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An opportunity space odyssey: historical exploration of demand-driven entrepreneurial innovation

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Abstract

Purpose – One of the crucial questions confronting strategy and entrepreneurship scholars continues to be: Where do new industry sectors come from? Extant literature suffers from a supply-side "skew" that focuses unduly on the role of heroic figures and celebrity CEOs, at the expense of demand-side considerations. In response, the purpose of this paper is to examine societal demand for entrepreneurial innovations. Employing historical data spanning nearly a century, the author assess more completely the role of latent demand-side signaling in driving the quantity and diversity of entrepreneurial innovation.

Design/methodology/approach – Applying the methods of historical econometrics, this study employs historical artifacts and cliometric models to analyze textual data in drawn from three distinctive sources: *Popular Science Monthly* magazine, from its founding in 1872 to 1969; periodicals, newsletters, club minutes, films and radio transcripts from the Science Society, from 1921 to 1969; and programs and news accounts from the US National High School Science Fair, from 1950 to 1969. In total, 2,084 documents containing 33,720 articles and advertisements were coded for content related to pure science, applied science and commercialized science.

Findings – Three key findings are revealed: vast opportunity spaces often exist prior to being occupied by individuals and firms; societal preferences play a vital role in determining the quantity and diversity of entrepreneurial activity; and entrepreneurs who are responsive to latent demand-side signals are likely to experience greater commercial success.

Research limitations/implications – This study intentionally draws data from three markedly different textual sources. The painstaking process of triangulation reveals heretofore unobserved latencies that invite fresh perspectives on innovation discovery and diffusion.

Originality/value – This paper constitutes the most panoramic investigation to-date of the influence wielded by latent demand-side forces in the discovery and commercialization of innovation.

Keywords Innovation, Diffusion, Entrepreneurship, Historical analysis, Demand-side, Opportunity development

Paper type Research paper

1. Introduction

One of the crucial questions confronting strategy and entrepreneurship scholars continues to be: Where do new industry sectors come from? As Schoonhoven and Romanelli (2009) noted, the great challenge inherent in this question is that scholars are trying to examine something before it comes into existence. How, they asked, is it possible for researchers to measure the existence of an open environmental space before new or existing firms act to occupy it? Prior research has addressed this issue through two very different lenses: one has focused on supply-side dynamics and the other, on demand-side dynamics (Thornton, 1999). While the supply-side perspective emphasizes individual characteristics and the ways in which founders access the mechanisms of innovation (Romanelli and Schoonhoven, 2001), the demand-side perspective addresses the role of environmental context (Aldrich and Wiedenmayer, 1993; Hunt and Kiefer, in press; Romanelli, 1989), societal signals (Hunt 2013c; Myers and Marquis, 1969; Schmookler, 1966), and user-provocated breakthroughs (Priem *et al.*, 2012; Von Hippel, 1976).

Recent demand-side scholarship has sought to examine the potent effects of explicit demand preferences developed and articulated by user-customers (e.g. Adner and Snow, 2010; Danneels, 2003, 2008; Di Stefano *et al.*, 2012; Priem, 2007; Priem *et al.*, 2012;

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Priem and Swink, 2012; Ye *et al.*, 2012). In particular, these demand-side approaches have sought to illuminate the role of well-established, incumbent firms in demanding the development of new products and services by their respective suppliers. The sum total of these research efforts has succeeded in demonstrating the importance of existing customer demands in instigating technological developments. What is notably missing, however, is an identification and explication of latent demand effects as they pertain to new sectors – before the sectors are even occupied by entrepreneurs and firms – which, I will argue in this paper, are both pervasive and powerful in determining the quantity and diversity of entrepreneurship supplied to the market. Latent demand refers to the condition in which a significant number of people experience a desire or need for something that does not exist in the form of an actual product or service (Kotler, 1973). Such demand can be, and often is, highly diffuse, since it stems from individual preferences, many of which are loosely constructed and largely unconscious (Earl and Potts, 2000; Hunt 2013c). The element of latency suggests that this demand is pre-existing, as opposed to conscious, fully expressed, well-understood decisions to act on choices that are already available (Earl, 1986; Lancaster, 1966).

While latent demand lies under the surface of market activity, consumer perceptions and potential innovations, its subliminal nature does not diminish its importance to the study of entrepreneurial innovation. On the contrary, the absence of studies on society-wide, latent demand-side signaling for innovation suggests that extant literature may fail to account for a recurrent market influence that is highly germane to the quantity and diversity of entrepreneurial activity. Priem *et al.* (2012) identified this gap while noting that much work remains to properly define and analyze the ways in which society-wide opportunity signaling shapes supply-side activity. This paper responds to that call, asking: When and how are demand-side forces instrumental in the generation of innovations, sectors and opportunity spaces?

Demand-side phenomena are notoriously difficult to isolate (Di Stefano *et al.*, 2012; Teece, 2008). Given the diffuse and shifting nature of demand-side effects, it is difficult to comprehend their existence, and impossible to evaluate their impact, without employing an historical perspective through the use "archival data" (Priem *et al.*, 2012). Alert to the underutilization of historical artifacts, multi-generational timeframes and historiographic methods in management research (Booth and Rowlinson, 2006; Delahaye *et al.*, 2009; Ingram *et al.*, 2012; Kipping and Üsdiken, 2014), and the comparative success of cliometrics in reshaping central discussions in economics (Alston, 2008; Fogel, 1966, 1970; Goldin, 1997; Greif, 1997; Hunt, 2013b), this study employs data that are amenable to the methodological rigor and the expansive perspective of historical econometrics. The data set I use spans nearly a century, involving the commercialization of scientific knowledge in the USA from 1872 to 1969, a time period with tectonic social shifts and epic technological changes. Consistent with the long timeframes employed by population ecologists (e.g. Hannan and Freeman, 1984), diffusion scholars (e.g. Benner and Tushman, 2002; Rogers, 2003; Tushman and Murmann, 1998), and a select group of scholars in strategy and entrepreneurship (e.g. Casson, 1982; Casson and Godley, 2005; Wadhwani and Jones, 2014), this study shares their panoramic scale, but with the added benefit of not sacrificing fine-grained empirics (Hunt, 2013b, c).

In venturing to underscore the utility of applying distant timeframes to key questions of innovation research, this study makes a number of contributions to the domains of entrepreneurship and strategy. First, my findings demonstrate that latent demand-side effects can be explicitly identified through the analysis of socially embedded historical artifacts that give a voice to demand-side perceptions. Latent demand, contrary to extant literature (e.g. Dosi, 1982; Mowery and Rosenberg, 1979; Teece, 2008), is readily distinguishable from supply-side effects, even in the context of new technologies and emerging sectors (Hunt, 2013b; Hunt and Ortiz-Hunt, 2017). However, it is only possible to discern these important differences with the benefit of historical distance. Second, I present compelling evidence that demand-pull effects generate technological innovation and entrepreneurial activity. Since the publication of highly influential work by Mowery and Rosenberg (1979) and Dosi (1982), economists and management scholars have largely depicted society-wide demand-side forces as selectors, not generators, of entrepreneurial activity (Di Stefano *et al.*, 2012; Priem *et al.*, 2012). Writing a quarter of a century later, Teece echoed Dosi assertion that no empirical evidence exists that provides evidence of the generative capacity of demand-side forces (Dosi, 1982, 1988; Teece, 2008). While this may be true of prior empirical work, the consequence of assuming away the generative capacity of demand-side forces implicitly abandons any pretense of maintaining an explanatory model that balances supply-push and demand-pull effects. My ability to demonstrate a generative role stemming from latent societal demand preserves the viability of a balanced supply-demand explanatory framework.

Finally, I offer conceptual, empirical and methodological alternatives to the study of innovation through the use of socially embedded historical artifacts. Absent a panoramic data set that offers pulse-like vital signs of societal preferences over the course of successive generations, it would be impossible to apprehend and understand demand-side influences. Successful use of historiographic tools suggests that other vexing challenges in management scholarship could be well served by employing a more historical approach to data.

2. Theory development and hypotheses

Which comes first: the demand for innovations and entrepreneurship or the supply? The question is more than simply an ontological curiosity. If the supply of innovations invariably precedes demand, then clearly supply shapes and steers demand, allowing it selection privileges but not a generative capacity. If societal demands – regardless of whether they are latent or explicit – invariably precede supply, then entrepreneurs are largely "sifters and sorters," possessing selection privileges, but not generative capabilities.

Innovation generation and selection refer to the processes through which competing solution sets are created and commercialized (Di Stefano *et al.*, 2012). The concepts are important because solution sets are the generalized means through which a need or a want is satisfied. For example, the vast array of smartphones constitutes competing solution sets to satisfy the desire for telephony and mobile internet access. The question is: are smartphone innovations developed to address a latent, demand-side conception of a mobile access, or are they a solution set in search of a potential audience, wherein consumers are drawn to an unforeseen category by novel innovations? This is the essence of the supply-push vs demand-pull debate. Supply-side generation of innovations means that entrepreneurs take the lead in developing products and services, after which society then chooses, through market-based transactions, which of these innovations are attractive to them. In one view, innovators may adopt a supply-push logic to the commercialization of possible solution sets designed to fulfill needs and wants. Extending the language of generators and selectors noted above, a supply-push focus suggests that solution sets are largely the product of innovations generated by enterprising entrepreneurs and society selects which among the various alternatives it most favors. Conversely, a generative demand perspective involves explicit and latent signaling of desirable solution sets, to which innovating entrepreneurs then respond in an effort to fulfill the needs and wants.

The demand-pull vs supply-push debate has occupied scholars of technological change for more than 40 years (Dosi, 1982; Freeman, 1995; Mowery and Rosenberg, 1979; Pavitt, 1984; Rosenberg, 1982; Schmookler, 1966; Von Hippel, 1976). The supply-push approach sees innovations emerging "independent of specific customer or market needs," while the demand-pull approach sees innovations emerging as a “direct attempt to satisfy specific market needs” (Ye *et al.*, 2012, p. 6).

Parsing supply-push and demand-pull forces is far from a discrete activity. As Mowery and Rosenberg (1979) asserted, the highly inter-related nature of demand-pull and supply-push forces makes it extremely difficult to identify and parse out the facets of innovation that are patently a result of demand. On the other hand, the supply of innovations by entrepreneurs is readily apparent in the form of patents, product designs, new launches and new sectors. Therefore, even while the push-pull debate has been settled through an acknowledgment of mutuality, the overwhelming tendency has been to side with Dosi (1982, p. 150), who claimed that scholars propounding the existence of demand-pull effects had failed “to produce sufficient evidence that needs expressed through market signaling” plays a demonstrable role in the generation of innovations.

2.1 Novel solution sets and demand-supply sequencing

Despite the emergence and promulgation of a supply-side skew concerning the origins of innovative solution sets (Dosi, 1982; Mowery and Rosenberg, 1979), recent work by Di Stefano *et al.* (2012) suggests that the debate over supply-push primacy is far from settled. In noting the need for more research exploring demand-side forces, they issued a call for new research to address the question: “Does demand generate innovation in addition to selecting it?” (Di Stefano *et al.*, 2012, p. 1291). Implicit in this call is the lingering sense that latent demand-side signaling has not received a proper accounting, theoretically or empirically.

The key to determining whether or not demand-side forces play a discernable role in generating innovations involves ascertaining if and when latent demand-side signaling of needs and wants for a solution set precede the supply of specific innovations designed to address that solution set. This is, in essence, a question of sequencing (Hunt and Ortiz-Hunt, 2017). If latent demand for a solution set can be shown to precede supply, then demand-side forces have the potential to generate the innovations that Dosi (1988), Teece (2008) and DiStefano *et al.* (2012) have pointedly questioned. In the absence of empirical data and applicable methodologies, the generative capacity of demand-side forces has been treated as a theoretical issue, rather than as an empirical challenge. Since demand-first sequencing had not been observed (Teece, 2008), theoretical frameworks describing and predicting innovation have assumed that it cannot be observed.

Skepticism regarding the potential efficacy of demand-first logics is not unanimous. For example, Rogers (2003) wrote about “popularized scientific conversations” exerting influence on the diffusion of new technologies, while Golder (2000) propounded concepts hinting at demand-side “design directives.” Similarly, opportunity spaces, as conceptualized by Schoonhoven and Romanelli (2009), also represent the fertile ground for competing solution sets; spaces that exist in latent fashion even before the emergence of entrepreneurial innovations to exploit the opportunities. If an opportunity spaces are only defined after they have been occupied, then the description of any given opportunity space is inherently cast in terms of the initial occupants. In Schoonhoven and Romanelli’s view, it is erroneous to only begin discussing an opportunity space once it is occupied because any given firm or any given solution set capitalizes on only a portion of an opportunity space’s full potential. To this point, Eisenhardt and Tabrizi (1995) noted that the initial occupants of an opportunity space typically constitute no more than a portion of what could be exploited as the wider potentiality the space came to be more fully appreciated.

Each of these counterpunctual perspectives drives toward an unanswered question: Do demand-pull forces play a role in generating new innovations, firms and sectors? Given that this question purports to address conditions that exist before the innovations, firms and sectors themselves exist, any sequencing that places demand-side forces ahead of supply-side entrepreneurial activity necessarily advances two important claims:

opportunity spaces exist prior to being occupied; and demand-side forces have the capacity to generate new innovations. Extending the initial work that is suggestive of latent demand-side forces (Golder, 2000; Rogers, 2003) and positing the existence of opportunity spaces prior to being occupied by entrepreneurs (Schoonhoven and Romanelli, 2009), demand-supply sequencing has potent implications regarding the generative capacity of demand-side forces. More formally:

H1. When latent demand for entrepreneurial innovation precedes supply, then demand serves as a generative force of innovation and supply serves as a selective force.

2.2 Demand-driven quantity and diversity of entrepreneurial activity

As the foregoing discussion reveals, disparate research streams support the premise that opportunity spaces may exist prior to being occupied by entrepreneurial innovators (e.g. DiStefano *et al.*, 2012; Golder, 2000; Rogers, 2003; Schoonhoven and Romanelli, 2009); however, a formal test is needed for the assertion that demand-side forces generate innovative solution sets through latent societal signaling. If it can be demonstrated in at least some material instances that demand-pull effects precede the supply of entrepreneurial activity, then it is conceivable that demand can serve as a generative source of entrepreneurial innovation, as opposed to simply being a selective force of promising innovations developed by entrepreneurs. In turn, demand-side generation of opportunity spaces and solution sets suggests that latent demand-side forces may have a role in shaping both the quantity and diversity of entrepreneurial activity that is brought to market (Hunt, 2013a, c; Sarasvathy, 2004). The quantity of "non-necessity" entrepreneurship – consisting of new business venturing that excludes those pushed into self-employment due to non-discretionary forces (Acs, 2006) – is indicative of a society's proclivity to pursue entrepreneurial opportunities (Baumol, 1990; North, 1990) as well as the broader influence of tangible and intangible forces that have come to be known as entrepreneurial ecosystems" (Gnyawali and Fogel, 1994; Isenberg, 2010). The diversity of entrepreneurship represents the breadth of distinctive solution sets introduced to the marketplace (Brown and Eisenhardt, 1995).

While the quantity and diversity of a society's entrepreneurship are emblematic of the interplay between both supply-side and demand-side forces. Extant conceptions of opportunity emergence and new business venturing have tended to focus on individual entrepreneurs. The supply-side preoccupation involves what Schoonhoven and Romanelli (2009) called the "lone, swashbuckling entrepreneur." Such mythologized representations of the "heroic entrepreneur" (McMullen, 2017) offer an incomplete and fatally over-simplified depiction of the entrepreneur-opportunity nexus (McMullen and Shepherd, 2006; Eckhardt and Shane, 2003) in that macro-environmental forces, including social-cultural norms, biases and preferences, must also be taken into account. Thus, by signaling latent societal preferences, demand-side forces exert influence over the quantity and diversity of solution sets that might be brought to market. Sprawling, high-potential opportunity spaces, for which society may signal strong interest, could invite more market actors and more competition among varied solution sets than a relatively narrow niche representing a smaller opportunity space.

For example, nearly 2,000 small firms were engaged in automobile manufacturing in the early 1900s (Eckermann, 2001; Georgano, 1985). Virtually all of these firms were focused on developing a "horseless carriage" powered either by steam or primitive batteries. However, the latent demand signaling for the specific features that consumers desired in an automobile ultimately made steam and battery-powered technologies untenable (Clymer, 1950; Eckermann, 2001). In order to adequately address the manner in which consumers intended to use autos, entrepreneurial inventors first had to develop and market safe and effective internal combustion technology (Clymer, 1950; Kimes and Clark, 1975). Therefore, the "opportunity space" for horseless, motorized land transportation would be portrayed inaccurately if it focused primarily on sector occupants who sought to develop steam or battery-based solutions.

Conversely, opportunity spaces suggested by latent demand for novel therapeutics to address "orphan" diseases, with a small population of sufferers would likely generate only rarefied interest from entrepreneurial innovators. The addressable market for a horseless carriage was immense, while the addressable market for Aagenaes syndrome – a rare genetic disorder occurring less than once in one million births – is extraordinarily low. Both automobiles and Aagenaes syndrome started out as ill-defined opportunity spaces, but dramatic differences in latent and explicit demand directly influenced the quantity and variety of innovative solution sets that were tested in the marketplace. In each case, the opportunity space was established by preferences, norms, biases, and even human biology, in the case of orphan diseases. Thus, pre-existing conditions for each opportunity space demarcated the boundaries for viable solution sets.

Both illustrations reveal the generative role of latent demand and the manner in which entrepreneurs subsequently serve as sifters and sorters of viable solution sets in search of specific ways in which a diffuse population of potential customers would use automotive technology or novel therapeutics for an orphan disease. This dynamic suggests that both the quantity and diversity of entrepreneurial activity will emerge as a consequence demand-side signaling:

H2a. Demand-pull forces are positively associated with the quantity of entrepreneurship that is supplied to the market.

H2b. Demand-pull forces are positively associated with the diversity of entrepreneurship that is supplied to the market.

2.3 Demand-driven outcomes

As noted earlier, existing literature has attempted to chart a middle course, asserting that supply and demand are interlocked, symbiotic and therefore, mutually dependent (Di Stefano *et al.*, 2012; Mowery and Rosenberg, 1979). Recent perspectives propounding inter-subjective mechanisms take this inter-relatedness of society and innovators to the fullest extent (Davidson, 2001; Sarasvathy *et al.*, 2008): "The relationships between supply and demand are circular, interactive and contingent rather than linear, unilateral and inevitable" (Sarasvathy, 2004, p. 299).

Inter-subjective conceptualizations of how new sectors, organizations and technologies are developed and commercialized provide additional support for Mowery and Rosenberg's (1979) argument for the mutuality of supply and demand forces, but the inter-subjectivity emphasis only further obscures the explicit role of demand-side forces. Regardless of whether scholars argue that the founder of a new venture is "causing" or "effectuating" outcomes, the reality is that either way the focus is patently set on the supply-side founder. If instead, the focus is on demand-side drivers of the "opportunity space" prior to being occupied, then technological change and successful innovations are not strictly a function of successful entrepreneurs, but rather attentive founders who develop a deft approach to society's signals. Regardless of *ex post* interpretations of "circular, interactive and contingent" processes, entrepreneurial activity emanating from demand-side signaling should display a "validation dividend," in the form of improved commercialization potential, as a market-based reward bestowed upon entrepreneurs who "answer the call" of latent societal demands. By adopting an historically panoramic, demand-side perspective, this study tests the validity of the assertion that:

H3. Entrepreneurial innovations that follow evidence of demand-pull preferences have a greater chance of commercial success than entrepreneurial innovation preceding evidence of demand-pull preferences.

3. Data and methods

The study of demand-pull effects, especially those pertaining to new firms and sectors (Forbes and Kirsch, 2011), has suffered for want of a viable methodological approach. While measures related to the analysis of supply-side, technology-push phenomena are plentiful and generally well documented, there are few viable mechanisms for the acquisition and analysis of demand-side effects. Recent research has made credible progress toward defining the ways in which existing companies service the explicit and latent demands of existing customers (Adner, 2002; Benner and Tripsas, 2012; Danneels, 2003, 2008; Ye *et al.*, 2012; Priem *et al.*, 2012; Von Krogh and Von Hippel, 2006). In this limited context, scholars have had good success distinguishing between demand-side and supply-side innovations, capturing the ways in which users often serve as innovators (Ye *et al.*, 2012; Nambisan and Baron 2010; Priem *et al.*, 2012). However, broadly diffuse societal preferences involving conditions that precede innovations, firms and sectors, are another matter entirely. In the period preceding the emergence of new organizational forms that is so central to the study of entrepreneurship, there has been virtually no empirical research whatsoever (Di Stefano *et al.*, 2012; Forbes and Kirsch, 2011; Priem *et al.*, 2012).

3.1 Latent demand-side signaling through historical artifacts

Cognizant of the many methodological impediments to examining demand-side forces, including temporal proximity biases (Forbes and Kirsch, 2011; Welter, 2011), I designed a study based on detailed historical artifacts. In escalating fashion, strategy and entrepreneurship scholars (e.g. Haveman *et al.*, 2012; Popp and Holt, 2013; Wadhwani, 2010) have recently sought to expand and amplify the use of historical perspectives and techniques by building on foundational work of economists such as Schumpeter (1947), Fogel (1966, 1970) and Casson (1982). Consistent with the methodological intent and design-related insights of these approaches, I employ socially embedded historical artifacts to examine the extent to which demand-side preferences may serve as verifiable drivers of entrepreneurship. To do this, I traced the migration from pure science to applied science to commercialized science (CS) (Table I) for hundreds of technology paradigms (Dosi, 1982, 1988). Precedence for the conception of technological growth along the trajectory from pure science to commercializable science has deep roots, including Dosi, who proffered the view of

Category	Summary Definition	Example
Pure science	A method of inductively or deductively investigating nature through the development and establishment of information to aid understanding – prediction and perhaps explanation of phenomena in the natural world. Scientists working in this type of research don't necessarily have any ideas in mind about applications of their work	Discovery that serotonin levels are associated with human depression
Applied science	Applied science is the exact science of applying knowledge from one or more natural scientific fields to practical problems. Many applied sciences can be considered forms of engineering. Applied science is important for technology development. Its use in industrial settings is usually referred to as research and development (R&D)	Screen thousands of chemical compounds for any that have the ability to affect serotonin levels
Commercialized science	Development of a product or service based on applied science that is offered for sale to existing or future customers	Identify and isolate agents that selectively inhibit the reuptake of serotonin in a fashion that is safe and effective for human treatment

Table I.
Categorization rubric for scientific content of historical artifacts

“ ‘normal science” as being the “actualization of a promise” a technological trajectory repeats itself as the pattern of “‘normal” problem solving activity, leading to what society commonly refers to as “progress” (Dosi, 1982, p. 152).

In order to insure that the findings are not simply a manifestation of the specific historical source material that I employed in the analysis, I used three separate longitudinal sources of historical artifacts: *Popular Science Monthly* magazine, from its founding in 1872 to 1969; periodicals, newsletters, club minutes, films and radio transcripts from the Science Society, from 1921 to 1969; and programs and news accounts from the US National High School Science Fair, from 1950 to 1969. The use of periodicals has strong precedence in prior studies that have sought to panoramic perspectives and historiographic techniques (e.g. Haveman *et al.*, 2012). By selecting an historical span that stretches from Post-Bellum Reconstruction to the first steps on the moon, these historical artifacts form an in-depth accounting of many of the greatest scientific and technological advances in human history (Mokyr, 1998). The use of periodicals and other historical artifacts has been shown to be a valid method for evidence of demand-side effects and entrepreneurial innovation (Golder, 2000). For instance, Petra Moser’s wonderful investigation into the relationship between patenting and innovation used programs and other artifacts from world fairs staged in the 1800s (Moser, 2005).

Popular Science Monthly was first published in 1872, just seven years after the end of the US Civil War, “to disseminate scientific knowledge to the educated layman” (*Popular Science* August 1872, p. 104). In its early years, the magazine was a frequent outlet for the likes of Darwin, Spencer, Huxley, Pasteur, James, Edison, Dewey, Becquerel, Maxwell, Tesla, and Ramsay. The magazine has been published continuously for 140 years, generating nearly 1,700 issues, and an exhaustive chronicle of science and technology, covering 60 percent of the history of the US.

The Science Service was the brainchild of publishing magnate E.W. Scripps, who started the organization in 1921 to present “unsensationalized, accurate and fascinating scientific news to the American public” (Smithsonian, 2012). Although Scripps and the Science Service’s newswire never fully realized its mission of enjoining editors nationwide in the mass circulation of scientific knowledge, the Service did spawn publications and clubs that left an indelible imprint on American culture (Astell, 1930). In so doing, the organization produced tens of thousands of historical artifacts that are pertinent to an assessment of commercializable science. The flagship publication was the *Science Newsletter*. Virtually a complete collection of publications, films, meeting minutes and radio transcripts are available through the Smithsonian Institute Archives. Artifacts from the Science Service were also used in this study due to the fact that they were first produced at almost the precise time that *Popular Science* was approaching maturity. This is important in order to demonstrate that the migration from pure science to applied science to CS was not simply the result of a specific news outlet.

National science fair. Through the influence and support of the Westinghouse Corporation, the first nationwide science competition was held in 1942, with the intent of encouraging talented high school students to pursue careers in science. In 1950, finalists for this competition met in Philadelphia for the first national science fair. Detailed programs, extensive news accounts and data about the background, college plans and career choices are available for each year’s event through the Smithsonian and the New York Public Library. In exactly the same fashion that the artifacts from the Science Service are introduced when *Popular Science* approached maturity, artifacts from the National Science Fairs are introduced as the Science Service approached maturity. I implemented this study design element in order to demonstrate that the migration from pure science to applied science to CS was not simply the result of more general societal trends involving the commercialization of technology.

Coding. In total, 2,084 documents containing 33,720 articles and advertisements were coded for content related to pure science, applied science and CS. Ten undergraduate science and engineering students were trained to perform the categorization in accordance with the rubric summarized in Table I. Inter-rater reliability exceeded 87 percent for the coding of each source and for any permutation of coders and document sources.

Innovation and sector data. Various measures of the quantity and diversity of entrepreneurial activity were captured through data from the USA Patent and Trade Office (1872-2012), SIC/NAICS classifications (1937-2012), and Dun & Bradstreet Classifications (1872-2012).

3.2 Dependent variables

Applying a cliometric approach, using multiple and logistic regression, I modeled and tested the four hypotheses using three separate dependent variables: Quantity of Entrepreneurial Activity, Diversity of Entrepreneurial Activity, and Commercialization Events.

Entrepreneurial activity – quantity (EAQ). The continuous variable, EAQ, is a blended rate comprised of the total number of new patents and the total number of new business sectors emanating from a scientific discovery. Scientific discoveries were coded from historical artifacts and then traced, wherever applicable, to patenting and commercialization.

Entrepreneurial activity – diversity (EAD). The continuous variable, EAD, is a blended rate comprised of the total number of distinct patent-holders and the numerical distance of new business sector codes (SIC/NAICS) emanating from a scientific discovery. Scientific discoveries were coded from historical artifacts and then traced to patenting and commercialization.

Commercialization events (CE). CE is a dummy variable, with 1 representing the commercialization of each scientific discovery identified in the coding of the historical artifacts. Commercialization is defined as the existence of at least one revenue-generating organization for which it can be demonstrated that technology was marketed to potential customers.

3.3 Predictors

Sequence (SEQ). SEQ is a dummy variable designed to capture the demand-supply sequence. Coding was determined by comparing the first date of latent demand-side signaling – indicated by mentions in one or more of the science-oriented historical artifacts during the observation window – to either initial an patent filing date or the initial marketing date for an actual product and service related to each opportunity space. A coded value of 1 indicates that evidence of demand-pull forces in the historical artifacts of this study preceded evidence of the entrepreneurial supply of commercializable opportunities.

Demand-pull velocity (DPV). DPV is a relative measure of the speed with which demand-first scientific discoveries (indicated through the historical artifacts of this study and patent application dates) move from an engineering conceptualization to an actively marketed product or service, calculated by subtracting the date of initial applied science (AS) from the date of initial CS. Values ranging between 0 and 1 are calculated through the ratio: 1/(CS Date – AS Date).

Demand-pull mass (DPM). DPM is a relative measure of the scale with which demand-first scientific discoveries indicated through the historical artifacts of this study. It is a source of considerable insight regarding the relative importance of demand-side effects in generating innovations because the mere existence of latent demand-side signaling is not sufficient to demonstrate the influence it exerts in fueling the pursuit of numerous, diverse solution sets. DPM solves this by counting the total number of artifacts mentioning a particular scientific discovery as a conceptual starting point for AS or CS. Values are included for all conditions in which AS + CS is greater than 0.

Key events. Three major historical events were modeled through dummy codes in order to assess and control for their respective effect on demand-side phenomena: the Great Depression, Second World War and the Space Race. The demand-side role of formal, government institutions is likely to be evident from the massive outlays associated with historically significant "spending shocks" instigated toward the achievement of political and socio-economic aims (Hunt, 2015; Hunt and Fund, 2016). These three events played a prominent role in public and private sector economics for the period, 1872-1969 (Engerman and Gallman, 2000) and should, therefore, be modeled distinct from the diffuse sources of latent societal demand.

Controls and instrumental variables. Consistent with cliometric models that aim to express the materiality and directionality of causal agents related to innovation for historical data over extended periods (e.g. Moser, 2005), control variables were employed: population, GDP per capita and time sequence. Models such as the ones developed for this analysis are potentially at risk of endogeneity on two fronts: omitted variables and reverse causality. In addressing the former, my models incorporated Heckman's two-step procedure (Campa and Kedia, 2002; Heckman, 1979), through which I generated an inverse Mills ratio to test for statistical significance in the context of a complete model of predictors.

To address potential confounds due to reverse causality, I took two precautions. First, I used lagged time-series variables to confirm the directionality of focal effects (Davidson and MacKinnon, 1995). Second, I developed instrumental variables (IV) for use in a two-stage least squared (TSLS) analysis, which is the preferred approach in dealing with multiple endogenous regressors and in models containing both continuous and categorical dependent variables (Bascle, 2008). Overall, a strong IV will be well correlated to the predictor that has been included in the model, but should be uncorrelated to the model error. This means that the IV is only related to the DV through the predictor. In this test for reverse causality, I regressed the model predictors onto a vector containing three instruments that included: graduate degrees in engineering, the percentage of the population engaged in agriculture, and the percentage of the population that died from infectious diseases. Given the extended time period across which measurements were taken, I elected to develop a vector of IVs, rather than relying upon a single IV that might exert differential influence across the lengthy observation window. Use of vectors is endorsed in cases involving the study of complex phenomena over extended periods of time (Angrist and Krueger, 2001).

3.4 Model specifications

Logistic regression, OLS regression and significant mean differences were employed to derive and explicate the focal effects and to preserve interpretability of the model coefficients. Key assumptions underlying the decision to employ an OLS design required four data properties: linearity in the parameters, random sampling of observations, a conditional mean of zero, and the absence of multi-collinearity (Judd *et al.*, 2011). Given a sample population of nearly 34,000 documents, drawn from diverse sources and continuously varied time periods, it was possible to achieve robust satisfaction of these OLS pre-conditions, confirming the suitability of the data for an OLS model.

H1, predicting that demand-pull effects often precede the supply of entrepreneurship was evaluated by using longitudinal mean differences of coded scientific content form each of the three sources of historical artifacts. *H2a* and *H2b* were analyzed using OLS methods represented by the generalized model:

$$\begin{aligned}\text{EAQ or EAD} = {} & \text{Controls} + \text{Instruments} + \text{Demand} - \text{Pull Velocity} + \text{Demand} \\ & - \text{Pull Mass} + \text{Key Events} + \text{Demand} - \text{Supply Sequence} + e \qquad (1)\end{aligned}$$

H3 predicted that when demand-pull effects precede supply-side technology-push, then there existed a greater likelihood of successful commercialization. In order to test this, the dependent variable for commercialization events was modeled using both a logistic regression and a Cox Proportional Hazard (PH) regression. The logistic regression model is represented by:

$$\begin{aligned} \text{CE} = {} & \text{Controls} + \text{Instruments} + \text{Demand} - \text{Pull Velocity} + \text{Demand} \\ & - \text{Pull Mass} + \text{Key Events} + \text{Demand}{-}\text{Supply Sequence} + e \end{aligned} \tag{2}$$

The survival analysis approach employs the Cox PH regressions, where each variable is exponentiated to provide the hazard ratio for a one-unit increase in the predictor:

$$h(t) = h_0(t)\exp(b_1 X + b_0) \tag{3}$$

The equation states that the hazard of the focal event occurring at a future time t is the derivative of the probability that the event will occur in time t. For the purpose of contrasting the effects of supply and demand sequencing and then relating that sequence to survival probabilities, I developed a matched set of 300 scientific discoveries that were randomly selected from two pools of coded data (150 each): one pool consisting of situations in which evidence of demand preceded supply, and one pool consisting of situations in which supply preceded demand. Pair-wise matching insured equivalent means and variance for each focal covariate, so that the paired innovations resembled one another in all respects other than the coding associated with sequencing (SEQ). The purpose of employing pair-wise analysis with data drawn from matched sets is to remove bias in the comparison of groups by ensuring equality of distributions for the matching covariates I employed (Casella, 2008). With pair-wise matching, the null hypothesis is that there are no significant differences between the paired subjects, tested using z-statistics and applying McNemar's test (McNemar, 1947). T-test scores for each of the dimensions used to associate the two matched set pools were not significant (ranging between 0.11 and 0.72), confirming that the pools were statistically indistinguishable aside from the element of sequencing.

4. Results

The purpose of this study was to address several vexing questions (Schoonhoven and Romanelli, 2009) central to the process of generating and commercializing new innovations: Do opportunity spaces exist prior to being occupied and, if so, what is the precise role of latent demand-side forces in creating and sustaining those opportunities? As noted above, the elusiveness of this line of inquiry necessitated the use of diverse data sources gathered across an unusually long observation window. Analysis of the findings indicates compelling support for all four hypotheses, with the statistical models exhibiting significant ($p < 0.01$) and material effects. Importantly, the findings provide substantial evidence that latent societal demand for entrepreneurship is a key determinant of opportunity space creation and supply-side entrepreneurial activity.

Moreover, the results strongly suggest that entrepreneurial attentiveness to demand-side signaling is a key determinant of entrepreneurial success or failure. The correlation coefficients reflect the directionality and materiality of the predicted relationships among the variables (Table II), while signaling no significant concerns for multi-collinearity. For example, the variable designed to capture demand-supply sequencing – wherein demand for an innovation precedes marketplace supply for an innovation – is positively correlated with commercialization, indicating that entrepreneurs seeking to service existing demand are more likely to realize a successful commercialization of an innovation.

H1 involved the prediction that when latent demand for entrepreneurial innovation precedes supply, it will serve as a generative force of innovation while supply serves as a

Variable	Mean	SD	1	2	3	4	5	6	7	8	9
1. Commercialization	0.24	0.13									
2. Diversity of Entre	0.33	0.18	*0.19*								
3. Quantity of Entre	0.28	0.13	*0.13*	0.05							
4. Demand-Pull Velocity	0.38	0.14	*0.21*	*0.17*	*0.18*						
5. Demand-Pull Mass	0.31	0.13	*0.15*	*0.14*	*0.17*	0.08					
6. Great Depression	0.07	0.04	0.08	0.04	0.05	0.04	0.05				
7. World War II	0.09	0.06	0.07	0.03	0.04	0.08	0.04	*0.11*			
8. Space Race	0.13	0.06	0.09	*0.11*	*0.10*	*0.14*	*0.12*	−0.02	0.04		
9. Sequence (D before S)	0.50	0.22	*0.23*	*0.19*	*0.18*	*0.21*	*0.16*	0.03	0.06	0.09	
10. Macro-Control Vector	0.27	0.18	0.07	0.05	0.04	0.02	0.04	−0.03	−0.03	0.04	0.05

Note: Italics indicate correlation with $p < 0.01$

Table II. Correlation coefficients and descriptive statistics

selective force. Longitudinal analysis of the three sources of historical artifacts provides strong evidence for this premise. Figures 1-3, display similar trend lines, indicating a consistent pattern of migration from content favoring pure science to content that largely supplants pure science in favor of an applied focus. Given the mushrooming of novel scientific pursuits across the observation period – involving quantum physics,

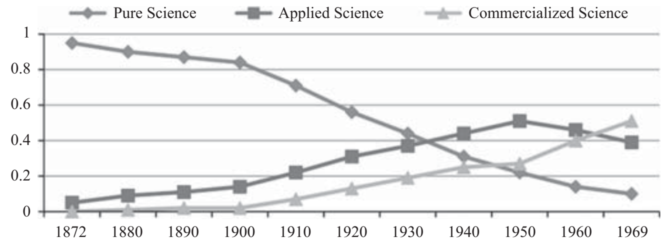

Figure 1. *Popular Science Monthly* article content (1872-1969)

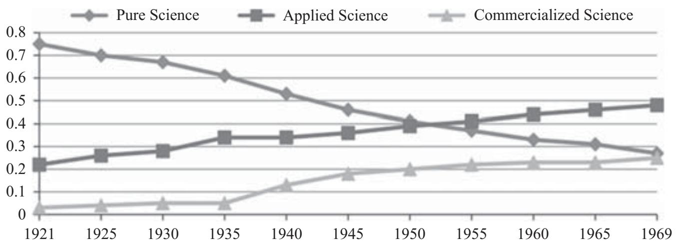

Figure 2. *Science Society Newsletter* content (1921-1969)

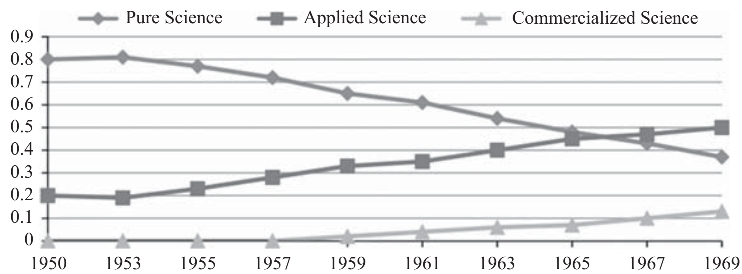

Figure 3. National science fair exhibits (1950-1969)

biomechanics, medicine, computational science, materials science, aeronautics, astronomy, and many others (Wheatley, 2011) – there is no obvious reason to explain why these popular outlets for scientific knowledge would have taken on a more commercial orientation, especially given the diverse audience that each services.

The most dramatic change is apparent in the *Popular Science* artifacts, where pure science content slipped from nearly 100 to 10 percent over the observation period (1872-1969). Meanwhile, content related to CS – that is, articles pertaining to products actively marketed to existing or future customers – rose to more than 50 percent, from 0 percent in 1872. Early interest in the writings of Darwin, Curie, and Spenser, evolved to a product orientation as readership demanded more focus on the applications stemming from scientific breakthroughs (Table III). The inexorable drift from a pure science focus to commercializable science focus underscores market-based motivations to seek productization of scientific breakthroughs.

Since *Popular Science* is a for-profit publication, there are reasons to be concerned that the commercialization drift is idiosyncratic to its consumer-based orientation. Therefore, in order to stress-test the generalizability of *Popular Science's* trends, it was necessary to examine whether similar trends are evident in looking at the not-for-profit *Science Society News* and National Science Fair artifacts. As Figures 2 and 3 bear out, both sources of embedded societal preferences reveal an escalation in applied science content that confirms the findings from *Popular Science.*

1872	1919	1969
		
The Study of Sociology	Hello Mars, This is Earth!	What the Apollo 8 Moon Flight
The Recent Eclipse of the Sun	Our Capital's Public Waste Baskets	Really Did for Us?
Science and Immortality	The Tale of Totem Pole	Are We Changing Weather by
The Source of Labor	Insects that Sail on Raindrops	Accident?
Quetelet on the Science of Man	Can You Save a Drowning Man?	New Brakes for Your Car
Disinfection and Disinfectants	Why Does a Curveball Curve?	The Growing Rage for Fun Cars
The Unity of Human Species	Money Making Inventions!	Canned Movies for Your TV Set
The Causes of Dyspepsia	Improving the Intake Manifold	Oil Drilling City Under the Sea
Woman and Political Power	Squaring a Board Without a Square	It's Easy Now to Form Your Own
Early Superstitions of Medicine	The Trouble with Hooves	Wrought Iron
Prehistoric Times	On the Trail of the Grizzly Bear	What's New in Tools
The Nature of Disease	How Fast is Your Brain?	How to Build the Microdorm
Southern Alaska	Keeping Paintbrush Handles Clean	New Math Discovery?
Hints on House Building	A Poultry Roost that Destroys Mites	Color from Black and White Film?
Production of Stupidity in Schools	Substitute for Battery Separators	Facts About Drinking and Driving

Table III. *Popular Science Monthly* – content examples by era

The unmistakable trend toward applied science across the data set indicates a groundswell of effort to identify practical applications of the burgeoning body of scientific knowledge; however, these trend lines do not enable us to assess the relative influence of supply-side and demand-side forces. The extent to which demand-pull forces are instrumental in fueling entrepreneurial activity requires isolating and measuring demand-side variables, DPV and DPM. Extending extant work on demand-side provocated innovations (Priem *et al.*, 2012; Ye *et al.*, 2012), *H2a* and *H2b* predicted that increases in demand-pull effects are associated with an increase in the quantity and diversity of entrepreneurial activity. Even after controlling for a wide array of macro-level effects, time-series factors and key events, the velocity and mass of demand-pull effects are shown to be significant (Table IV – Models 2a and 2b) predictors of both the quantity and diversity of entrepreneurial activity. This finding supports *H2a* and *H2b* as well as the qualitative assessment performed in regard to *H1*. Taken in total, these findings further underscore the generative role of latent demand-pull forces.

Evidence of latent demand's generative capacity demonstrates that the customers of entrepreneurial innovations are not merely sifters and sorters of the products and services brought to the marketplace as CS. Rather, demand-side wants and needs are a fountainhead of latent opportunity spaces. Left unanswered, however, is whether new innovations succeed or fail commercially due to the effects of demand-side influence or in spite of it. Attentive to this critical question, *H3* extends the examination of demand-pull and supply-push effects into a comparative context by predicting that when demand-pull forces precede supply-side technology-push, then innovations have a greater probability of resulting in a commercialized product or service. In essence, this suggests that

Table IV. OLS regression models

	Model 2a (OLS)		Model 2b (OLS)		Model 3 (Logistic)	
Dependent variable	Entrepreneurial activity – quantity (EAQ)		Entrepreneurial activity – diversity (EAD)		Commercialization event (1 = CE) (Odds Ratio)	
Hypotheses	Base model	Increased demand-pull positively related to increased quantity	Base model	Increased demand-pull positively related to increased diversity	Base model	Increased CE when demand precedes supply
Predictors						
Constant	Incl	Incl	Incl	Incl	Incl	Incl
Controls	0.97*	0.88	1.10*	1.03	1.38*	1.29*
SD	*(0.19)*	*(0.22)*	*(0.34)*	*(0.30)*	*(0.40)*	*(0.38)*
Demand-Pull Velocity	1.56*	1.22*	1.31	1.2	2.20**	2.13**
SD	*(0.48)*	*(0.37)*	*(0.47)*	*(0.43)*	*(1.32)*	*(1.25)*
Demand-Pull – Mass	0.87	0.81	0.68	0.65	1.19*	1.18*
SD	*(0.21)*	*(0.20)*	*(0.14)*	*(0.14)*	*(0.56)*	*(0.56)*
Great depression	3.01**	2.40**	2.12**	1.72*	1.49*	1.22*
SD	*(1.77)*	*(1.32)*	*(0.51)*	*(0.41)*	*(1.02)*	*(0.95)*
Second World War	2.33**	2.17**	1.80*	1.72*	1.54*	1.36*
SD	*(0.82)*	*(0.61)*	*(0.55)*	*(0.52)*	*(.83)*	*(0.79)*
Space race	1.68*	1.43*	2.04**	1.99*	2.16**	2.12**
SD	*(0.70)*	*(0.58)*	*(0.89)*	*(0.82)*	*(1.27)*	*(1.21)*
Demand-supply sequence		2.85***		2.60**		3.43***
SD		*(1.59)*		*(1.88)*		*(2.21)*
Adjusted R^2	0.53	0.66	0.47	0.58	–	–
F-value	117.4	131.2	98.8	102.1	–	–
ΔAdjusted R^2		0.13		0.11		
χ^2					342.5	412.6
Predictive accuracy					77.00%	96.0%

Notes: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

entrepreneurs who are attentive to the contexts in which societal signaling plays a generative role, are more likely to find commercial viability for their innovations than when supply-push innovations precede indications of latent demand. In order to test this comparison, I used 150 randomly paired scientific discoveries, half of which involved evidence of demand preceding supply and half evidencing supply preceding demand. As indicated in Table IV (Model 3), *H3* finds support; that is, primacy of demand is expected to lead to more frequent success. The variable for demand-supply sequence, is highly significant ($p < 0.001$) in predicting the logistic model outcomes for the commercializability of each sequence.

To more precisely determine the comparative effects of demand-supply sequencing, I also generated probabilities using a hazard rate model, for which the relevant focal end-point consisted of a commercialization event. In further support of *H3*, the findings show that when demand precedes supply the effect on commercializability is positive, while the effect on commercializability is significantly negative when supply precedes demand (Table V). The significant difference is evident in the Kaplan-Meier plot (Figure 4).

With respect to endogeneity concerns, neither omitted variables nor reverse causality proved to be a material factor. As a robustness test for omitted variables, my models incorporated Heckman's two-step procedure (Campa and Kedia, 2002; Heckman, 1979), through which I generated an inverse Mills ratio that was found to be not statistically significant. Thus, I could reasonably conclude that any omitted variables could only influence the dependent variables through the predictors already included in the models. I tested for the potential effects of reverse causality through the use of instrumental

	Demand precedes supply ($n = 150$)			Supply precedes demand ($n = 150$)		
	Probability of CE (95% CI)	SD	p-value	Probability of CE (95% CI)	SD	p-value
Variables						
Controls – Macro	1.13	0.25	< 0.01	1.03	0.15	< 0.01
Demand-pull velocity	1.03	0.26	0.06	0.93	0.04	0.03
Demand-pull – Mass	1.01	0.30	0.14	0.98	0.11	0.18
Great depression	1.02	0.40	0.11	1.00	0.05	0.01
Second World War	1.04	0.32	0.05	1.01	0.02	0.01
Space race	1.02	0.38	0.14	1.01	0.04	0.12
Demand-supply sequence	2.07	0.32	< 0.001	0.88	0.09	< 0.001
χ^2	103.8			78.1		
p-value	< 0.001			< 0.001		

Table V. Cox proportional hazard model

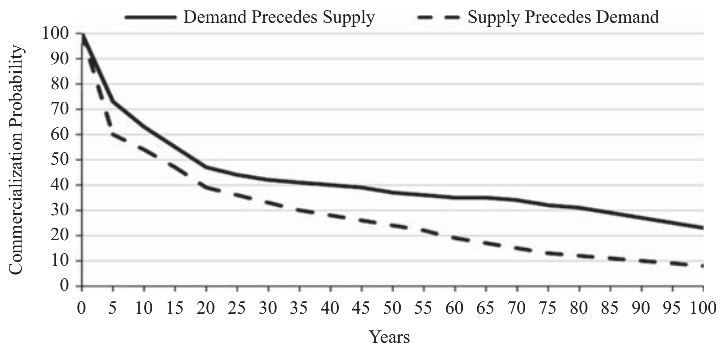

Figure 4. Kaplan-Maier Plot based on demand-supply sequencing

variables (IV), aggregated into a vector, for use in a TSLS analysis (Bascle, 2008). Using Staiger and Stock's (1997) procedure for first-stage F-statistics, I confirmed that the correlation strength of the IV vector was well above the target threshold. Applying both Sargan's (1958) test and Hansen's J-statistic (Hansen and Singleton, 1982) confirmed the exogeneity of the IVs. When tested in the context of a complete model, the IV vector was found to be significant at $p < 0.001$. Since the components of the vector are only related to the dependent variables through the original model regressors, I concluded that the hypothesized relationships are not materially subject to the confounding effects of endogeneity.

5. Discussion

Considerable effort has been expended over the course of the past 30 years in seeking to investigate what Dosi referred to as "the role of science and technology in fostering innovation along a path leading from initial scientific advances to the final innovative product/process" (Dosi, 1982, p. 151). As the empirical results of this study demonstrate, the progression is not a matter of mere conjecture. In providing one of the most expansive longitudinal investigations of society-wide, latent demand-side signaling, this study makes evident the inexorable drift from pure science to applied science to commercializable science, for a multitude of technological paradigms (Dosi, 1988; Teece, 2008). This is accomplished by exposing embedded societal preferences through thousands of historical artifacts across nearly a century of intensive innovation. By employing historical data spanning multiple generations, this study addresses significant gaps in existing theory that have inappropriately relegated demand-side forces to a subordinate role.

The empirical evidence presented here of primordial, unoccupied opportunity spaces fundamentally changes the way in which the quantity and diversity of entrepreneurship is conceptualized. Existing scholarship focusing exclusively on the supply of innovation and entrepreneurship inherently defines emerging sectors in terms of the new sector occupants since the opportunity space is only explicitly acknowledged at the time the opportunity is exploited. This "supply-side skew" is inevitable when empirical studies of innovation and entrepreneurship rely exclusively upon recent data from occupied opportunity spaces. Equally inevitable are the significant gaps this approach has created. As a consequence of supply-side biases, the technologies and innovators that initially populate new sectors often define new markets; thereby presupposing that supply-side forces serve as the primary generative mechanism of entrepreneurship, while demand-side forces serve as the primary selective mechanism. The problems with this approach are numerous, but most conspicuously the approach errs in failing to account for latent preferences that are presented through societal signals of its needs and wants regarding the quantity and diversity of entrepreneurship. As Priem *et al.* (2012) noted, "The process of opportunity signaling, and the conditions under which potential customers actively drive opportunities toward entrepreneurs who are cognizant of those signals, represents an important new stream of research for entrepreneurship scholars" (p. 366). This is precisely the juncture at which this study has sought to answer the call in addressing this new stream.

The cumulative weight of these findings provides compelling empirical evidence that: opportunity spaces often exist prior to being occupied; societal preferences play a key role in determining the quantity and diversity of entrepreneurial activity; and entrepreneurs who are responsive to latent demand-side signaling are likely to face significantly greater prospects of long-term survival. All three findings have implications for scholars, practitioners and policy-makers.

5.1 Implications for scholars

For scholars, a heightened focus on demand-side research is the first step toward credibly addressing the "supply-side skew" and, in so doing, bringing the supply-push and demand-pull perspectives into a more reasonable balance. Future studies will find fertile soil in demarcating more thoroughly the boundary conditions that apply to supply-side-centric frameworks. Additional work to address the paucity of empirical research on latent demand-side signaling can stimulate fresh progress toward better describing and predicting demand-pull phenomena. Conceptually, a reassessment of supply-push and demand-pull forces enables scholars in economics, strategic management, entrepreneurship and innovation to develop more integrated frameworks.

Although Dosi (1982) joined Mowery and Rosenberg (1979) in making the strong-case assertion that "most of the studies with a demand-pull approach fail to produce sufficient evidence that needs expressed through market signaling are the prime movers of innovative activity" (Dosi, 1982, p. 150), it is not obvious that the same could be said today, especially in the context of game-changing business models, such as multi-sided platforms, freemiums and open innovation. Novel business models that intentionally blur the lines that separate supply and demand fundamentally alter the ways in which scholars conceptualize value creation and value capture. By allowing for demand side's generative capacity, these emerging business models make considerably more sense, as do the trends that increasingly highlight user-provocated innovation (e.g. Ye *et al.*, 2012). Absent the consideration of latent demand-side signaling, scholars will be at a loss to explain how and why novel business models emerge that appear to cede control over the innovation process even while creating and capturing new sources of value (Von Hippel, 2005).

By providing a portal to the generative effects of latent demand-side forces, this study paves the way for follow-on research wherein scholars can move beyond the traditional focus on differential access to resources (Astley, 1985; Tushman and Anderson, 1986) and the role of institutions (Aldrich and Fiol, 1994; Baum and Oliver, 1991; Thornton, 1999) in creating environmental conditions that are conducive to entrepreneurial activity (Baumol, 1990; Hunt and Kiefer, In Press; North, 1990). In this sense, the results of my investigation offer methodological insights as well as a reorientation in the explanatory models for commercializable innovations.

Adoption of a non-historical approach, noted the Economist Avner Greif (1997), is not only self-limiting, but can result in patently wrong empirical interpretations and conceptual frameworks. Nowhere is this more apparent than in the study of nascent-stage industry sectors, where the ill effects of data truncation (Cameron and Trivedi, 2005; Hunt, 2013a, 2015) and historical proximity biases (Grosjean, 2009) are most acutely apparent; each stemming from the exclusive use contemporary data. By sacrificing long-term intelligibility for near-term data accessibility (Heckman, 1997; Solow, 1987) non-historical approaches run the risk of irrelevance when examined by future generations of scholars who have the benefit of longitudinal data and greater historical context (Welter, 2011).

Within just the past several years, leading management journals have published special issues focusing on historical perspectives and methodologies, including *Academy of Management Journal*, *Strategic Management Journal* and *Strategic Entrepreneurship Journal*. Editorial concerns underlying these various calls underscore the growing awareness that there are grave risks in ignoring history. The fine line separating recency and relevance, on the one hand, and measured reflection, on the other hand, places a premium on studies that incorporate lessons worth learning from the distant past as well as the most current events (Hunt, 2013a).

5.2 Implications for practitioners and policy-makers

For practitioners, the implications of these findings are also illuminating. As the PH model suggests, the commercialization of scientific breakthroughs is likely to be far more common when business models focus on developing and executing accurate assessments of latent demand (Hunt and Ortiz-Hunt, In Press). In an era of "mass customization," (Da Silveira *et al.*, 2001) businesses increasingly find themselves catering to customers who possess what Franke and von Hippel (2003) labeled a "very high heterogeneity of need." Under such circumstances, latent demand-side signaling is not only an important driver of successful innovations, but in some sectors attentiveness to latent demand may be indispensable to a firm's survival (Von Hippel, 2005).

The results further suggest that entrepreneurs, incubators, investors and other parties with a vested stake in commercializing science, will be well-served by investing time and effort into better understanding opportunity fields as they are defined by current and future customers, rather than isolated supply-side pre-conceptions of when, how, why, where and by whom technologies might be acquired and used. Unquestionably, there exists a highly interactive testing and exploration process (Di Stefano *et al.*, 2012; Mowery and Rosenberg, 1979; Priem *et al.*, 2012; Rogers, 2003) between suppliers and consumers of entrepreneurial activity; but, supply-side explanatory models that have ignored the generative role of demand-side forces handicap entrepreneurs who buy into the myths of swashbuckling individualism (Hunt and Lerner, 2012; Schoonhoven and Romanelli, 2009). As the illustration of the automotive industry demonstrated, entrepreneurs who selected technological solution sets that were most closely akin to the latent opportunity space generated by society for motorized transport faired far better than those who pushed an unwanted set of technological solutions.

The popular media is perhaps partially to blame for the "supply-side skew." On this score, policy-makers would also be well advised to avoid the quick sand that often accompanies supply-side fanfare. Deification by popular acclaim of successful individuals ranging from Thomas Edison to Steve Jobs is deeply engrained in the culture and myths that surround the generation and commercialization of innovations. These myths perpetuate a sort of "great man" approach to history that fuels popular and scholarly fascination with supply-side details. And, since supply-side details tend to be more accessible than relatively subtle and diffuse latent demand, it is readily understandable why a supply-side perspective dominates not just scholarly research, but also the ways in which policy-makers look for institutional support mechanisms for entrepreneurial ecosystems and business models (Hunt and Ortiz-Hunt, 2017) that favor the roll-out of emerging technologies.

5.3 Limitations and opportunities

As with all studies, design-related decisions associated with this investigation exhibit both strengths and weaknesses. Questions can reasonably be raised regarding two potential limitations: generalizability and endogeneity. Regarding the former, the degree to which my historical artifacts are representative of latent societal demand is a worthwhile debate. By choosing three different sources, each of which possesses a broad and deep reach into American society, it was obviously my hope to triangulate on material findings, rather than investing hope in the potential effects drawn from a single source. Further study using substantial collections of historical artifacts from other eras and nations will allow for intriguing comparisons and fruitful boundary conditions for society-wide demand-side drivers of the quantity and diversity of entrepreneurial activity. Regarding the latter concern, the risks of endogeneity are endemic to analyses involving time-series data and causal directionality. As discussed above in the methods and results sections, care was taken to ensure that the analytical models used in this investigation were not subject to the potentially biasing effects of omitted variables and reverse causality.

5.4 Conclusion

"History rarely provides the full measure of people during their lifetimes," wrote Wren and Bedeian (2009) in their classic tome *Evolution of Management Thought* (p. 211). The same can be said about inventions and social movements, as well as the business organizations that they spawn. For this reason, the paucity of expansive, temporally distant data sets and historiographic methods employed in management research (Landstrom and Lohrke, 2010; Rowlinson *et al.*, 2014) continues to play havoc with the conceptual frameworks drawn from limited data and non-historical methods (Forbes and Kirsch, 2011).

The increasing willingness and ability of entrepreneurship scholars to employ historiographic methods and historically panoramic data (e.g. Casson and Godley, 2005; Landstrom and Lohrke, 2010; Wadhwani, 2010) is the cause of justified optimism that significant impediments to the development of robust explanatory frameworks can be overcome, particularly those concerning phenomena that only become intelligible when observed over the course of many generations (Popp and Holt, 2013). Nowhere is this more apparent than in the study of innovation, entrepreneurship and emerging industrial sectors (Forbes and Kirsch, 2011). This is, as the foregoing results demonstrate, a key facet of matching entrepreneurship research questions to the most effective and coherent entrepreneurship research methodologies. Supply-side vs demand-side drivers of entrepreneurial innovation are a compelling case in point. Although extant theories of innovation posit interactive, highly interdependent demand-pull and supply-push forces; functionally, scholarship has focused overwhelmingly on the supply of innovation and entrepreneurship, not the demand. The result of this supply-side skew is that the influence of demand-side opportunity signaling has been relegated to a subordinate, virtually non-existent role. The sparse exploration of demand-pull effects has occurred for a wide range of theoretical and empirical reasons, but one of the primary culprits – at least in the past – is the underutilization of historical evidence and methods.

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