The Superstar Inventors and Entrepreneurs: How Were They Educated?

William J. Baumol
Stern School of Business
40 West Fourth Street
New York University
New York, NY 10012
wbaumol@stern.nyu.edu

Melissa A. Schilling
Stern School of Business
40 West Fourth Street
New York University
New York, NY 10012
mschilli@stern.nyu.edu

Edward N. Wolff
Department of Economics
19 West Fourth Street, 6th Floor
New York University
New York, NY 10012-1119
ew1@nyu.edu

Observations, such as the many celebrated inventive entrepreneurs with minimal schooling, lead to the hypothesis that protracted and rigorous education can impede entrepreneurship. Systematic analysis of biographies of noted inventors and entrepreneurs appears not to support the hypothesis. We do find that with time, entrepreneurial and inventor education increases as technology grows more complex. However, we find at the same time that the educational attainment of inventors has grown more rapidly than that of entrepreneurs and the educational gap has tended to widen over time.

"Imagination is more important than knowledge."

(Attributed to Albert Einstein)

They are deeply grateful to the Ewing Marion Kauffman Foundation of Kansas City for its very generous support of this research and the late Sue Anne Batey Blackman for her substantial contributions to this paper.

Journal of Economics & Management Strategy, Volume 18, Number 3, Fall 2009, 711–728

1. Introduction

It is at least highly plausible that, throughout history, the availability or absence of Joseph Schumpeter's innovating entrepreneurs has played a crucial role in the speed of growth of an economy. There is good reason for the surmise that absence of entrepreneurs with the appropriate qualifications and interests helps to explain the failure of effective utilization of inventions such as the working steam engine of Heron of Alexandria in Imperial Rome, or the spate of new products that made their appearance in China during Europe's Dark Ages. However, there seems to be surprisingly little evidence on the role of education—particularly the effect of advanced college training—in the success of the prospective innovating entrepreneur. This paper seeks to contribute to the collection of evidence on this important matter, in particular, how education may facilitate (or impede) the work of inventors and the entrepreneurs who fill the crucial gap between the original inventions and their subsequent adoption and utilization in the economy's productive activities. For this purpose, we present evidence garnered from a unique biographical database on the potential role of education in this process.

For reasons that will be brought out below, we began work on this paper with the conjecture that standard educational approaches, particularly those that are most rigorous and technical, rather than helping, tend to impede innovative entrepreneurship by constraining heterodox thinking and exercise of the imagination. As will be seen, the evidence we were able to collect tended not to support this assertion, although the matter is still far from settled, with evidence on both sides of the matter. Nevertheless, even if it does not enable us to settle this basic issue, our research has provided a number of significant insights on the general subject.

Here, we define individuals to be entrepreneurs if, in their economic activities, they demonstrate initiative, imagination and willingness to expend effort in the pursuit of wealth, power and prestige. In particular, it is common to speak of the founders of new business firms as entrepreneurs. It is useful for the discussion that follows to divide those entrepreneurs into two groups, innovative and replicative, with the innovative entrepreneurs obviously engaged in enterprises that offer new products, or new production processes, enter new markets, etc. It seems generally agreed that innovative entrepreneurs require some special skills and even particular types of education. But no one seems to be sure about the characteristics of the education that will most effectively prepare those innovators, unlike

the replicative entrepreneurs, whose educational requirements seem relatively clear-cut. Indeed, there may well be reason to suspect that the most traditional and rigorous approaches to education can be counterproductive so far as the preparation of innovative entrepreneurs is concerned.

A few words must be said about the importance and complementary roles of breakthrough and incremental innovation. The term "breakthrough" will refer to what may be deemed to be an initial idea and its first successful model (e.g., the Wright Brothers' airplane, or the ENIAC computer). The incremental improvements are the succession of cumulative steps that bring us from these crude breakthrough models to the subsequent product that is in widespread and convenient use (e.g., the Boeing 777, or the latest laptop computer, containing chips whose speed has increased some 3 million percent in about 3 decades).

Materials on these subjects are gleaned here from a substantial data set that we have created from biographical information about notable inventors and entrepreneurs. While we do not engage in formal hypothesis testing in this paper, we are able to make some observations on the role of education in entrepreneurship on the basis of our data analysis.

We begin the paper with a review of previous literature on the subject (Section 2). Section 3 describes the new biographical data that we collected on inventors and entrepreneurs, and Sections 4 and 5 describe our findings from the biographical data. Our concluding remarks are made in Section 6.

2. Previous Literature

A number of earlier studies have suggested that, before being able to contribute a significant insight to a field, an individual must first have substantial preparation in that field, and have built huge reservoirs of discipline-relevant information (see, e.g., Simonton, 1999a, 1999b). Simon and Chase (1973) even quantified the required expertise by studying chess grand masters and other experts, concluding that individuals need approximately 50,000 "chunks" of richly connected information before making a fruitful discovery. Other authors have observed that individuals typically require at least a decade of intense study in a particular domain of knowledge before they can provide any significant contribution in that domain (Hayes, 1989; Gardner, 1993; Simonton, 1999a, 1999b). The more knowledge individuals possess in

a particular domain, the more likely they are to understand the nature of the relationships among different ideas. As associations within the domain are challenged or reinforced over time, the more accurate the recognition of the pattern of associations should become, and the more efficient the individual should be in searching for relationships among them (Harlow, 1959; Dosi, 1988).

On the other hand, some studies have suggested that an individual's substantial previous experience in a domain can also inhibit creative problem-solving (Wertheimer, 1945/1959). Individuals who are highly specialized within a particular domain, for example, are prone to "einstellung," whereby learners who have earlier learned to solve a problem in a particular way will adopt a pattern that mechanizes their problem solving, inhibiting them from arriving at creative solutions (Luchins, 1942; Mayer, 1995). Many forms of learning can become automatized to such an extent that, when faced with a variant issue, the learners automatically recall a representative approach, and it is difficult for them not to do so (Gick and Lockhart, 1995). When individuals have well-reinforced expectations about the direction a search path should take, it constrains their ability to explore different possibilities and may prevent them from generating "preinventive forms" with a more natural or universal structure (Finke, 1995, p. 262). Similarly, individuals who are deeply immersed in the established orthodoxy of a field of study may find their creativity stifled by extant paradigms and institutional pressures to conform (McLaughlin, 2001).[1]

Extensive training in a particular field can thus impede cognitive insight. It is notable that both Einstein and Piaget claimed that formal schooling detracted from their intellectual development (Feldman, 1999). Sociologically inspired work on the "marginal man" provides support for that contention. This work argues that marginal intellectuals (those who may participate in multiple intellectual domains but are central to none) are more likely to introduce creative breakthroughs than well-established experts in a domain (Ben-David and Collins, 1966; Edge and Mulkay, 1976; Dogan and Pahre, 1990; Martindale, 1995, p. 252; McLaughlin, 2001). The two primary theoretical explanations for this relationship between marginality and innovation are that: (a) marginal scientists use different assumptions or skills than specialists in

1. This is also argued by Simonton, who pointed out that excessive specialization can inhibit cognitive insight: "Too often, persons fail to make significant insights because they exclude whole domains of elements from entering into the combinative hopper. Yet what appears logically irrelevant may actually provide the missing piece of the puzzle" (1995, p. 473).

the field, permitting more novel outcomes, and (b) marginal scientists are motivated to undertake riskier areas of research as a faster route to recognition and resources (Gieryn and Hirsh, 1983). Consistent with this, an early study by Channon (1979) observed that entrepreneurs were likely to come from relatively humble origins and receive an education through secondary school only. Similarly, a study by Collins and Moore (1970) concluded that it was common for entrepreneurs from relatively disadvantaged backgrounds to pursue aggressive, often flamboyant strategies, presumably in order to achieve recognition and esteem. There have also been some writings, some of them also rather dated, supporting the idea that individuals who are "self-made" are more risk-prone and more likely to pursue innovation than people who receive a professional education in management (e.g., a masters in business administration) (Collins and Moore, 1970; Hambrick and Mason, 1984).

Jones (2009), using a microdata sample of inventors, documented a broad increase in educational attainment among this group. Jones (forthcoming), using a sample of Nobel Prize winners and great inventors, also found that the age of peak performance of Nobel Prize winners and the age at which inventors received their first patent have been advancing over the 20th century (by as much as 8 years). He argues that these distinct shifts in age are consistent with a knowledge-based theory in which the accumulation of knowledge over time leads innovators to seek more and more schooling over time. Lamoreaux and Sokoloff (2005) also document increasing educational requirements for "great inventors" as revealed by patent records over the late 19th and early 20th century.

In a related study, Weinberg and Galenson (2005) provided evidence on the basis of their analysis of Nobel laureates in economics that those that specialize in conceptual and theoretical work publish their best work when young (at age 25 or so for the most theoretical) while those who do experimental research do their best work in their mid 1950s. A shift from conceptual innovation toward experimental and empirical innovation might help explain age shifts and the relative reliance on education in the creative process. Galenson and Weinberg (1999), using auction records, estimated the relationship between artists' ages and the value of their paintings for two successive cohorts of modern American painters. They found a substantial decline over time in the age at which these artists produced their most valuable work. However, in this case, they were led to conclude that the declining age was attributable to a shift in the nature of the demand for modern art during the 1950s.

3. Biographical Data on Inventors and Entrepreneurs

We have constructed our own list of famous inventors and entrepreneurs throughout history by aggregating lists created by others. In total, we searched over 50 books and numerous online encyclopedias devoted to noted inventors, inventions, and entrepreneurs. There is significant overlap in such lists, however, and nearly our entire sample can be found in a reduced list of the 15 sources we found to be most useful: (Iles, 1912; Feldman and Ford, 1979; Abbot, 1985; Fucini and Fucini, 1985; Hallett and Hallett, 1997; Culligan, 1998; Haskins, 1998; Sullivan, 1998; Smith, 2002; Vare and Ptacek, 2002; Klein, 2003; Evans et al., 2004; Entrepreneurs.about.com, 2007–2009; Inventors.about.com, 2007–2009; www.invent.org). Because all of the lists are from English language sources, there is likely to be an Anglo-American bias in the selection of both inventors and entrepreneurs.

Biographical information on the inventors and entrepreneurs were then obtained through targeted searches. The most prominent inventors and entrepreneurs often were the subject of several published biographies; others were profiled in one of the many biographical compilations about leaders in science and business. Approximately, 500 sources were used to gather data on the individual inventors and entrepreneurs in total (a complete list of sources is available from the authors upon request).

Our list spans the time period from Johann Gutenberg, who was born around 1400, to Richie Stachowski (the discoverer of pulsars), born in 1985. In all, our list includes 513 inventors and entrepreneurs (see Table I). We have divided the list into three periods, based on date of birth: (a) before 1800, (b) 1800–1899, and (c) 1900–1985. Of the 486 individuals in our sample with known birth dates, 11% were born in the period before 1800, 53% in the 19th century, and 36% in the 20th century. We also divided our sample into three groups: (a) inventors, (b) entrepreneurs, and (c) those who can be classified as both entrepreneurs and inventors (e.g., Thomas Edison). Of our sample, 32% were pure inventors, 27% were pure entrepreneurs, and 41% were both. We also show a breakdown by country of birth for our sample. The United States clearly dominates our list of inventors and entrepreneurs. Of those for whom we have the pertinent information, nearly 60% were born in the United States. The second largest representation is from the United Kingdom, at 12% of the total, followed by Germany at 7%. All the other countries have a smaller representation.[2]

2. In all, 38 countries are represented in our sample.

Table I.
Sample of Inventors and Entrepreneurs: Sample Characteristics (Sample Counts)

Sample Characteristic	Number of Inventors or Entrepreneurs	Number of Inventors	Number of Entrepreneurs	Number of Inventor-Entrepreneurs
Total	513	378	348	212
Birth Year				
1. Before 1800	55	45	31	21
2.1800–1899	255	181	195	121
3. 1900–1985	176	129	111	63
No information	27	23	11	7
Country of Birth				
1. United States	285	183	219	116
2. United Kingdom	55	46	29	20
3. Germany	32	28	19	15
4. France	16	13	9	6
5. Other European*	61	51	38	28
6. All others†	28	23	18	13
No information	36	34	16	14

Notes: Inventor-entrepreneurs are individuals who are classified as both inventors and entrepreneurs.
The number of inventors includes inventor-entrepreneurs.
The number of entrepreneurs includes inventor-entrepreneurs.
*Includes: Italy (13 citations), Sweden (7), Austria (6), Hungary (5), Poland (5), Croatia (4), Russia (4), Belgium (4), Netherlands (3), Ireland (3), Spain (3), Switzerland (3), Denmark (1), Serbia (1), Bosnia (1), Lithuania (1), Yugoslavia (1), Norway (1), and Slovakia (1).
†Includes: Canada (12), China (5), Japan (2), New Zealand (1), Australia (1), India (1), Brazil (1), South Africa (1), Afghanistan (1), Antigua (1), Nigeria (1), St. Croix (1), Lebanon (1), Turkey (1), and Java (1).

4. The Geographic and Temporal Distribution of Our Sample

Table II shows the geographic distribution of the entrepreneurs and inventors in our sample over time. Collectively, inventors and entrepreneurs from the United States and the United Kingdom dominate the sample, which is not surprising given our reliance on English-language sources. The United Kingdom dominated the list before 1800 and then fades in prominence on our list in the ensuing centuries. For the 1900 to 1985 time period, over 70% of our list is from the United States. Furthermore, there are a larger number of entrepreneurs from the United States on our list for every time period.

As noted above, because of the Anglo-American bias in our sample, it is not possible to make international comparisons of the relative creativity or degree of entrepreneurship of different countries. (For example, does the United States have a greater number of inventors

Table II.
Distribution of Sample by Country and Year of Birth (Percentage of Total)

Country of Birth	Birth Year		
	Before 1800	1800–1899	1900–1985
Panel A. Inventors or Entrepreneurs			
1. United States	30.2	58.9	71.3
2. United Kingdom	34.0	9.9	7.2
3. Germany	9.4	7.9	3.6
4. France	5.7	2.8	3.6
5. Other European	15.1	13.8	10.2
6. All others	5.7	6.7	4.2
Total (with relevant information)	100.0	100.0	100.0
Panel B. Entrepreneurs			
1. United States	46.7	62.9	79.0
2. United Kingdom	26.7	9.3	2.9
3. Germany	10.0	6.7	1.9
4. France	0.0	1.5	5.7
5. Other European	13.3	12.9	7.6
6. All others	3.3	6.7	2.9
Total (with relevant information)	100.0	100.0	100.0
Panel C. Inventors			
1. United States	27.9	53.1	62.2
2. United Kingdom	32.6	11.2	10.1
3. Germany	9.3	9.5	5.0
4. France	7.0	3.4	3.4
5. Other European	16.3	15.6	13.4
6. All others	7.0	7.3	5.9
Total (with relevant information)	100.0	100.0	100.0
Panel D. Inventor-Entrepreneurs			
1. United States	50.0	56.7	66.7
2. United Kingdom	20.0	10.8	5.3
3. Germany	10.0	8.3	3.5
4. France	0.0	1.7	7.0
5. Other European*	15.0	15.0	12.3
6. All others†	5.0	7.5	5.3
Total (with relevant information)	100.0	100.0	100.0

Notes: Inventor-entrepreneurs are individuals who are classified as both inventors and entrepreneurs.
The number of inventors includes inventor-entrepreneurs.
The number of entrepreneurs includes inventor-entrepreneurs.
Table excludes observations with missing country or year of birth information.
See notes to Table I for country details.

per capita than France?). However, we can focus here on differences in characteristics between entrepreneurs and inventors. We believe that there is unlikely to be a bias in this comparison (unless the United States and the United Kingdom are peculiar in this regard). In particular, we

will focus here on the relative educational attainment of entrepreneurs as compared with that of inventors.

5. Trends in Educational Attainment of Inventors and Entrepreneurs

We next consider the educational attainment of the inventors and entrepreneurs on our list of outstanding performers. Our results are shown in Table III, which excludes all observations with missing information on either year of birth, country of birth, or pertinent educational information (see Table AI for details on the resulting sample).

All of the countries studied show an increasing share over time of inventors and entrepreneurs who have attained high school, college, masters and Ph.D. degrees. The United Kingdom and other European countries have a higher share of inventors and entrepreneurs with degrees than the United States, and this lead is maintained over time. There is a particularly high share of inventors with Ph.D.s in the 20th century, a fact that suggests that as technology has grown cumulatively more complex, further advances have required ever more extensive educational preparation, so that those inventors and entrepreneurs who have contributed significant breakthroughs have undergone steadily more advanced education.[3]

These data in Table III also indicate that inventors appear to be better educated than entrepreneurs in terms of the share of those who attained a high school degree, at least in the 1800s. That difference seems to disappear by the 1900s, but our results indicate that inventors continue to be better educated than entrepreneurs in terms of the share who earned a college degree. The differential holds in all three time periods: before 1800, 1800–1899, and 1900–1985.

Finally, the results show a large difference in advanced degrees (M.A.s and Ph.D.s) between inventors and entrepreneurs. Moreover, this differential widens between the 1800s and the 1900s. For M.A. degrees, the difference in the percentage of inventors and entrepreneurs holding this degree climbs from 9.2 to 23.2 percentage points between the two periods. In the case of Ph.D. degrees, the difference grows from 22.7 to 34.9 percentage points.[4]

In Table IV, we compare the educational attainment of our sample of inventors and entrepreneurs in the United States with that of the total population (adults, 25 years of age or older). We used the

3. More extensive data that also provide support for this argument are provided by Jones (2009). See Section 2.

4. We exclude the joint inventor–entrepreneur category in these comparisons.

Table III.
Educational Attainment of Inventors and Entrepreneurs by Birth Cohort and Country of Birth (Percentage of Total with Information on Educational Attainment)

	Inventors			Entrepreneurs			Inventor-Entrepreneurs		
Country of Birth	Before 1800	1800–1899	1900–1985	Before 1800	1800–1899	1900–1985	Before 1800	1800–1899	1900–1985
Panel A. High School Degree (%)									
1. United States	67	70	96	57	64	93	80	67	92
2. United Kingdom	50	90	100	20	83	–	–	80	–
3. European except UK	100	79	100	100	65	100	100	69	100
4. All others	–	89	83	–	86	100	–	83	100
Total (with relevant information)	76	76	96	59	66	94	82	70	94
Panel B. University Degree (%)									
1. United States	50	51	88	40	38	71	67	43	83
2. United Kingdom	60	71	100	0	50	–	–	50	–
3. European except UK	88	68	88	60	42	75	75	50	80
4. All others	–	88	80	–	71	100	–	83	100
Total (with relevant information)	71	61	89	36	42	72	63	49	83

Continued

TABLE III. CONTINUED

Country of Birth	Inventors			Entrepreneurs			Inventor-Entrepreneurs		
	Before 1800	1800–1899	1900–1985	Before 1800	1800–1899	1900–1985	Before 1800	1800–1899	1900–1985
Panel C. Master's Degree (%)									
1. United States	33	18	63	25	7	36	50	13	45
2. United Kingdom	43	10	33	0	10	–	–	0	–
3. European except UK	20	16	30	0	5	22	0	6	29
4. All others	–	0	50	–	0	–	–	0	–
Total (with relevant information)	33	15	54	8	7	34	14	9	41
Panel D. Doctorate Degree (%)									
1. United States	0	24	49	0	9	18	0	15	36
2. United Kingdom	0	25	43	0	10	–	–	0	–
3. European except UK	20	46	58	0	9	22	0	13	29
4. All others	–	25	50	–	0	–	–	0	–
Total (with relevant information)	7	30	50	0	8	19	0	12	34

Notes: The number of inventors includes inventor-entrepreneurs.
The number of entrepreneurs includes inventor-entrepreneurs.
Table excludes observations with missing country or year of birth information or educational information.
See notes to Table I for country details.

Table IV.
Educational Attainment of US Individuals: Comparison of Inventors, Entrepreneurs, and All Adults (Percentage of Total with Information on Educational Attainment)

Educational Attainment By Birth Cohort	Inventors	Entrepreneurs	Inventor-Entrepreneurs	US Adults Age 25 or Older 45 Years Later with a College Degree*
High School Degree (%)				
Birth Cohort:				
Before 1800	67	57	80	NA
1800–1899	70	64	67	NA
1900–1985	96	93	92	63
Breakout of 1900–1985:				
1900–1910	87	72	75	39
1911–1920	100	100	100	46
1921–1930	100	100	100	58
1931–1940	100	100	100	71
1941–1950	100	100	100	79
1951–1985	100	100	100	83
University Degree (%)				
Birth Cohort:				
Before 1800	50	40	67	NA
1800–1899	51	38	43	NA
1900–1985	88	71	83	15
Breakout of 1900–1985:				
1900–1910	67	44	57	7
1911–1920	90	70	80	9
1921–1930	92	83	83	12
1931–1940	100	73	100	18
1941–1950	100	92	100	21
1951–1985	100	75	100	25

Notes: Inventor-entrepreneurs are individuals who are classified as both inventors and entrepreneurs.
The number of inventors includes inventor-entrepreneurs.
The number of entrepreneurs includes inventor-entrepreneurs.
Table excludes observations with missing year of birth information or educational information.
*For example, for the cohort born between 1911 and 1920, we use the percentage of adults with a high school (or college) degree in 1961.
Source: US Bureau of the Census, http://www.census.gov/hhes/income/histinc/.

average educational attainment of adults in the population 45 years after the median birth date of each cohort for comparison. First, it is noteworthy that there were dramatic gains in both high school and college attainment of the population from 1947 to the present. The share of high school graduates in the adult population grew from in 33% in 1947 to 83% in 2003; that of college graduates increased from 5% to 25%.

The results in Table IV also indicate that in the United States at least, both inventors and entrepreneurs are better educated than the set of all adults. The difference is particularly striking for those with a college degree, and the difference widens over time. In 1950, only 7% of the US adult population had graduated from college, compared to 67% of US inventors born between 1900 and 1910 and 44% of US entrepreneurs. According to our data, 100% of US inventors and 75% of US entrepreneurs born between 1951 and 1985 graduated from college, compared to 25% of the corresponding US population. It is also of note that the difference in the percentage of inventors with a university degree and that of entrepreneurs with the same degree widens over time, from 13 percentage points in the 1800s to 17 percentage points in the 1900s. Moreover, looking at 10-year intervals by birth cohort, we find that the difference actually fell from 23 percentage points for birth cohort 1900–1910 to 9 percentage points for birth cohort 1921–1930 but then grew to 25 percentage points for birth cohort 1951–1985.

We were also able to identify a reduced set of 220 entrepreneurs and inventors for whom we had more complete information and only those with birth years 1800 or later. The note to Table V provides details on the number of those who are known to have a particular degree, and the number of those degree-holding individuals for whom we have the field of degree. In all, we were able to identify field of study for 185 in our sample of 220.

Individuals that were coded as inventors only were most likely to have engineering backgrounds, followed by physics and chemistry. The majority of those inventors with a Ph.D. had their degree in physics though, interestingly, the next highest Ph.D. category for inventors was medicine. Individuals who were both inventors and entrepreneurs similarly came overwhelmingly from engineering backgrounds, with the second most common degree fields of physics and chemistry, in that order. A handful also had degrees in other fields such as genetics, bacteriology, computer science, etc.

Individuals that were entrepreneurs only were still fairly likely to have their degree in engineering, but were also significantly more likely to have a degree in business. Notably, none of the entrepreneur-only individuals in our restricted list of persons with more complete data had a Ph.D. The list of entrepreneurs has a much more diverse range of backgrounds, with fields of study like fashion, government studies, history, political science, psychology, and religion.

In sum, it appears from these data in our sample inventors are very likely to come from engineering, physics, and chemistry/medical backgrounds. Entrepreneurs are much less likely to have a Ph.D., and much less likely to have a science background.

Table V.
Educational Attainment of Inventors and Entrepreneurs by Field of Study, Birth Years 1800 or Later (Number with Information on Field of Study)

	Inventors			Entrepreneurs			Inventor-Entrepreneurs		
Field of Study	Under-Grad.	M.A.	Ph.D	Under-Grad.	M.A.	Ph.D.	Under-Grad.	M.A.	Ph.D.
Count by Field of Study									
1. Physics	9	8	9	0	0	–	7	7	5
2. Engineering	11	9	2	3	3	–	19	6	3
3. Chemistry	7	1	2	1	0	–	5	3	3
4. Business	0	0	0	2	4	–	1	0	0
5. Economics	0	0	0	2	0	–	1	0	0
6. Computer Science	0	1	1	0	0	–	2	2	2
7. Medicine	1	2	5	1	0	–	0	0	2

	Number with Degree	Number with Field of Study
These Data are Based on the Following Sample:		
Undergraduate	125	98
Masters	57	49
Doctorate (Ph.D.)	45	38

6. Concluding Comments

Our main findings are, first, that all of the countries we studied show an increasing share over time of inventors and entrepreneurs who have attained high school, college, masters, and Ph.D. degrees. Second, both inventors and entrepreneurs in the United States are better educated than the general population. Third, for all countries in our sample, inventors are better educated than entrepreneurs and the difference has increased over time. The difference in the proportion of inventors and entrepreneurs holding M.A. degree grew from 9 to 23 percentage points between the 1800s and 1900s, and the difference in the share with Ph.D. degrees from 23 to 35 percentage points.

Thus, while invention has come to be dominated by Ph.D.s, entrepreneurs can still apparently get by with lower educational attainment. While the process of invention is likely subject to the "burden of knowledge" emphasized by Jones (2009, forthcoming) it appears likely that the development of new business forms or the opening up of new market opportunities may not be as sensitive to

an increasing educational requirement. For example, whereas nearly all modern Nobel Prize winners in the life sciences received a Ph.D., noted entrepreneurs such as William Gates, Lawrence Ellison, and Steven Jobs never even received a bachelors' degree. Entrepreneurship still appears to be the domain of "generalists" who can sense an uncommon but promising market opportunity or idea for a new business form. These findings seem to provide support for the Lazear (2005) "Jack-of-all-Trades" theory of entrepreneurship, which asserts that successful entrepreneurship requires a wide range of general abilities. Our findings on fields of study of both inventors and entrepreneurs also provide support for the Lazear hypothesis.

These results suggest that as technology has grown cumulatively more complex, further advances have required ever more extensive educational preparation, so that those inventors and entrepreneurs who have contributed significant breakthroughs have undergone steadily more advanced education. The results also raise important questions about the role of culture, institutions, and the availability of capital, as well as differences in educational performance, in contributing to entrepreneurship. This is especially important for understanding of cross-country differences and for planning of the relevant portions of the educational system.

Appendix

Table AI.

Number of Inventors or Entrepreneurs with Pertinent Educational Information by Country and Year of Birth

	Birth Year		
Country of Birth	Before 1800	1800–1899	1900–1985
Panel A. High School Degree?			
1. United States	8	93	93
2. United Kingdom	8	11	7
3. European except United Kingdom	6	35	15
4. All others	1	10	6
Total (with relevant information)	23	149	121
Panel B. College (University) Degree?			
1. United States	6	93	96
2. United Kingdom	8	16	8
3. European except United Kingdom	9	37	19
4. All others	0	9	5
Total (with relevant information)	23	155	128

Continued

Table AI.
Continued

Country of Birth	Birth Year		
	Before 1800	1800–1899	1900–1985
Panel C. M.A. (Master's) Degree?			
1. United States	5	82	82
2. United Kingdom	10	13	6
3. European except United Kingdom	6	31	12
4. All others	0	8	4
Total (with relevant information)	21	134	104
Panel D. Ph.D. (Doctorate) Degree?			
1. United States	6	86	79
2. United Kingdom	9	14	7
3. European except United Kingdom	6	35	14
4. All others	0	9	4
Total (with relevant information)	21	144	104

Notes: Inventor-entrepreneurs are individuals who are classified as both inventors and entrepreneurs.
The number of inventors includes inventor-entrepreneurs.
The number of entrepreneurs includes inventor-entrepreneurs.
Table excludes observations with missing country or year of birth information or educational information.
See notes to Table I for country details.

References

Abbot, D., 1985, *The Biographical Dictionary of Scientists: Engineers and Inventors*, New York: Peter Bedrick Books.

Ben-David, J. and R. Collins, 1966, "Social Factors in the Origins of a New Science: The Case of Psychology," *American Sociological Review*, 31, 451–465.

Channon, D., 1979, "Leadership and Corporate Performance in the Service Industries," *Journal of Management Studies*, 16, 185–201.

Collins, O. and D.G. Moore, 1970, *The Organization Makers*, New York: Appleton-Century-Crofts.

Culligan, J., 1998, *Tycoons and Entrepreneurs*, New York: Macmillan Library Reference USA.

Dogan, M. and R. Pahre, 1990, *Creative Marginality: Innovation at the Intersections of Social Sciences*, Boulder, CO: Westview Press.

Dosi, G., 1988, "Sources, Procedures, and Microeconomic Effects of Innovation," *Journal of Economic Literature*, 26, 1120–1171.

Edge, D.O. and M.J. Mulkay, 1976, *Astronomy Transformed: The Emergence of Radio Astronomy in Britain*, New York: Wiley Interscience.

Entrepreneurs.about.com 2005–2007, [Data retrieved on multiple dates from 2005 to 2007]. Available at www.entrepreneurs.about.com

Evans, H., G. Buckland, and D. Lefer, 2004, *They Made America: From the Steam Engine to the Search Engine: Two Centuries of Innovators*, London: Little Brown & Company.

Feldman, A. and P. Ford, 1979, *Scientists and Inventors*, Menlo Park, CA: Aldus Books Limited.

Feldman, D.H., 1999, "The Development of Creativity," in R.J. Sternberg, ed., *Handbook of Creativity*, Cambridge: Cambridge University Press, 169–186.

Finke, R.A., 1995, "Creative Insight and Preinventive Forms," in R.J. Sternberg and J.E. Davidson, eds., *The Nature of Insight*, Cambridge, MA: The MIT Press, 255–280.

Fucini, J. and S. Fucini, 1985, *Entrepreneurs: The Men and Women Behind Famous Brand Names and How They Made It*, Boston, MA: G.K Hall.

Galenson, D.W. and B.A. Weinberg, 1999, "Age and the Quality of Work: The Case of Modern American Painters," NBER Working Paper No. 7122, May.

Gardner, H., 1993, *Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*. New York: Basic Books.

Gieryn, T.F. and R.F. Hirsh, 1983, "Marginality and Innovation in Science," *Social Studies of Science*, 13, 87–106.

Gick, M.L. and R.S. Lockhart, 1995, "Cognitive and Affective Components of Insight," in R.J. Sternberg and J.E. Davidson, eds., *The Nature of Insight*, Cambridge, MA: The MIT Press, 197–228.

Hambrick, D.C. and P.A. Mason, 1984, "Upper Echelons: The Organization as a Reflection of its Top Managers," *Academy of Management Review*, 9, 193–206.

Harlow, H.E., 1959, "Learning Set and Error Factor Theory," in S. Koch, ed., *Psychology: A Study of a Science*, Vol. 2, New York: McGraw-Hill, 492–537.

Haskins, J., 1998, *African American Entrepreneurs*, New York: Wiley.

Hayes, J.R., 1989, *The Complete Problem Solver,* 2nd ed., Hillsdale, NJ: Erlbaum.

Iles, G., 1912, *Leading American Inventors*, New York: Holt.

Inventors.about.com 2005–2007, [Data retrieved on multiple dates from 2005 to 2007]. Available at www.inventors.about.com

Jones, B.F., 2009, "The Burden of Knowledge and the 'Death of the Renaissance Man': Is Innovation Getting Harder?," *Review of Economic Studies*, 76(1), 283–317.

——, Forthcoming, "Age and Great Invention," *Review of Economics and Statistics*.

Klein, M., 2003, *The Change Makers: From Carnegie to Gates, How the great Entrepreneurs Transformed Ideas into Industries*, New York: Holt.

Lamoreaux, N.R. and K.L. Sokoloff, 2005, "The Decline of the Independent Inventor: A Schumpterian Story?," NBER Working Paper No. 11654, October.

Lazear, E., 2005, "Entrepreneurship," *Journal of Labor Economics*, 23(4), 649–680.

Luchins, A.S., 1942, "Mechanization in Problem Solving: The Effect of Einstellung," *Psychological Monographs*, 54(6, Whole No. 248), 1–95.

Martindale, C., 1995, "Creativity and Connectionism," in S.M. Smith, T.B. Ward, and R.A. Finke, eds., *The Creative Cognition Approach*, Cambridge, MA: The MIT Press, 249–268.

Mayer, R.E., 1995, "The Search for Insight: Grappling with Gestalt Psychology's Unanswered Questions," in R.J. Sternberg and R.A. Finke, eds., *The Nature of Insight*, Cambridge, MA: The MIT Press, 3–32.

McLaughlin, N., 2001, "Optimal Marginality: Innovation and Orthodoxy in Fromm's Revision of Psychoanalysis," *The Sociological Quarterly*, 42(2), 271–288.

National Inventors Hall of Fame, 2005–2007 [Data retrieved on multiple dates from 2005 to 2007]. Available at www.invent.org

Simon, H.A. and W.G. Chase, 1973, "Skill in Chess," *American Scientist*, 61, 394–403.

Simonton, D.K., 1999a, "Creativity as Blind Variation and Selective Retention: Is the Creative Process Darwinian?" *Psychological Inquiry*, 10(4), 309–328.

——, 1999b, *Origins of Genius*, New York: Oxford University Press.

Smith, R., 2002, *Inventions and Inventors*, Vol. 1 & 2, Pasadena, CA: Salem Press.

Sullivan, O.R., 1998, *African American Inventors*, New York: Wiley.
Vare, E.A. and G. Ptacek, 2002, *Patently Female: From AZT to TV Dinners, Stories of Women Inventors and Their Breakthrough Ideas*, New York: Wiley.
Weinberg, B.A. and D.W. Galenson, 2005, "Creative Careers: The Life Cycle of Nobel Laureates in Economics," NBER Working Paper No. 11985, November.
Wertheimer, M., 1945/1959, *Productive Thinking*, Chicago, IL: University of Chicago Press.