three primary tactics: first, creating illusions through the use of deception, shielding intentions and exaggerating one's importance; second, exploiting others' natural tendencies, such as risk aversion or relationship preferences; and third, using asynchronous timing to either preempt or delay competitive activity. Santos and Eisenhardt (2009) proposed that firms using these tactics "are more likely to achieve cognitive dominance (become the cognitive referent in a distinct market) and competitive dominance (face a lower level of competition, have greater market share)" (p. 663). Dominant early-stage firms are thereby able to claim, demarcate and control nascent markets (p. 648).

While the new institutional perspectives and the Santos-Eisenhardt conception of soft power do not negate the Teece framework of innovation value appropriation, they do successfully correct for the mistaken emphasis on identifiable complementary assets to the apparent exclusion of institutional imperatives and soft-power strategies. Each of these forces is critical when considering innovation in the context of entrepreneurial tweaking because the appropriation of value stemming from secondary inventions is the norm rather than the exception. The operationalization of institutional forces and soft-power strategies by the dominant designers explains why entrepreneurial tweakers lose control over the value as quickly as the value is created. Applying these elements more formally to Teece's conception of value appropriation, I predict that:

H3. On average, entrepreneurial tweakers will not share in the appropriation of rents created by their secondary inventions and design modifications.

3. Entrepreneurial tweaking – the phenomenon and the data

"Modern economic history has long ago distanced itself from the heroic hagiographics in which the Industrial Revolution was attributed to the genius of a few superstar inventors," wrote Meisenzahl and Mokyr (2010, p. 3). Instead, scholars have come to recognize the indispensible contributions of those who were able "to tweak, adapt, combine, improve and debug existing ideas" and in so doing, "turn them into economic realities" (Meisenzahl and Mokyr, 2010, p. 41). To assess this phenomenon in a more systematic fashion, this paper draws parallels between two separate instances involving the diffusion of radical innovations: the mechanized reaper and cloud computing services. Although these examples arose in markedly different environments and eras, each instance demonstrates that without the sustained introduction of secondary inventions and design modifications by entrepreneurs, the dominant designs (Abernathy and Utterback, 1978; Anderson and Tushman, 1991; Tushman and Murmann, 1998) would have remained dormant. In Antebellum America, the mechanized reaper remained virtually unused for two generations after its invention. Similarly, cloud computing remained largely dormant after its original conceptualization because early formulations were laden with operational, strategic and security risks (Buyya *et al.*, 2008). As with the reaper, secondary inventions and design modifications by entrepreneurs drove the commercializability of cloud computing (Rimal *et al.*, 2009; Armbrust *et al.*, 2010).

3.1 Data sources

This paper utilizes two distinct data sets, one highlighting the development of the mechanized reaper and the other highlighting the development of commercializable cloud computing. These radically different contexts were selected for three primary reasons: the technologies, settings and eras are sufficiently different to provide breadth to the study; the innovations were both characterized by high latent demand but tremendous challenges in overcoming adopter resistance by delivering a commercializable solution; moreover, the two technologies provide detailed data for archival research.

For the analysis of the mechanized reaper, data were drawn from US patent filings, historical accounts and agricultural equipment catalogues for the years 1803-1884, including 43 separate accounts of reaper field trials. Throughout this span of time, numerous patent claims were filed for mechanized reapers (Hutchinson, 1930), virtually all of which involved incremental enhancements to the models patented by Hussey (in 1833) and McCormick (in 1834). Studies of this era are inherently complicated by the document losses incurred during the 1836 patent office fire. However, Hutchinson's McCormick biography (1930), work by cliometricians (David, 1966; Olmstead, 1975; Olmstead and Rhode, 1995) and my own comprehensive review of newspapers, magazines, diaries and catalogues yielded an excellent collection of formal and informal records detailing the incremental innovations of the reaper. In all, 517 sources were used to identify 348 secondary inventions (including 147 patents) and design modifications.

The second data set is drawn from firms involved in the commercialization of cloud computing, an industry that provisions "convenient, on-demand network access to a shared pool of configurable computing resources" (National Institute for Standards and Technology (NIST), 2009). For the analysis of cloud computing, US Patent Office records revealed 3,882 patent filings related to cloud computing through 2011. In all, 28 percent of these were assigned to incumbents (e.g. Microsoft, Google, Cisco, etc.) while the remaining claims were assigned to individuals or start-up firms. To evaluate financial and operational performance of cloud computing firms I used data drawn from the Dun and Bradstreet database for all of the 382 firms presenting or exhibiting at the 2011 Cloud Expo in New York City. Non-US patent filings were excluded from the data set, although it is likely that foreign claims have been instrumental to the process of developing commercializable cloud computing services. To insure that the relative proportion of innovations from non-US incumbents and start-ups substantively resembled the proportions found in the USA, a representative sampling of cloud computing patent applications was obtained from ten technology-intensive countries that were selected based on a blended calculation of PC use, broadband use, corporate computing expenditures and cloud computing firms (Canada, UK, France, Germany, Italy, Australia, China, India, Russia, Spain). An examination of 100 randomly selected cloud computing patents in each country indicated that, on average, 34 percent of the assignees were from large-scale incumbents, which is only slightly higher than the 28 percent found in the USA. This broadly consistent pattern confirms that the vast majority of cloud computing patents is the product of entrepreneurial tweakers.

3.2 The mechanized reaper

The first step in harvesting grain is called "reaping," which involves a cutting and gathering process. When completed by hand, reaping is labor intensive, exhausting and, given the time sensitive nature of the harvest and the vagaries of the weather, literally a matter of life or death (Hutchinson, 1930). So it was with considerable importance that the first US patent on a mechanized reaper was issued in 1803 (Quick and Buchele, 1978). Any hopes for viability were quickly dampened by the fact that among the early prototypes mechanical failures were legendary. One report from a field trial in Maryland captured the flavor of the challenges: "When the horses slowed to a pace less than that being a trot, the cutting bars seized, shaking the machine and team so that one horse fell to the ground and the reaper itself suddenly failed, sending metal parts into the crowd of astonished observers and one blad(e) into the flesh of the fallen horse" (Wood, 1846, p. 33). Such spectacles did little to engender confidence in the new technology. Despite the extreme ardor associated with conventional hand reapers, potential adopters generally believed that the new technology was far riskier and ultimately more costly than hand harvesting (Olmstead, 1975; Olmstead and Rhode, 1995).

Development of the mechanized reaper took a notably positive turn with patented improvements by Obed Hussey (in 1833) and Cyrus McCormick (in 1834) of side-draft reapers that were pulled rather than pushed across the fields. The basic features of these two machines constituted the dominant designs in mechanized farm equipment for nearly a century (Quick and Buchele, 1978). However, neither design was immediately viable. In trial after trial, fatal flaws in multiple facets of the devices yielded disappointing results: "The reaper sank in soft ground, uprooted and flattened the tangled oat straw, was prone to clogging, and needed frequent repairs" (Pusey, 1851, p. 613). To many farmers, early reapers appeared fragile and unreliable. The *London Times* called the McCormick reaper "a cross between a wheelbarrow, a chariot, and a flying machine" (Pusey, 1851).

More than 300 secondary inventions and design modifications were required before the Hussey and McCormick reapers were widely trusted as an alternative to human labor. The sum total of these incremental innovations resulted in a structurally robust, mechanically reliable reaper that slashed labor resource requirements by more than three-quarters and, with these reductions, permanently altered not just agricultural economics but the general disposition of labor throughout Europe and North America (Olmstead, 1975). Sales of the reaper and its cousins, the harvester and the combine, soared, and by 1870 more than 400,000 machines were in use (Quick and Buchele, 1978). Although the basic design of McCormick Reaper ca. 1870 embodied the dominant design developed in the 1830s, by 1870 McCormick's leading reaper included more than 200 modifications produced through entrepreneurial tweaking.

3.3 Cloud computing

While the reaper aimed to liberate farmers from exogenous forces such as weather and labor supply, cloud computing promised to liberate businesses from the impossible task of accurately predicting the vector and velocity of changes in information technology (Catteddu and Hogben, 2009). Future generations will doubtlessly look with great bemusement upon the era of computer use in which floppy disks, legacy systems, flash drives, expensive customized software, clustered processing and storage capacity limits ruled the computer landscape like so many cumbersome electronic dinosaurs. In stark contrast, cloud computing represents the long-held dream of computing as a utility (NIST, 2009). The overarching concept of delivering computing resources through a global network is rooted in the late 1950s and early 1960s. Early pioneers, including computer scientists such as Bremer, McCarthy and Parkhill articulated a framework known then as time-share computing, the conceptual ancestor of cloud computing (Parkhill, 1966). The essence of the shared computing paradigm is that computing services function as a utility that are instantaneously scalable web-based resources "that no longer require tremendous hardware/software investments and professional skills to acquire" (Kaplan, 2011). From the very beginning, the stakes have been significant and have grown exponentially. Annual enterprise spending on information technology will approach $2.7 trillion in 2012 (Gartner Report, 2012), up to 30 percent of which is related to issues arising from legacy systems, which are residual programs, applications and processing systems that are difficult or even impossible to supplant in an environment of cluster management software (Foster and Kesselman, 1999).

As with the long march to a commercially viable mechanized reaper, efforts to commercialize cloud services faced resistance and skepticism as security breaches and performance concerns cast a long shadow over development efforts (Catteddu and Hogben, 2009). Infamous examples of catastrophic security failures abound, such as the massive outage experienced with Amazon's S3 outsourced cloud solution (Lazard Capital Markets, 2009). In a fashion that is reminiscent of the great mechanized reaper field trials of the early 1800s, public failures of cloud computing underscored the technical deficiencies, which in turn curtailed support by potential adopters despite tremendous latent demand for a viable solution (Gartner Report, 2012). Entrepreneurial tweaks specifically addressing cloud security concerns and operational attenuation issues sought to reduce the perceived risks and thereby hasten diffusion of commercializable cloud computing services (Armbrust *et al.*, 2010; Rimal *et al.*, 2009). Now, more than 50 years into the development process, a steady flow of secondary inventions and design modifications (Armbrust *et al.*, 2010) by entrepreneurial tweakers has fueled the delivery of commercializable services, evidenced by nearly 4,000 cloud-related US patents (Rimal *et al.*, 2009), thousands of non-patented enhancements and an estimated $41 billion in 2011 cloud computing revenue (Gartner Report, 2012).

4. Methods and models

The overarching predictive framework for this study is that entrepreneurial tweaking is indispensible to the diffusion of commercializable breakthrough technologies. And yet, the rewards of these indispensible contributions seldom accrue to the benefit of entrepreneurs. In order to test these predictions, OLS and logistic regression models were employed for each of the four hypotheses in each of the two contexts.

4.1 Dependent variables

In addressing *H1*, *H2a* and *H2b*, this study employs an aggregate measure of market acceptance to evaluate the relationship between incremental innovations and technology diffusion. The measure yields a quantity representing the diffusion rate, expressed in terms of the utilization of reapers and cloud services. For the analysis of the mechanized reaper, the diffusion rate was captured through reapers in use, based on data from year-end estimates gathered from prior studies (Hutchinson, 1930; David, 1966; Olmstead, 1975; Quick and Buchele, 1978), triangulated estimates, US census data and corporate histories, such as those published by the two most prominent

American manufacturers of farm equipment, John Deere and International Harvester. For the analysis of cloud computing, the diffusion rate was captured through total revenue generated from cloud computing services. The cloud computing measures were calculated from a blended rate of values drawn from data compiled by Gartner Report (2012), Lazard Capital Markets (2009) and Dun and Bradstreet for the population of companies routinely attending premier cloud computing trade shows. In addressing *H3*, regarding the appropriation of rents, I used a discrete dichotomous variable, rents appropriated, indicating whether or not an entrepreneur-inventor received payment for the innovation through product sales, royalties or by being acquired.

4.2 Predictors

Risk reduction. This is a continuous variable for the internalization of adopter information costs by entrepreneurial tweakers. For reapers, the measure of risk reduction is draft, the force required to operate a farm implement, as measured using a dynamometer. Dynamometers were widely used and relatively sophisticated even in early 1800s. Field judges and farmers associated high draft with "poor workmanship and faulty design" (Olmstead, 1975, p. 350) since it was indicative of clogging and other inefficiencies that exhausted the horses and damaged both crops and reapers (New York State Agricultural Society, 1857). For cloud computing, the continuous measure of risk reduction is security, the probability of a security breach based on the evolving threshold of deployable encryption (Armbrust *et al.*, 2010), under specified processing performance conditions. The values range from 0, indicating an utterly open system with no security capabilities, to 1, indicating perfect security. The measure captures the productive security threshold achieved (i.e. the tradeoff between security and dynamic functionality), by assessing the security solution for a system in the context of a specific set of operational requirements stipulating multilateral access to and manipulation of data housed in cloud-based storage services (Lazard Capital Markets, 2009; Armbrust *et al.*, 2010; Gartner Report, 2012).

Innovation source. This is a dummy-coded variable, with a value of "1" indicating incremental innovations from entrepreneurial start-ups and "0" indicating a large incumbent firm as well as all firms that have a proprietary claim to the dominant design.

Innovation impact. Consistent with techniques developed by Douthwaite (2001) and Rogers (2003), this is a categorical variable that ranks the relative importance of incremental innovation on a detailed scale ranging from 0 (i.e. no contribution to commercializability of the dominant design) to 5 (i.e. an indispensible contribution to the dominant design). For the mechanical reaper, three licensed mechanical engineers independently ranked all 348 innovations on the 0-5 scale. The average inter-rater reliability was 0.88. For cloud computing services, five technology professionals (two developers, two sales engineers and one technology columnist) independently ranked a sample of 500 innovations (including 325 randomly selected patents) on the 0-5 scale. The average inter-rater reliability was 0.83. Both reliability correlations are well above the levels necessary to establish inter-rater validity (Hayes and Krippendorff, 2007).

Cumulative innovations. The number of incremental innovations at the end of each year.

Cumulative impact. This variable is product of the aggregate incremental innovations at the end of each calendar year times the innovation impact for each incremental innovation.

Product sales. Unit sales by year, by company.

Royalties. This is a dummy-coded variable indicating whether or not an inventor received royalties or licensing revenue from each documented innovation.

Acquisition. This is a dummy-coded variable indicating whether or not a firm was acquired.

Cumulative time. The number of years since the emergence of the dominant design.

4.3 Controls

The diffusion rates for reapers and cloud computing were subject to an array of control variables that were grouped into three separate vectors in order to capture year-specific, industry-specific and macro-economic effects. In particular, economic conditions affect the rate of investment in new technologies (Anderson and Tushman, 1991). Accordingly, annual GDP growth was controlled. As a broad proxy for financial market effects, a market-weighted average interest rate was incorporated, by year. Specifically germane to reapers, the wheat prices were used as a control variable. Unobserved fixed year effects were controlled through a series of dummy codes. This was particularly important for reaper diffusion effects related to labor market disruptions from industrialization and, of course, the Civil War (Olmstead, 1976).

4.4 Models

The predictive models for the diffusion of mechanized reapers and cloud computing are derived separately for each of the four hypotheses. The generalized OLS model for *H1* (Model 1), examining the relationship between incremental innovations, is expressed as:

$$\begin{aligned}(H1)\ Diffusion = {} & \beta_0 + \beta_1 CON_{year} + \beta_2 CON_{macro} + \beta_3 CON_{indus} \\ & + \beta_4 CUM\text{-}INNOV + \beta_5 CUM\text{-}IMPACT\end{aligned} \tag{1}$$

In Model 2, pertaining to *H2a*, the source of a given innovation was added:

$$\begin{aligned}(H2a)\ Diffusion = {} & \beta_0 + \beta_1 CON_{year} + \beta_2 CON_{macro} + \beta_3 CON_{indus} \\ & + \beta_4 CUM\text{-}INNOV + \beta_5 CUM\text{-}IMPACT \\ & + \beta_6 INNOVATION\ SOURCE\end{aligned} \tag{2}$$

H2b predicts that entrepreneurial tweakers will assume a primary role in internalizing adopter information costs through risk-reducing innovations. Therefore, risk reduction is added in Model 3 as the product term relating risk reduction to the innovation source. In order to model this effect using metrics that are relevant to adopter information costs, reaper risk is measured using draft improvements, while risk-reducing improvements in cloud services are modeled using system security capabilities. The key will be to see if the product term is statistically significant:

$$\begin{aligned}(H2b)\ Diffusion\,Rate = {} & \beta_0 + \beta_1 CON_{year} + \beta_2 CON_{macro} + \beta_3 CON_{indus} \\ & + \beta_4 CUM\text{-}INNOV + \beta_5 CUM\text{-}IMPACT \\ & + \beta_6 INNOVATION\ SOURCE + \beta_7 RISK\ REDUCTION \\ & + \beta_8 INNOVATION\ SOURCE \times RISK\ REDUCTION\end{aligned} \tag{3}$$

H3, regarding appropriation, is tested through a logistic regression model:

$$\begin{aligned}(H3)\ \mathit{Rents\ Appropriated} = {} & \beta_0 + \beta_1 CON_{year} + \beta_2 CON_{macro} + \beta_3 CON_{indus} \\ & + \beta_4 \mathit{CUM\text{-}INNOV} + \beta_5 \mathit{CUM\text{-}IMPACT} \\ & + \beta_6 \mathit{IMPACT\text{-}RANK} + \beta_7 \mathit{CUM\text{-}YEAR} \\ & + \beta_8 \mathit{INNOVATION\ SOURCE}\end{aligned} \tag{4}$$

5. Results

Analysis of the empirical data indicates strong support for all four hypotheses, with material effect sizes and a low probability of error. For both the mechanized reaper and cloud computing services, lengthy gaps followed the initial conception of each technology. Even after the emergence of dominant designs, adoption curves indicate a reluctance to acquire and deploy the nascent technologies. Only after several hundred secondary inventions and design modifications is there evidence of accelerating adoption rates.

The directionality and magnitude of the key correlations (Tables I and II) are consistent with the hypothesized relationships.

Most notably, incremental innovation by start-ups is significantly and positively correlated with diffusion. However, product sales and royalties are significantly and negatively correlated with the source of an innovation. Taken together, this means that start-ups produce innovations leading to commercialization but fail to realize the benefits of having facilitated adoption.

In its basic form, the OLS regression indicates that for both the reaper (Table III, Model 1) and cloud computing services (Table IV, Model 1), incremental innovation is significantly and positively related to the diffusion rate. Even without stipulating the innovation source, secondary inventions and design modifications account for 48 percent and 39 percent of the explanatory variance, respectively, over and above the control variables (Model 0). Both cumulative innovations and the cumulative impact of innovations are significant, thereby supporting *H1*, which predicts that diffusion is positively related to incremental innovations.

Variable		Mean	SD	DV	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DV	Reapers in use (year end)	239,652	291,691	x							
1	Risk reduction (draft improvements)	458	278	0.43**	x						
2	Innovation source	0.74	0.44	0.32**	0.31**	x					
3	Innovation impact	2.61	1.33	0.28**	0.27**	0.37**	x				
4	Cumulative innovations	168	115	0.17*	0.13*	0.14*	−0.11*	x			
5	Cumulative impact	439	300	0.27**	0.29**	1.22*	−0.07	−0.1	x		
6	Product sales	0.04	0.20	0.08	0.39**	−0.34**	0.11	−0.03	−0.28**	x	
7	Royalties	0.04	0.20	0.02	0.07	−0.22**	0.07	−0.08	−0.22**	0.04	x
8	Acquisitions	0.02	0.15	0.03	0.03	−0.09	0.03	−0.05	−0.03	0.06	−0.04

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$

Table I. Mechanical reaper – correlation table

Table II.
Cloud computing services – correlation table

Variable		Mean	SD	DV−1	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DV	Cloud Revenue (year end \$MM)	87,000	191,000	x							
1	Risk reduction (security improvements)	0.37	0.51	0.30**	x						
2	Innovation source	0.72	0.45	−0.27**	0.14*	x					
3	Innovation impact	2.59	1.37	0.24**	−0.08	0.38**	x				
4	Cumulative innovations	250	168	0.19*	0.23*	0.20*	−0.17*	x			
5	Cumulative impact	727	418	0.29**	0.41**	0.25**	−0.25**	−0.22**	x		
6	Product sales	0.02	0.153	0.07	0.09	−0.22**	0.05	0.10	−0.11*	x	
7	Royalties	0.05	0.21	0.06	0.07	−0.13*	0.04	0.07	−0.16**	0.07	x
8	Acquisitions	0.06	0.234	0.12*	0.11*	0.05	0.01	0.04	0.02	0.09	0.07

Notes: $*p < 0.05$; $**p < 0.01$

Table III.
Mechanical reaper – OLS regression results OLS results for mechanized reapers

Hypotheses	Model 0 controls DV is reapers in use	Model 1 Diffusion is positively related to incremental innovations	Model 2a Start-ups generate majority of incremental innovations	Model 2b Start-ups internalize the information costs
Independent variables				
Constant	Incl.	Incl.	Incl.	Incl.
Macro effects	41.4*	27.3*	25.5*	19.40
	(26.0)	(18.8)	(17.8)	(14.3)
Fixed year effects	47.8*	33.4*	26.1*	11.50
	(22.4)	(17.7)	(14.3)	(8.2)
Fixed industry effects	11.30	2.65	2.58	2.40
	(4.72)	(1.78)	(1.65)	(0.61)
Cumulative innovations		177*	172*	161*
		(53)	(51)	(47)
Cumulative impact			320**	174*
		(72)	(65)	(41)
Innovation source (startup = 1)			5,789***	3,994***
			(1,270)	(991)
Risk reduction (draft)				760***
				(51)
Risk reduction × source				1,141***
				(190)
Adjusted R^2	0.09	0.57	0.74	0.87
F-value	11.2	38.8	47.6	63.9

Notes: Non-standardized coefficients. Units are expressed in incremental reapers. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

H2a predicted that entrepreneurial tweakers are the primary force in reducing resistance to dominant designs. In support of this prediction, Tables V and VI, demonstrate the relatively greater impact of incremental innovations produced by start-ups. Entrepreneurial tweakers were responsible for 74 percent of all secondary

Hypotheses	Model 0 controls DV is revenues	Model 1 Diffusion is positively related to incremental innovations	Model 2a Start-ups generate majority of incremental innovations	Model 2b Start-ups internalize the information costs
Independent variables				
Constant	Incl.	Incl.	Incl.	Incl.
Macro effects	0.31*	0.15	0.14	0.13
	(0.18)	(0.12)	(0.11)	(0.11)
Fixed year effects	0.18*	0.12*	0.11	0.12
	(0.20)	(0.12)	(0.12)	(0.10)
Fixed industry effects	0.18*	0.17	0.13	−0.14
	(0.14)	(0.14)	(0.14)	(0.15)
Cumulative innovations		1.198**	1.17**	1.02**
		(0.65)	(0.60)	(0.57)
Cumulative impact		1.37***	1.03**	0.89*
		(0.88)	(0.79)	(0.51)
Innovation source (startup = 1)			5.45***	3.13***
			(1.28)	(1.13)
Risk reduction (security)				2.30***
				(0.37)
Risk reduction × source				2.88***
				(0.79)
Adjusted R^2	0.12	0.51	0.69	0.81
F-value	14.7	31.3	42.2	55.7

Note: Standardized coefficient. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table IV.
Cloud computing services – OLS regression results

Innovation impact rating (5 = highest)	Incumbents No.	 %	Start-ups No.	 %	Total No.	 %
0	8	47	*9*	*53*	17	5
1	26	46	*30*	*54*	56	16
2	35	36	*61*	*64*	96	28
3	10	11	*83*	*89*	93	27
4	6	12	*43*	*88*	49	14
5	4	11	*33*	*89*	37	11
Total	89	26	*259*	*74*	348	100
	Incumbents		Start-ups			
Average impact value	1.91***		2.85***			
SD	1.20		1.29			
Mean difference	$T_{1.347} = 6.02, p < 0.001$					

Notes: These data represent the results of a forced ranking of 348 secondary inventions and design modifications for the mechanical reaper from 1803-1884 (inter-rater reliability: 0.88). Startups produced 74 percent of all incremental innovations and accounted for nearly 90 percent of those that most profoundly reduced adoption risk and facilitated commercialization. $^{***}p < 0.001$

Table V.
Mechanized reaper – the impact of incremental innovations

Innovation impact rating (5 = highest)	Incumbents No.	 %	Start-ups No.	 %	Total No.	 %
0	17	45	*21*	*55*	38	8
1	28	41	*41*	*59*	69	14
2	45	34	*89*	*66*	134	27
3	30	26	*87*	*74*	117	23
4	16	16	*85*	*84*	101	20
5	5	12	*36*	*88*	41	8
Total	141	28	*359*	*72*	500	100
	Incumbents		Start-ups			
Average impact value	2.11***		2.79***			
SD	1.29		1.35			
Mean difference	$T_{1,499} = 5.12$, $p < 0.001$					

Table VI.
Cloud computing – the impact of incremental innovations

Notes: These data represent the results of a forced ranking of 500 secondary inventions and design modifications for cloud computing services from 1960-2011 (inter-rater reliability: 0.83). Startups produced 72 percent of all incremental innovations and accounted for more than 85 percent of those that most profoundly reduced adoption risk and facilitated commercialization. ***$p < 0.001$

inventions and design modifications leading to the commercialization of the mechanized reaper (Table V) 72 percent of innovations related to cloud computing (Table VI). Further, among the 100 highest-ranked innovations, 89 percent were attributable to entrepreneurs who tweaked the dominant reaper design and 85 percent were attributable to entrepreneurial tweaks of cloud computing.

These findings are further underscored by the OLS regression results in Model 2a (Tables II and IV), in which the source of innovation is found to be a significant predictor of diffusion for both reapers ($\Delta R^2 = 0.17$) and cloud services ($\Delta R^2 = 0.18$), respectively. *H2b* examines the information costs of potential adopters, predicting that diffusion is positively related to the ability and willingness of entrepreneurial tweakers to internalize the information costs of risk-averse consumers. This assertion will be supported if it can be shown that entrepreneurial tweakers were decisive in the reduction of perceived risk and the subsequent increase in sales. The mean differences displayed in Table V show that entrepreneurial innovations were 49 percent more instrumental to the commercialization of the reaper than were incumbent innovations (2.85 vs 1.91, $T_{1,347} = 6.02$, $p < 0.001$). Similarly, incremental innovations by start-ups were 32 percent more impactful to the commercialization of cloud computing (Table VI) than were incumbent innovations (2.79 vs 2.11, $T_{1,499} = 5.12$, $p < 0.001$). To further examine this effect, a product variable was added to Model 2b (Tables II and IV), relating risk reduction to the innovation source. Importantly, the product coefficient was found to be highly significant for reapers and cloud computing services, thereby supporting the prediction that entrepreneurial start-ups, not incumbents, are primarily responsible for the internalization of adopter information costs through the development of secondary inventions and design modifications that tangibly improve the dominant design.

H3 tested the premise that while entrepreneurial tweakers may be indispensible to the creation of rents associated with the commercialization of new technologies, they generally do not share in the appropriation of rents generated by their secondary inventions and design modifications. Table VII provides the results of a logistic regression examining the probability that the creation of incremental innovations results in value accrued by the entrepreneurial tweakers. The premise is tested across three scenarios: all innovations, only start-up innovations and only high-impact innovations.

The odds ratios reveal two dynamics that are supportive of *H3*. On the one hand, cumulative innovation and the unique impact of a given innovation strongly increase the odds of rents being created. On the other hand, the innovation source strongly decreases the odds of appropriation. In fact, an entrepreneurial tweaker had only a one in 14 chance of deriving gains from a reaper innovation (innovation source odds ratio $= 0.07$, $p < 0.001$) and a one in nine chance of garnering gains from a cloud services innovation (odds ratio $= 0.11$, $p < 0.001$).

Overall, it is apparent that incremental innovations to the reaper, especially high-impact innovations that reduced the draft, increased the likelihood that the incumbent owner of a dominant design will appropriate rents from the innovations created by start-ups. However, it is also apparent that start-ups did not improve their chances of appropriating rents through their innovations. Even among those start-ups producing tweaks that had the highest impact on commercialization, failed to earn rents on their innovations. The storyline is repeated with cloud computing, though with somewhat less dramatic results. Incumbents benefit from entrepreneurial tweaks, but start-ups generally do not. These findings strongly support *H3*, which asserts that resource-rich, business-savvy incumbents will outmaneuver start-ups by appropriating the value of entrepreneurial innovations.

	Model 3 – reapers Rent appropriation from incremental entrepreneurial innovation		Model 3 – cloud services Rent appropriation from incremental entrepreneurial innovations	
Independent variables	Odds (SD)	Value creations and appropriation	Odds (SD)	Value creation and appropriation
Constant	Incl.		Incl.	
Macro effects	0.96* (0.19)		0.98* (0.08)	
Fixed year effects	1.02* (0.22)		1.07 (0.15)	
Fixed industry effects	0.97 (0.14)		0.99 (0.21)	
Cumulative innovation	8.34*** (6.87)	8 × odds that value is created	7.63*** (5.32)	8 × odds that value is created
Innovation impact	13.82** (2.91)	14 × odds that value is created	9.48*** (3.58)	9 × odds that value is created
Innovation source (1 = start-up)	0.07*** (0.03)	1 in 14 chance of start-up appropriating value	0.11*** (0.13)	1 in 9 chance of start-up appropriating value
χ^2	74.4		63.8	
Predictive accuracy	95.6%		91.7%	

Notes: The following data demonstrate that while secondary inventions and design modifications increase the probability of rent appropriation, start-ups face low probability of harvesting value. $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table VII.
Mechanized reaper and cloud services – logistic regression results

6. Discussion

As the foregoing results demonstrate, entrepreneurial tweaking played a leading role in the diffusion of the reaper and cloud computing. By voluntarily engaging in incremental innovations, entrepreneurs internalized the information costs associated with deep-seeded doubts among the population of potential adopters. Existing firms, including those who developed the dominant designs, were either unwilling or unable to absorb adopter information costs; yet they were the primary beneficiaries of the diffusion. The ability of incumbents to appropriate rents that were generated by start-ups is a curiosity requiring an understanding of how and why institutional forces (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Aldrich and Fiol, 1994) and soft power (Santos and Eisenhardt, 2009) are effectively employed by some firms but not others.

In this sense, the process of entrepreneurial tweaking is one that the dominant designers simultaneously encourage and decry. On the one hand, tweaking by start-ups is encouraged because without the steady flow of secondary inventions and design modifications, the dominant design will remain dormant. On the other hand, the dominant designers also decry entrepreneurial tweaking because incumbents do not want to see their controlling patents supplanted by new innovations. One interesting example of this tension involved the use of serrated cutting tools for the mechanized reaper. By all accounts, the use of a serrated cutter bar, which was invented by the entrepreneurial tweaker, George Rugg, improved cutting efficiency and reduced the occurrence of clogging (Quick and Buchele, 1978). This, in turn, reduced mechanical failures and maintenance costs (Olmstead and Rhode, 1995). Nonetheless, it was the official position of McCormick and Sons that the patent for serrated cutter bars did not require special consideration despite the fact that the innovation was new and produced superior results (Quick and Buchele, 1978). Conspicuously, all McCormick reapers featured serrated cutter bars by 1853 (Hutchinson, 1930), even though Rugg himself never received financial benefit from this important secondary invention.

The serrated blade issue underscores McCormick's understanding of legitimacy, myth building and soft power, which was pivotal in perpetuating the wide-spread claims that McCormick produced the original and premier mechanized reaper, when in fact, neither was true (Hutchinson, 1930). There were many reapers that were patented earlier than McCormick's and many that performed better (Quick and Buchele, 1978). In combating these inconvenient truths, McCormick was masterful. For instance, rather than participating in field trials where anything less than a strong first place finish would erode the image of McCormick's preeminence, the company focussed on advertising abroad. In 1856, important reaper field trials were staged in Maryland, but the McCormick reaper, which often did not win such contests, was not entered. Instead, McCormick was demonstrating his reaper in Hungary, where it performed adequately but received the adulation of amazed onlookers who declared the McCormick reaper "the greatest machine ever invented" (Tucker, 1856, p. 117). Such anecdotes are emblematic of the issue-framing and myth-building activities explanations that are central to new institutional theory (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Zucker, 1987). As Aldrich and Fiol (1994) noted, organizations operate at a considerable advantage when they can control the social stage enough to successfully produce and direct "great theater" (p. 651).

The effects of soft power, myth building and perceived legitimacy have not been diluted in the 130 years since McCormick. As the data indicate, start-ups have played a dominant role in the development of innovations that led to the commercialization of cloud computing services, yet incumbents have successfully convinced adopters that their interests are best served by working through better-known entities, such as Salesforce.com, Oracle, Microsoft, HP, IBM, Cisco, EMC, VMware, SAP and Google (Lazard Capital Markets, 2009). Soft power tactics have played a prominent role in this nascent industry. For instance, the propensity to exaggerate one's importance while exploiting risk aversion (Santos and Eisenhardt, 2009) is commonplace. One particularly brazen gambit of self-promotion occurred when Dell sought to trademark the term "cloud computing" (Koman, 2008). The US Patent Office repudiated Dell's demarcation attempt, but the effort is indicative of tactics used by incumbents. In similar fashion, Google HP, EMC, Cisco and IBM have each invested heavily in advertising that cautions adopters to be careful when taking "a leap of faith to find solid footing in the cloud for mission critical applications" (Wallis, 2008).

6.1 Implications for scholars and practitioners

The findings from this study have potent implications for both scholars and practitioners. For scholars, the leading role played by entrepreneurial tweakers in facilitating diffusion suggests a theoretical dislocation of considerable consequence. For near half a century, the depiction of large incumbents as being the dominant producers of incremental innovation has been deeply ingrained in both popular and scholarly literature (Ahuja and Lampert, 2001; Baumol, 2004). Challenges to this core assumption may necessitate a comprehensive reassessment of the relationships between dominant designs (Anderson and Tushman, 1991; Tushman and Murmann, 1998), adoption risk, adopter resistance and the trajectory of technological diffusion (Rogers, 2003). If small, entrepreneurial firms have a superior capacity for both radical breakthroughs and incremental improvements, then the examination of organizational ambidexterity as a function of firm size, age and structure (e.g. He and Wong, 2004; Gupta *et al.*, 2006) takes on even greater importance. Additional research is needed to determine whether entrepreneurial firms are actually more ambidextrous than large firms or whether some small firms excel at radical innovation and others excel at incremental innovation. It is possible that these two facets of innovation are mutually exclusive for most firms, large or small (Benner and Tushman, 2003).

As with all industry-specific studies, there are questions of generalizability. For this reason, additional contexts can and should be explored for both confirmatory and contradictory evidence. It is likely that other industries, eras and socio-political contexts will display both similarities to and differences from the conditions found with mechanized reapers and cloud computing services. Of particular interest are industry-specific conditions that may affect the manner in which entrepreneurial tweakers internalize adopter information costs through a reduction in the perceived risks associated with dominant designs.

Then too, there is the issue of innovation value. As the study of value creation and appropriation (Jacobides *et al.*, 2006; Santos and Eisenhardt, 2009; Teece, 1986) continues to gather momentum and gain sophistication, the findings of this study propound a cautionary statement: going forward, it will be important to study the glaring differences between value creation and value appropriation, not just among competing incumbents, but also among those entrepreneurial tweakers who are able to establish a more formidable protection schema for their respective incremental innovations. Several key avenues still need to be carefully explored to better understand how and why tweakers engage in incremental modifications to dominant designs despite the low probability of ever harvesting gains. And, as technological innovation increasingly is played out in an international context, there are important cross-border implications of entrepreneurial tweaking, as diffusion becomes a matter of global proportions.

Similarly, practitioners are likely to find the results of this study to be both enlightening and daunting. For entrepreneurial innovators, seldom has the case for early and aggressive intellectual property protection been made more palpable. As discussed earlier, Teece (1986) observed that the creators of innovations often fail to become the beneficiaries. The decisiveness with which Teece's predictions are supported through the findings in this study underscores the peril entrepreneurial tweakers face in ever harvesting value from their respective innovations. However, the study provides evidence that perhaps there has been progress. While a one in nine chance of harvesting gains from incremental innovations leading to the commercialization of a dominant cloud design may not seem like favorable odds, it is much better than the specter of one in 14 odds faced by innovators of the mechanized reaper. The overall trend is clearly toward greater protection. While slightly more than 40 percent of mechanized reaper innovations were patented, more than 90 percent of cloud computing innovations have been, despite the fact that the patenting process has actually become much more complicated in the past 170 years.

Innovating entrepreneurs would do well to comprehend the role of perceived legitimacy, myth building and soft power in commanding the upper hand in commercialization (Meyer and Rowan, 1977; Aldrich and Fiol, 1994; Suchman, 1995; Santos and Eisenhardt, 2009). The lesson from McCormick & Sons in the nineteenth century and cloud behemoths such as Cisco, Google and Oracle in twenty-first century is that marketing the message of superiority is at least as important as actually developing a superior technical solution.

Inter-firm alliances are also likely to provide a key to the value appropriation challenge. In addition to the formal protection of intellectual property, entrepreneurial tweakers may benefit from favorable alliance partnerships with incumbents who have the capacity to provide complementary resources (Teece, 1986; Sinha and Cusumano, 1991; Barringer and Harrison, 2000). If carefully developed, alliance partnerships (Ireland *et al.*, 2002) may constitute the most impactful and long-lasting means through which to successfully protect the value created through entrepreneurial tweaking contemporary entrepreneurs can choose from among many more organizational forms and complex commercial partnerships than those that were available to tweakers from earlier times. However, successfully navigating this emerging landscape of diverse opportunities requires entrepreneurs to be as adept at comprehending soft power as they are at solving the technical riddles of incremental innovation. Such a fortuitous blend is likely to be a lucrative, but comparatively rare, combination.

6.2 Conclusion

Through the deft management of soft power by incumbents (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Santos and Eisenhardt, 2009; Zucker, 1987), secondary inventions and design modifications by entrepreneurs have been mistakenly accorded a subordinate role in the innovation and diffusion literature. Entrepreneurial tweakers have become capitalism's "invisible innovators." In addressing this misconception, the detailed cliometric analysis provided through this study casts serious doubt upon the prevailing dichotomy of incumbent incrementalism and entrepreneurial radicalism. Whether the circumstances are situated in Antebellum times or the modern era, the leading role of entrepreneurial start-ups in generating indispensible incremental innovations finds strong support. Although the detailed examination of mechanized reapers and cloud computing services cannot anticipate all the differences across various industries, the study of these disparate contexts nonetheless suggests startlingly similar antecedents and outcomes. Absent the willingness and ability of start-ups to internalize the information costs of potential adopters, diffusion of these important technological breakthroughs would have remained in abeyance.

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