Demand-Side Drivers of Entrepreneurial Activity: A Cliometric Reassessment Using Socially Embedded Historical Artifacts

Richard Hunt
Virginia Polytechnic Institute
Pamplin College of Business
Blacksburg, VA

ABSTRACT

Which comes first: the demand for entrepreneurial innovations or the supply? Although existing theories posit an interactive, highly interdependent model of demand-pull and supply-push forces; functionally, scholarship has focused overwhelmingly on the supply of entrepreneurial innovations, 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. In one of the first expansive empirical analyses highlighting societal demand for entrepreneurship, I use historical artifacts and cliometric models to analyze data spanning 97 years -- from the launch of Popular Science Monthly magazine (1872) to the first moon landing (1969) – in order to assess the ways in which society signals demand-side preferences for a greater quantity and diversity of entrepreneurial activity. By employing panoramic data and an historical approach, my study provides 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 demand-side opportunity signaling are likely to face significantly greater prospects of long-term survival. The findings offer transformative insights for scholars and practitioners by revealing the critical role of demand-side opportunity signaling and reestablishing mutuality between supply-push and demand-pull forces in generating and selecting new innovations.

Correspondence: Richard A. Hunt, Ph.D., Virginia Polytechnic Institute, Richard.Hunt@colorado.edu.

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> "What was here before we knew that here was here?" Parmenides, *On Nature,* 5th century BCE

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> "Economists no longer question whether to extend a data series into the past; rather, the issue today is how far and at what cost." Goldin, 1997. *Exploring the Present through the Past.*

INTRODUCTION

One of the crucial questions confronting strategic management and entrepreneurship scholars continues to be: Where do new industry sectors come from? As Schoonhoven and Romanelli noted, the great challenge inherent in this question is that scholars "are trying to examine something before it comes into existence" (2009: 235). 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 (Schoonhoven & Romanelli 2001), the demand-side perspective addresses the role of environmental context (Aldrich & Wiedenmayer 1993; Romanelli 1989), societal signals (Meyers & Marquis 1969; Schmookler 1966), and user-provocated breakthroughs (Priem, LI & Carr 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. Di Stefano, Gambardella & Verona 2012; Priem, Li & Carr 2012; Priem & Swink 2012; Ye, Priem & Alshwer 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. Priem, Li and Carr identified this gap while noting that much work still remains to properly define and analyze the ways in which society-wide "opportunity signaling" shapes supply-side activity (2012:366). 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. In this vein: "One potentially feasible approach for distinguishing demand-side and technology-driven innovations," wrote Priem, et al., is to use "archival data" (2012:365). This paper responds to that call.

"History rarely provides the full measure of people during their lifetimes," wrote Wren and Bedeian in their classic tome *The Evolution of Management Thought* (2009: 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 datasets and historiographic methods employed in management research (Wren & Bedeian, 2009) continues to play havoc with the conceptual frameworks drawn from the limited data and non-historical methods that are routinely employed by management scholars (Golder, 2000).

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 (Aldrich & Ruef, 2006; Yang & Aldrich, 2012), where the ill effects of historical proximity biases (Grosjean, 2009) are most acutely apparent, stemming from the exclusive use contemporary data. By sacrificing long-term intelligibility for near-term data accessibility (Barzel, et al., 1978; 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.

Alert to both the underutilization of historical artifacts, multi-generational timeframes and historiographic methods in management research (Booth & Rowlinson, 2006), and the comparative success of cliometrics in reshaping central discussions in economics (Alston 2008; Fogel, 1966, 1970; Goldin, 1997; Greif, 1997), my study employs data that are amenable to the methodological rigor and the expansive perspective of historical econometrics. The dataset I use spans nearly a century, involving the commercialization of scientific knowledge in the United States 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 & Freeman, 1984), diffusion scholars (e.g. Benner & Tushman, 2002; Rogers, 2003; Tushman & Murmann, 1998), and a select group of scholars in strategy and entrepreneurship (e.g. Casson, 1982; Godley & Casson, 2010), this study shares their panoramic scale, but with the critical enhancement of not sacrificing fine-grained empirics.

In venturing to convincingly underscore the utility of applying distant timeframes to central research questions of management scholarship, this study makes a number of contributions to management history, particularly in the domains of entrepreneurship and strategy. First, my findings demonstrate that latent demand-side effects can be explicitly identified if the analysis employs socially embedded historical artifacts that give a voice to demand-side perceptions. Latent demand, contrary to extant literature (e.g. Dosi, 1982; Mowery & Rosenberg, 1979; Teece, 2008), is readily distinguishable from supply-side effects, even in the context of new technologies and emerging sectors. 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 form latent societal demand preserves the viability of a balanced supply-demand explanatory framework. Finally, I offer exciting methodological alternatives through the use of socially embedded historical artifacts. Absent a panoramic dataset 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 co-opting a more historical approach to data.

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. In all likelihood, it is some of each. And, in fact, extant theory has largely settled on the view that demand and supply forces exert symbiotic, often indifferentiable influence on one another to produce technological advances (Mowery & Rosenberg 1979; Di Stefano, Gambardella & Verona 2012). In this paper I will argue that frameworks propounding a comingling, cross-fertilizing middle ground are functionally tilted towards supply-side perspectives. I argue further that these dominant frameworks tend to give short shrift to demand-side forces, if they are addressed at all.

A detailed review of entrepreneurship articles published in the 59 leading entrepreneurship journals (Stewart & Cotton 2012) over the past twenty-five years reveals that supply-side articles out-number demand-pull perspectives by nearly 50:1. The supply-side emphasis of most entrepreneurship scholarship occurs for very a simple reason: while it is possible to readily witness, model and analyze the supply of innovation and entrepreneurship, it is often impossible to isolate and quantify situations in which demand for innovation and entrepreneurship precedes supply. Supply-side analyses can take advantage of contemporary settings and recent data, but demand-side perspectives inherently involve highly diffuse populations for which trends may develop over a long period of time.

In seeking to gain some foothold in the debate regarding supply-demand primacy, the tendency among demand-side scholars has been to focus on either differential access to resources (Astley 1985; Tushman & Anderson 1986), or the role of institutions (Aldrich & Fiol 1994; Baum & Oliver 1991; Thornton 1999) in creating environmental conditions that are conducive to entrepreneurial activity (Baumol 1990; North 1990). Each of these demand-side approaches has been heavily reliant upon anecdotal evidence, rather than statistically significant samples and longitudinal designs. The primary consequence of this is that the supply-side perspective has exerted significantly more influence in addressing the question of sector and firm origins. A recent renaissance in demand-side studies (e.g. Franke & Shah, 2003; Priem, Li & Carr 2012; Priem & Swink 2012; Ye, Priem & Alshwer 2012) has reinvigorated the analysis of demand-pull effects; however, this scholarship has relied upon small populations, limited time-frames and incumbent firms operating within well-established industries, thereby limiting the applicability of the demand-pull findings to contexts involving existing firms interacting with existing customers. Still unanswered is the fundamental question: Do demand–pull forces play a role in generating new innovations, firms and sectors? (Di Stefano et al., 2012) Given that this question purports to address *conditions that exist before the innovations, firms and sectors themselves exist*, an entirely new methodology is required, relying upon longer historical time-frames that allow for longitudinal designs and frequent, fine-grained sampling of evolving conditions.

Addressing the Supply-Side Skew

The demand-pull versus technology-push debate has occupied scholars of technological change for nearly fifty years (Dosi 1982; Freeman 1974; Mowery & Rosenberg 1979; Pavitt 1984; Rosenberg 1982; Schmookler 1966; von Hippel 1976). The technology-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" (Li, Priem & Verona 2012: 6). Over time, the debate has been substantively resolved by a general consensus that there exists a mutual dependence between demand-pull and technology-push (Di Stefano, et al., 2012). Functionally, however, research emanating from the technology-push, supply-side perspective has largely overshadowed the demand-side output in both the generation of comprehensive empirical support and the development of a strong theoretical foundation. 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 superficially settled through an acknowledgement of mutuality, the overwhelming tendency has been to side with Dosi (1982: 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.

The central argument of this paper is to assert that the mutual dependence approach to demand-pull and supply-push has largely failed to model and describe latent demand. This has, in turn, resulted in a pointed over-emphasis of supply-side innovation and entrepreneurship, which may, as Schoonhoven and Romanelli have claimed, over-romanticized the role of the lone, swashbuckling entrepreneur (2009). The supply-side emphasis has resulted in a mutual dependence model that is severely skewed towards supply-side effects. In such a model, it has become common to consider demand forces serving as a selection mechanism of innovation and entrepreneurship, but not as a generative mechanism. In an effort to offer a counterpunctal approach that rebalances the mutual dependence model, this study aims to test the following hypotheses. First, consistent with emerging demand-side research that has thus far primarily focused on incumbent firms and existing customers (Priem et. al. 2012a, 2012b; Ye, Priem & Alshwer 2012):

> **Hypothesis 1:** *When latent demand for entrepreneurial innovation precedes supply, then demand serves as a generative force of innovation and supply serves as a selective force.*

Demand-Driven Quantity and Diversity of Entrepreneurial Activity

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 for promising innovations developed by entrepreneurs. Scholars have already established that key customers will provide critical insights and original design specifications to their providers of goods and services (Li, Priem & Verona 2012; Priem, Li & Carr, 2012; Priem & Swink 2012) however, these phenomena typically involve resource-rich, well-established companies coordinating their activities with existing customers. Left largely unanswered is how societal demand defines an opportunity space prior it being inhabited by supply-side entrepreneurs. If an opportunity space is only defined after it has been occupied, then any description of the opportunity is inherently cast in terms of the initial occupants.

This has been a common error among scholars, and a perilous one. 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 (Eckermann, 2001; Georgano, 1985). However, the latent demand signaling for the specific features that consumers wanted 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 safe and effective internal combustion technology (Clymer 1950; Kimes & Clark 1975). Therefore, the “opportunity space” for small-scale, motorized land transportation would be portrayed inaccurately if it focused primarily on sector occupants who sought to develop steam or battery-based solutions.

As the automotive industry example reveals, the generative role of latent demand positioned entrepreneurs as sifters and sorters of viable solution sets for the specific ways in which a diffuse population of potential customers would use automotive technology. In just such a fashion I predict that both the quantity and diversity of entrepreneurial activity will be primarily a consequence demand-side signaling:

> **Hypothesis 2a:** *Demand-pull forces are positively associated with the quantity of entrepreneurship that is supplied to the market.*
>
> **Hypothesis 2b:** *Demand-pull forces are positively associated with the diversity of entrepreneurship that is supplied to the market.*

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 & 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 2004:20).

Inter-subjective conceptualizations of how new sectors, organizations and technologies are developed and commercialized provide additional support for Mowery & Rosenberg’s argument (1979) 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 inescapable reality is that 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:

> **Hypothesis 3:** *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.*

DATA AND METHODS

As noted from the outset, the study of demand-pull effects, especially those pertaining to new firms and sectors, 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 towards defining the ways in which existing companies service the explicit and latent demands of existing customers (Adner 2002; Baldwin & von Hippel 2010; Benner & Tripsas 2012; Li, et al., 2012; Priem, et al., 2012a; von Krough & von Hippel 2006). In this 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, Priem & Alshwer, 2012; Nambisan & Baron 2010; Priem et al. 2012a, 2012b). 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.

Cognizant of the many methodological impediments to examining demand-side forces, I devised a longitudinal study design based on nearly one hundred years of detailed historical artifacts. The study of strategy and entrepreneurship does not have a strong tradition of using historical sources, but the validation of historical techniques has significant precedent in other social sciences, including economics, sociology, political science and anthropology (Golder 2000). Using historical artifacts involving nearly a century of societal signaling, I examined the extent to which latent demand-side preferences served as verifiable drivers of innovation and entrepreneurship. To do this, I trace the migration from pure science to applied science to commercialized science (Table 1). 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 "'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: 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: (i.) *Popular Science Monthly* magazine, from its founding in 1872 to 1969; (ii.) periodicals, newsletters, club minutes, films and radio transcripts from the *Science Society*, from 1921 to 1969; and, (iii.) programs and news accounts from the *U.S. National High School Science Fair*, from 1950 to 1969. 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 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 American Civil War, "to disseminate scientific knowledge to the educated layman" (*Pop Sci* Aug 1872:104). 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% of the history of the U.S.

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 commercialized science was not simply the result of a specific news outlet.

National Science Fair. Through the influence and support of Scripps, the Science Service and Westinghouse, the first nationwide science competition was held in 1942, with the intent of encouraging talented high school students to pursue a career 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 commercialized science 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 commercialized science. Ten undergraduate science and engineering students were trained to perform the categorization in accordance with the rubric summarized in Table 1. Inter-rater reliability exceeded 87% 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 United States Patent and Trade Office (1872 – 2012), SIC/NAICS classifications (1937 – 2012), and Dun & Bradstreet Classifications (1872 - 2012).

Dependent Variables

Applying a cliometric approach through OLS and logistic regression models, 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). This continuous variable 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). This continuous variable 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). This 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.

Predictors

Sequence is a dummy variable designed to capture the demand-supply sequence. 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 is a relative measure of the speed with which demand-first scientific discoveries indicated through the historical artifacts of this study move from an engineering conceptualization to an actively marketed product or service (commercialized science - CS). Values ranging between 0 and 1 are calculated through the ratio: 1 / (CS Date – AS Date).

Demand-Pull Mass is a relative measure of the scale with which demand-first scientific discoveries indicated through the historical artifacts of this study. D-P Mass is determined by counting the total number of artifacts mentioning a particular scientific discovery as a conceptual starting point for applied or commercialized science. 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, World War II 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 towards the achievement of political and socio-economic aims. These three events played a prominent role in public and private sector economics for the period, 1872 – 1969 (Engerman & 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: reverse causality and omitted variables. In addressing the former, I used lagged time-series variables to confirm the directionality of focal effects (Davidson & MacKinnon 1992). For the latter, I employed instrumental variables (Angrist, Imbens & Rubin 1993) that are correlated with the focal predictors of demand-side signaling but not the error term.

Models

*Specifications***.** Logistic regression, OLS regression and significant mean differences were employed to derive and explicate the focal effects. Hypothesis 1, 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. Hypotheses 2a and 2b were analyzed using OLS methods represented by the generalized model:

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

Hypothesis 3 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:

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

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:

$$\mathrm{h}(t) = \mathrm{h}_0(t)\exp(b_1\,\mathrm{X} + b_0) \tag{3}$$

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*.

RESULTS

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 supply-side entrepreneurial activity. Each of the correlation coefficients reflects the directionality and materiality of the predicted relationships among the variables (Table 2).

Support for Hypothesis 1 is richly in evidence from each of the three sources of historical artifacts. Figures 2, 3 and 4, display pronounced trend lines indicating an assertive, inextricable migration from content favoring pure science to content that crowds out pure science, relegating its theory-focused aims to a subordinated role. The most dramatic change is apparent in the *Popular Science* artifacts, where pure science content slipped from nearly 100% to 10% over the observation period (1872 – 1969). Meanwhile, content related to commercialized science – that is, articles related to products actively marketed to existing or future customers – rose to more than 50%, from 0% in 1872. Early interest in the writings of Darwin, Curie, and Spenser, evolved to a product orientation as readership demanded more focus on applications stemming from scientific breakthroughs (Table 3). Since *Popular Science* is a profit-seeking publication, it is necessary to examine whether this trend also appears in looking at the not-for-profit *Science Society News* (Figure 3) and artifacts from the National Science Fair (Figure 4). In both of these additional sources of embedded societal preferences, the escalation in applied science content confirms the findings from *Popular Science.*

Hypotheses 2a and 2b 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 4) predictors of both the quantity and diversity of entrepreneurial activity. This finding supports Hypotheses 2a and 2b as well as the qualitative assessment performed in regard to Hypothesis 1. Taken in total, these findings further underscore the generative role of latent demand-pull forces.

Hypothesis 3 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 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 developed a matched set of 300 scientific discoveries that were randomly selected from two pools of coded data, one pool consisting of situations in which evidence of demand preceded supply, and one pool consisting of situations in which supply preceded demand. As indicated in Table 4 (Model 3a), Hypothesis 3 finds support; that is, primacy of demand is expected to lead to more frequent success. The variable, *Sequence,* is highly significant ($p < .001$) 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 used a hazard rate model, for which the relevant focal end-point consisted of a commercialization event. In further support of Hypothesis 3, 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 5). The significant difference is evident in the Kaplan-Meier plot (Figure 1).

DISCUSSION

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

Considerable effort has been expended over the course of the past thirty years in seeking to investigate what Dosi has 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, 1982:151). As the empirical results of this study demonstrate, the progression is not a matter of mere conjecture. In the first expansive investigation that resolves the temporal proximity problems confounding prior research, 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) spanning nearly a century. This is accomplished by exposing embedded societal preferences through thousands of historical artifacts from *Popular Science*, the *Science Service* and the U.S. *National Science Fair*. By employing historical data and a longitudinal analysis spanning multiple generations, my study addresses significant gaps in existing theory that have inappropriately relegated demand-side forces to a subordinate role, despite the fact that extant theory posits mutual inter-dependencies between demand-pull and supply-push forces.

In reacting to the market-based, economics-influenced conceptions of innovation that dominated much of the 1970s (Di Stefano et al., 2012; Teece, 2008), Dosi (1982) joined Rosenberg and Mowery (1979) in asserting 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, 1982:150). Teece went even further in declaring, "The neoclassical perspective is at best a caricature of how innovation takes place, and it gives little credit to the role of technology and new supply side opportunities. Nor does it give any credit to entrepreneurship" (Teece, 2008:509).

More recent research by Priem, Li, Carr, and Swink (2012), and Di Stefano, Gambardella, and Verona (2012), largely confirms the extent to which prior studies have failed to provide compelling evidence regarding the generative role of demand-side signaling (Priem et al., 2012) in the emergence of new sectors. However, the empirical limitations related to the call for "sufficient evidence" have been mistakenly morphed into conceptual limitations, such that readily observed supply-side effects have over-shadowed the more diffuse, subtle, long-acting demand-side effects. As a result, extant theory is largely silent on the generative role of demand-side opportunity signaling in the creation of new sectors and new ventures, leading Di Stefano, et al., to ask as recently as 2012: "Does demand generate innovation in addition to selecting it?" (2012:1291). In extending the work of Priem et al. (2012a) to the domain of new sectors and pre-existing opportunity fields, the answer from my study is a resounding "Yes." This is a key contribution emanating from the historically panoramic approach.

Implications for Scholars and Practitioners

For scholars, a heightened focus on demand-side research is the first step towards credibly addressing the "supply-side skew" and, in so doing, bringing the supply-push and demand-pull perspectives into a more reasonable balance. As I noted at the outset, extant literature has largely settled on the viewpoint that both supply and demand forces are instrumental to the discovery and development of new innovations. However, attempts to advance a balanced framework (e.g. Mowery & Rosenberg 1979) have not resulted in balanced empirical scrutiny, which has in turn limited scholars' ability to understand the explicit role of demand-side forces in driving the path-dependent progression (Dosi 1982, 1988) from pure science to applied science to commercializable science. By a wide margin, supply-side forces, meticulously depicting the nature and substance of innovating individuals and groups, have overshadowed demand-side research. Those studies that have elucidated demand are almost exclusively focused on the processes of incumbent firms responding to the preferences and needs of existing customers. Entirely absent from prior scholarship are large-scale empirical studies that focus attention on the influence of demand forces with respect to new sectors, emerging technologies and nascent-stage firms.

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 preferences regarding the quantity and diversity of entrepreneurship. As Priem and colleagues 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" (2012:366). This is precisely the juncture at which my study has sought to answer the call to service this important new stream.

For practitioners, the implications of these findings are also illuminating. As the proportional hazard model suggests that 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. The results 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 exits a highly interactive testing and exploration process (Di Stefano et al. 2012; Mowery & Rosenberg, 1979; Priem et al., 2012a, 2012b; Rogers 2003) between suppliers and consumers of innovative, 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 swash-buckling individualism (Schoonhoven & Romanelli, 2009). As the illustration that was presented earlier 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." Practitioners would 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 business models for the roll-out of emerging technologies. The peril to this skew is palpable when observed from an historical perch. As a somewhat humorous illustration, scores of robots and other automated mechanisms have been patented to cut people's hair, but not one has survived commercially (*Popular Science*, 1952; USPTO Data). Aside from reasonable concern about an accidental lobotomy, inventions like these tend to fail as a category because there is no evidence that demand exists for such a device. Ignoring the sociology of barbers, hairdressers and their customers (Black, 2002) is tantamount to failing to understand the opportunity space that society has created as well as the viable technological choices that society has implicitly generated. A supply-centric perspective might judge that the technology was insubstantial or that the entrepreneurs were inept marketers, but a demand-side explanation might instead focus on the fact that entrepreneurial solution sets were inattentive to the opportunity field.

Limitations and Opportunities

As with all studies, design-related decisions associated with this research 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. Accordingly, I performed robustness checks involving the use of instrumental variables (IV). To test for reverse causality and errors-in-variables I developed IVs for use in a two-stage least squared (TSLS) analysis, which is a preferred approach in dealing with multiple endogenous regressors and in models containing both continuous and categorical dependent variables (Bascle 2008). To test for these potential sources of endogeneity, I regressed the model predictors onto an instrumental vector containing three instruments that included: change in oil consumption, the rate of urbanization, and the change in agricultural labor. Using Staiger and Stock's (1997) procedure for first-stage F-statistics, the correlation strength was well above the Staiger-Stock threshold of 10.83, thereby providing ample support for the IV relevance. The IVs were found to be correlated with the dependent variables, but only through the model predictors, meaning that the predictors are not subject to the potential confounds of endogeneity.

Conclusion

The widespread unwillingness or inability of management scholars to employ historiographic methods and historically panoramic data has created significant impediments to the development of robust explanatory frameworks, particularly those concerning phenomena that only become intelligible when observed over the course of many generations. Nowhere is this more apparent than in the study of innovation, entrepreneurship and emerging industrial sectors. 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 is the underutilization of historical evidence and methods.

On the strength of the results generated from these analyses, this paper makes several noteworthy contributions to the use of historical techniques and historical artifacts in the study of management, particularly entrepreneurship theory and practice. First, I provide decisive empirical tests of demand-side effects for entrepreneurial activity. This is important because prior research largely relegates demand-side dynamics to merely a contextual role. In stark contrast, our results indicate that societal demand is a key determinant and primary antecedent of entrepreneurial activity. Second, I identify and explicate potent mechanisms used to signal demand preferences related to entrepreneurship. Third, I contribute fresh methodological innovations by using cliometric models and novel historical data to illuminate elusive phenomena that challenge existing theoretical assumptions.

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Table 1: Categorization Rubric for Scientific Content of Historical Artifacts

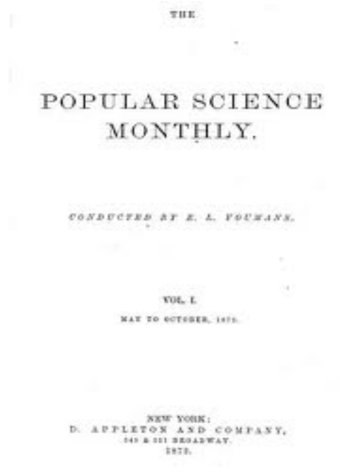
Category	Summary Definition	Example
Pure Science	A method of inductively or deductively investigating nature through the development and establishment of information to aid understanding—prediction and perhaps explanation of phenomena in the natural world. Scientists working in this type of research don't necessarily have any ideas in mind about applications of their work.	Discovering 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 2: Correlation Coefficients and Descriptive Statistics

Variable		Mean	Std Dev	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

Italics indicate correlation with p < .01

Table 3: *Popular Science Monthly* - Content Examples by Era

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

Table 4: 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 Quantiity*	*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
Macro Control Vector	0.97*	0.88	1.10*	1.03	1.38*	1.29*
s.d.	*(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**
s.d.	*(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*
s.d.	*(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*
s.d.	*(1.77)*	*(1.32)*	*(0.51)*	*(0.41)*	*(1.02)*	*(0.95)*
World War II	2.33**	2.17**	1.80*	1.72*	1.54*	1.36*
s.d.	*(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**
s.d.	*(0.70)*	*(0.58)*	*(0.89)*	*(0.82)*	*(1.27)*	*(1.21)*
Demand Precedes Supply		2.85***		2.60**		3.43***
s.d.		*(1.59)*		*(1.88)*		*(2.21)*
Adjusted R^2	0.53	0.66	0.47	,58	--	--
F-value	117.4	131.2	98.8	102.1	--	--
Δ Adjusted R^2		0.13		0.11		
χ^2					342.5	412.6
Predictive Accuracy					77.00%	96.0%
N = 33,720						
Standardized Coefficients.						
*** p < 0.001, ** p < .01, * p < .05						

Table 5: Cox Proportional Hazard Model

	Demand Precedes Supply (n = 150)			Supply Precedes Demand (n = 150)		
	Probability of CE (95% CI)	*Std dev.*	*P Value*	*Probability of CE (95% CI)*	*Std dev.*	*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
World War II	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		

Figure 1: Kaplan-Maier Plot Based on Demand-Supply Sequencing

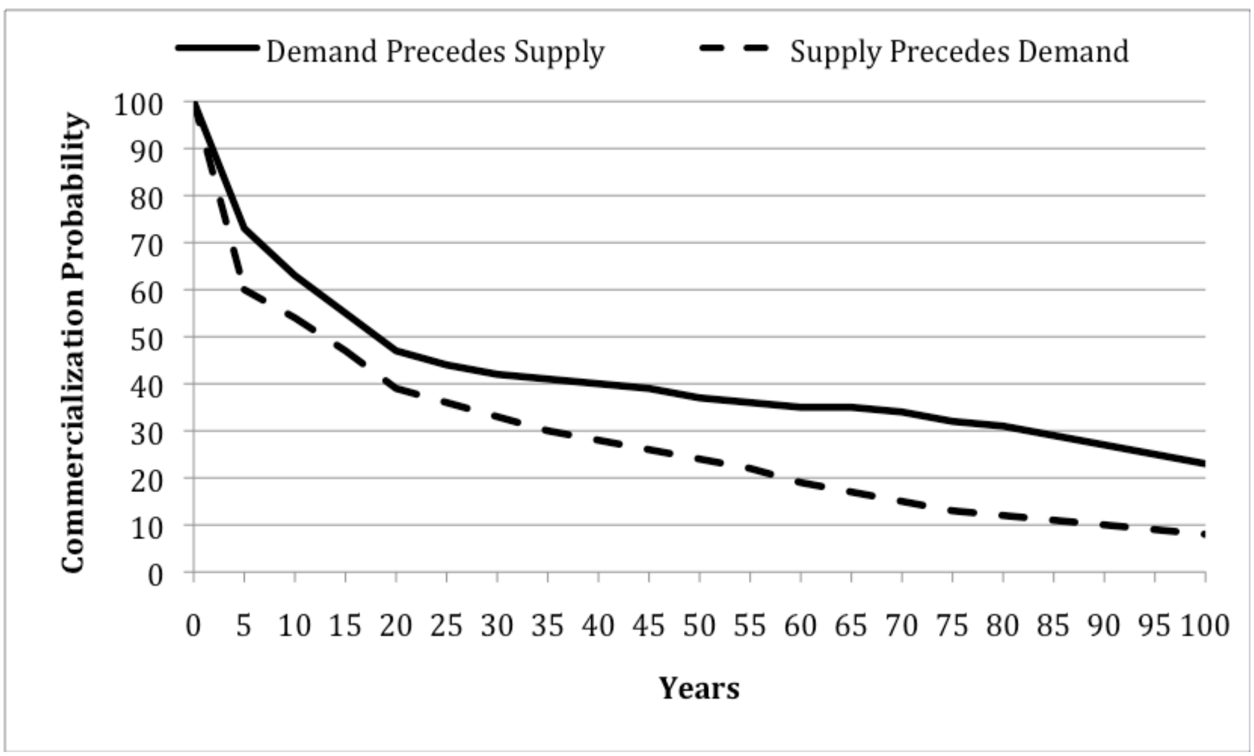

Figure 2: *Popular Science Monthly* Article Content (1872 – 1969)

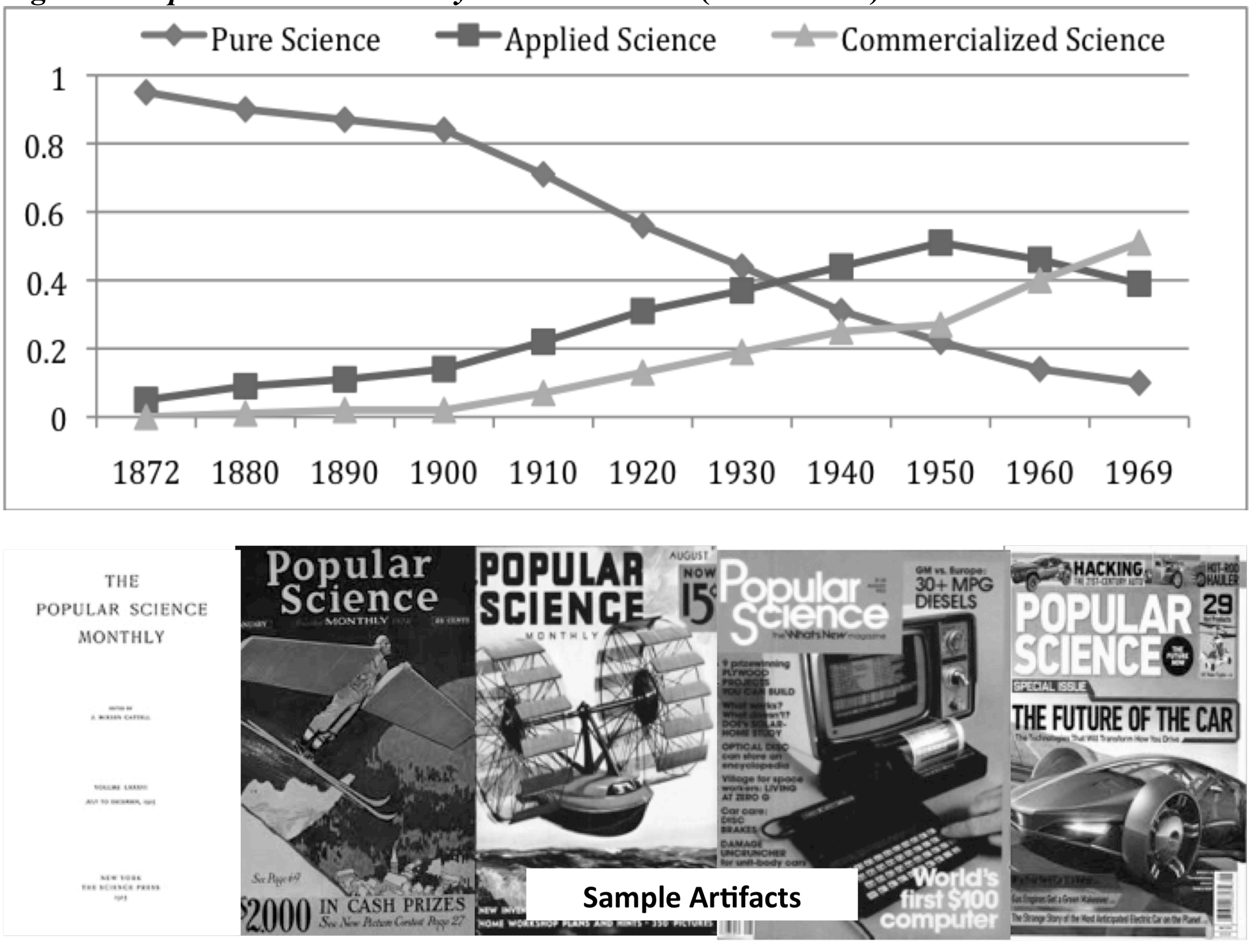

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Figure 3: Science Society Newsletter Content (1921 – 1969)

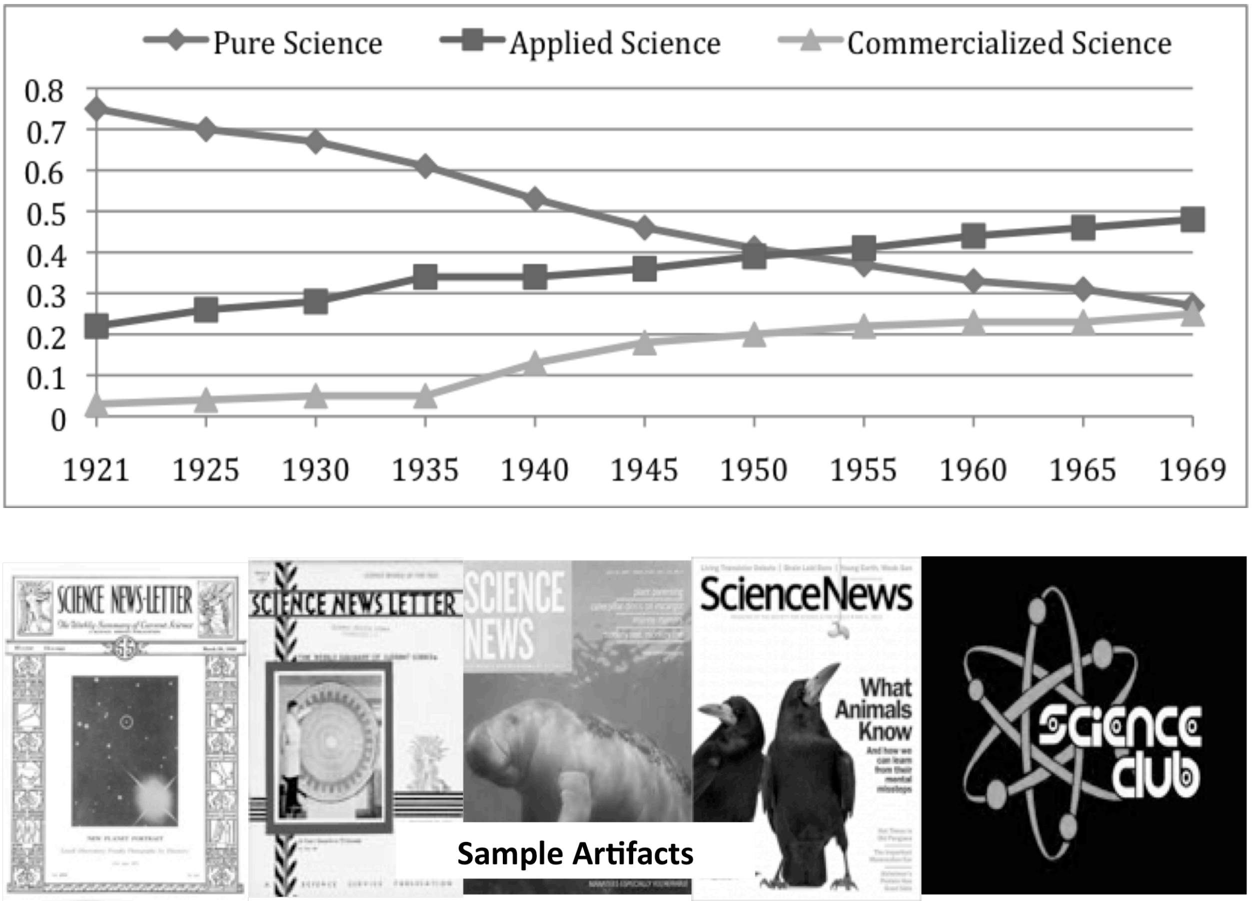

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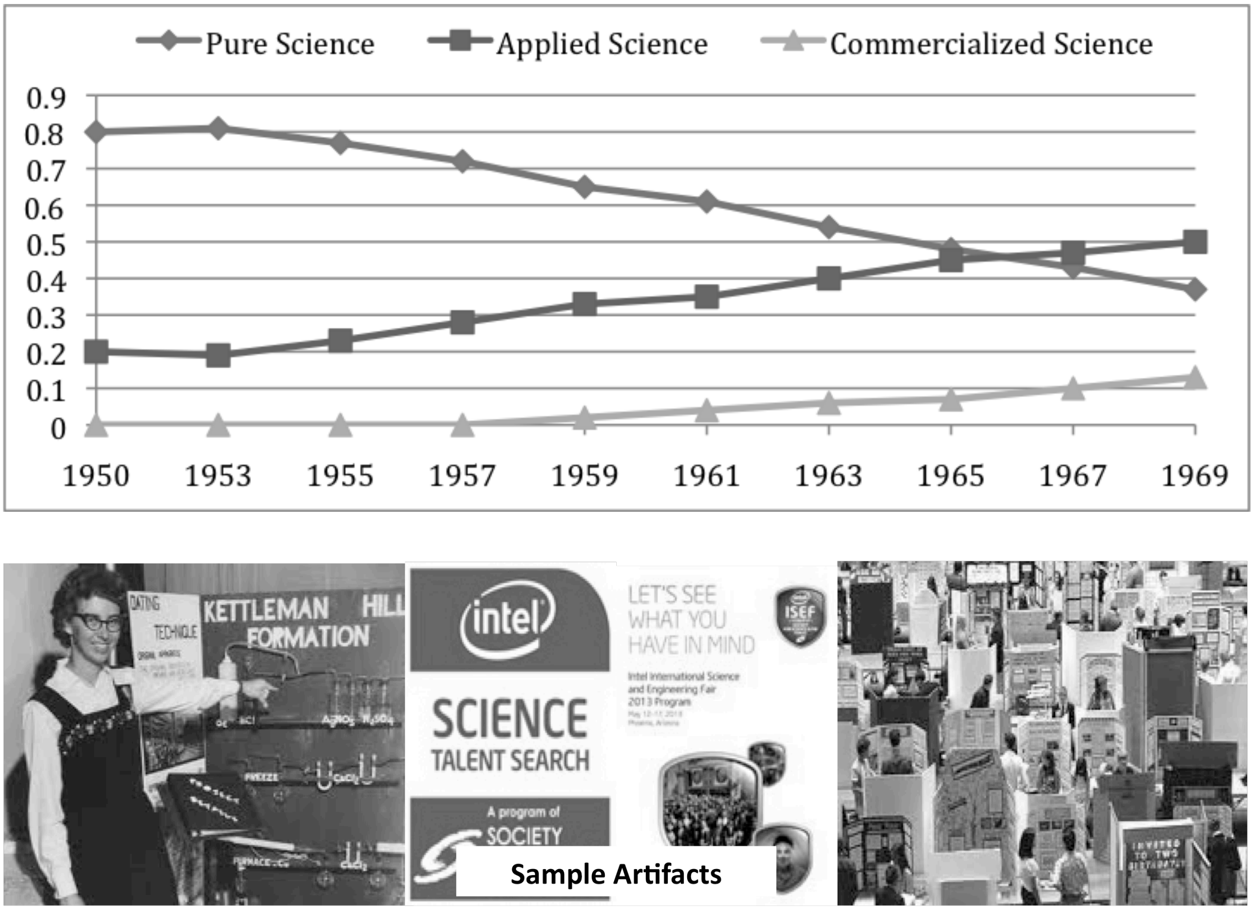
Figure 4: National Science Fair Exhibits (1950 – 1969)



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