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Responses in Technical Change to Uncertainty: Evidence from Patenting Activity Among African Americans, 1821-1919

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ABSTRACT

A number of emerging markets are attempting to make the technological leap that many rapidly growing emerging economies have made in the recent past, e.g., Singapore, or that developed countries made during the period of rapid industrialization, such as the United States. Among many economic policymakers and economists in emerging and developing market economies, the conventional wisdom is that intellectual-property-rights protection can be separated from more general protection of all forms of property. That is, implementing rules, laws, and practices that protect intellectual property is a sufficient incentive to attract foreign investors to, for example, a nascent information-technology sector, regardless of the overall property-rights regime. However, countries like Russia and Nigeria find it relatively difficult to attract investment in patent-generating and -intensive industries. This research attempts to find an example in American economic history that may shed light on this problem. Using a new data set on patenting by African Americans from 1821 to 1919 that I have constructed, I find that the aforementioned reasoning may be flawed. The preliminary evidence suggests that rates of innovation are correlated with *overall* protection of property rights, rather than with more narrow protection of *intellectual* property rights (or market opportunities). Increases in inventive activity between 1880 and 1899 are associated with greater security of intellectual property through the development of patent intermediaries, and a continued fall between 1900 and 1919 is related to less certainty in the overall property-rights environment. The economic significance of this finding suggests that, then and now, uncertainty in general property-rights protection may result in nontrivial and persistent declines in inventive activity, the source of improvements in technology that allow sustained increases in per capita income.

A harvester. A cotton gin. A propeller for steamboats. A treatment for smallpox. Modern ice cream. These are a few inventions by slaves and other African Americans that are reported in the historical literature but were never patented by the inventors.

The traffic light. A nuclear reactor. The golf tee. Corn and cotton planters. Cortisone. Electrogasdynamic processes. The gas mask. *Cascade* dishwashing detergent. A helicopter. "Duggerite." The carbon filament for Edison's electric incandescent lamp. The separation of plutonium from uranium and fission products. The lubricator cup. Railway telegraphy. A broadband data-reception system. The ironing board. A torpedo launcher. A toy rocket launcher. Margarine. The "third rail." Laser apparatus for surgery of cataractous lenses. A microcomputer system with bus control means for peripheral processing devices. These are a few of the inventions patented by African Americans in the U.S. between 1821 and 2000.

Economic historians have debated whether the motives of inventors and patentees are consistent with profit or expected-return maximization rather than non-market factors. Recent papers by Sokoloff and co-authors, for example, suggest that this debate is settled in favor of expected-return maximization. Other economists studying patenting and innovation, especially protection, assume market behavior of firms and individuals.

In a data set that I constructed that has matched African American inventors to patent records, extended periods of divergence between overall patenting behavior and that of African Americans are identified.[1] What explains the variation in patenting rates among African Americans? What is the decision these inventors face? Are African American inventors not responding to the expansion and contraction of business opportunities, like the rest of the patenting population? Are there other market factors or non-market factors that affect inventors differentially? Given the careful attention economists have paid to the outcomes of policies and practices affecting the rate and composition of inventive activity and technical change, surprisingly little has been done on this topic. In fact, there is essentially no literature on this question of the intersection of race and innovation. Therefore, the exercise begins in earnest here.

This study continues the line of research in economic history that investigates factors influencing patenting activity over time, industry, and space, typically within the U.S. It also takes seriously the literature on the economics of innovation that examines changes in patent activity along the same dimensions with extensions of the space dimension beyond the U.S. and emphasis on protection, e.g., Lerner (2002). Further, the proposed research draws on the African American Studies literature, which often focuses on individual inventor case studies but, in general, does not seek to explain variation in patenting activity systematically. The innovation of the research proposed is that, unlike these literatures, it attempts to explain differences in patenting outcomes, given the *same*

[1] The term "innovator" will be used throughout the paper to denote a person who has patented an invention. The term "inventor" will be used throughout the paper to refer to a person who is engaged in inventive

institutional changes, with respect to industrial organization for instance, and the *same* patent regime.

The African American patentee data set may shed light on puzzles concerning general patenting activity and the process of technical change.[2] Such an exercise has not been undertaken systematically since 1913. To my knowledge, it is the most comprehensive data set of its kind, and, when finished, it should allow a number of interesting questions to be addressed.

The preliminary evidence suggests that innovators who are African American are profit-maximizers and face a classic portfolio-choice problem, like other American inventors. Due to risk aversion, however, they appear to increase their patent activity when expected returns from patenting become more certain and reduce it when they become more uncertain. Property-rights protection appears to be a source of uncertainty that affects them differentially in the period 1821 to 1919, and they respond to other sources of uncertainty during the period of divergence in the late 20th century.

The paper is in five parts. I begin the paper with a discussion of the data I have collected. I compare my sample with more conventional patent data and report on the likely extent of missing data. The second part narrows the reader's attention to the period 1821 to 1919. The third part introduces the basic model of

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activity and may or may not have patented an invention.

[2] Unless otherwise stated, "patent" in the paper will refer to a utility patent. A utility patent is issued for any new and useful process, machine, manufacture, composition of matter, or any new and useful improvement thereof. From 1995, utility patents are effective for 20 years from the date of application.

uncertainty and offers some intuition on the results. An exposition of the empirical model to be estimated and anticipated results constitute the fourth part. The fifth part lays out the remainder of the research agenda.

I. Data Collection and Appraisal

Data Collection

Since race is not recorded in patent applications, the first task in constructing the data set was to identify African Americans among the population of inventors. This was accomplished by consulting a number of traditional and non-traditional historical and contemporary sources, including the *Journal of Negro History*, directories of scientists and other professionals engaged in scientific endeavors, and biographical compilations of inventors.[3] In some instances, patentee names or patent numbers were given with biographical data, which could be matched to

[3] Articles from the *Journal of Negro History* include Charles R. Drew, "Negro Scholars in Scientific Research," Vol. 35, Issue 2 (Apr., 1950), pp. 135-149; Sidney Kaplan, "Jan Ernst Matzeliger and the Making of the Shoe," Vol. 40, No. 1 (Jan., 1955), pp. 8-33; and Dorothy Cowser Yancy, "The Stuart Double Plow and Double Scraper: The Invention of a Slave," Vol. 69, No. 1 (Winter 1984), pp. 48-52. An important directory is Vivian O. Sammons's *Blacks in Science and Engineering,* New York: Hemisphere Publishing, 1990. Her compilation draws extensively on a number of non-traditional sources, including popular magazines, the *Crisis* (official NAACP publication), a medical journal, biographies, and other directories of African American doctors, engineers, mathematicians, nurses, and scientists dating from 1915. Biographical data in the inventors data set were primarily gathered from Nathan Aaseng, *Black Inventors*, New York: Facts on File, 1997; Ersky Freeman, Alaiyo Moseley, and Cedric Stroud, "1001 Black Inventions," Washington, DC: Pinpoints, Inc., 1991; Louis Haber, *Black Pioneers of Science and Innovation*, New York: Harcourt, Brace, and World, 1970; Patricia Carter Ives, *Creativity and Inventions: The Genius of Afro-Americans and Women in the United States and Their Patents*, Arlington, VA: Research Unlimited, 1987; Edward Sidney Jenkins, *To Fathom More: African American Scientists and Inventors*, Lanham, MD: University Press of America, 1996; Otha Richard Sullivan, *Black Stars: African American Inventors*, New York: John Wiley & Sons, Inc., 1998; and James C. Williams, *At Last Recognition in America: A Reference Handbook of Unknown Black Inventors and Their Contributions to America, Volume I*, Chicago: B.C.A. Publishing Corp., 1978.

data from the U.S. Patent and Trademark Office (USPTO). Specifically, the USPTO database is searchable by name from 1976 and by patent number from 1790 (or at least since numbers were assigned), and the European Patent Office (EPO) database is searchable by name and other criteria from 1920.

A number of web sites also provide less complete compilations of inventors and their patents.[4] All such lists seem to rely upon the work of Henry E. Baker, an attorney and Assistant Patent Examiner who was African American and conducted surveys of African American patentees in 1900 and in 1913.[5] The matching process used in the current data set cannot take advantage of recent methods used to identify "black" names. This is discussed more fully in the data-appraisal section.

The main data set extends from March 3, 1821 to June 13, 2000 and includes all utility patents granted to African Americans during this period. The current stock of utility patents assigned to African Americans is 1132 patents, and there are 555 patent-holders in the data set. Slightly more than one third of patents were obtained prior to the 20th century.

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[4] These compilations or search engines include "Black Facts Online;" Great Lakes Patent and Trademark Center of the Detroit Public Library, "African American Inventors Database;" National Inventors Hall of Fame Homepage; The Ohio Historical Society, "The Afro-American Experience in Ohio, 1850-1920," (mainly biographical information, articles on inventions displayed at exhibitions and fairs); Princeton University, "The Faces of Science: African Americans in the Sciences;" and The University of the State of New York, "African-American Bibliography – Science, Medicine, and Allied Fields: Selected Sources from the Collections of the New York State Library," 1991. If these sources identify an inventor as a patent-holder, typically a patent number and brief description are, at most, given. Missing data of interest include co-inventors, patent-assignment characteristics, location, and patent classification. See Data section for more discussion of missing data.

[5] The Patent Office survey was sent to approximately 9,000 of the 12,000 registered patent attorneys in 1913, and the results appeared in Henry E. Baker, "The Colored Inventor," The Crisis Publishing Company, 1913 (pamphlet reprinted by Arno Press, 1969); "The Negro in the Field of Invention," *Journal of Negro History*, Vol. 2, No. 1 (Jan., 1917), pp. 21-36; and *Negro Inventors*, Vols. 1-4, 1921, Moorland-Spingarn Research Center, Howard University. The last work contains patent records, including drawings, from 1834 to 1900.

Table 1 and Figure 1 summarize the data currently available in the data set. At present, the data comprise the innovator's name, the name or brief description of the patent, and the grant date for each observation. Once complete, it will contain for each patent the inventor's full name; the name of the patent; the grant date; the geographical location of the (African American) patentee (zip code, neighborhood); the names of co-inventors; the order of appearance of the names of inventors (or some measure of relative magnitude of patentee's contribution); citations made and received (measure of patent value); the patent attorney used (and location, if available); the patent's assignment status; and the assignee's name, location, and type. For earlier patents (prior to 1940), the proportion of assignment is available and will be included. Also, patents have not yet been codified by type. The USPTO uses 460 three-digit patent classes and over 120,000 sub-classes to codify patented inventions. Alternatively, the NBER-Hall, Jaffee, and Trajtenberg utility-patent data set (PAT63_99) can be used to obtain their higher-level (six main) classifications of patents granted after 1963. Patents prior to 1963 may be codified by consulting individual patent records in either of the aforementioned databases and matching them to the NBER-Hall, et al. data.

Series not available in the patent data sets that will also be collected include patentee education, training, and property-ownership status. It has not yet been determined whether data on application dates and the possession of foreign patents, for instance, will be collected. Specific data requirements are discussed in Sections 4 and 5.

Each patent-holder has been issued approximately two patents, on average, which is what Hall, Jaffee, and Trajtenberg (2001) finds for the entire population of utility-patent-holders.[6] While most black patent-holders have one or two patents, 15 have 10 or more patents, and 11 have 20 or more patents. David N. Crosthwait, Jr., Lloyd Augustus Hall, Lonnie G. Johnson, Fredrick M. Jones, Percy L. Julian, James E. West, and Granville T. Woods patented 40 or more inventions between 1884 and 1989. There is a high degree of concentration among innovators: these six account for nearly half the patents issued to African Americans in the current data set.

Forty-seven innovators patented throughout their careers, that is, at least over one decade. The longest patenting career belongs to Richard Spikes, who received 14 patents for primarily brake-, gear-, and transmission-related inventions between 1906 and 1962. A few hold foreign patents. I identified one British, one Canadian, one Austrian, six German, and five Swiss patents out of 101 patents held by Dr. Percy Julian. Elijah McCoy held patents in these countries, as well as in Russia and Austria. Four inventors in the sample were inducted into the National Inventors Hall of Fame: George Washington Carver, Mark Dean, Percy L. Julian, and James E. West.

Norbert Rillieux and Elijah McCoy are among the early inventors who received degrees in engineering (from France and Scotland) in the early and mid-19th century. Granville Woods went to night school in New York City to obtain a

[6] Bronwyn Hall, Adam B. Jaffe, Manuel Trajtenberg, "The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools," NBER Working Paper 8498, October 2001.

degree in electrical and mechanical engineering.[7] After approximately 1930, as in the larger population of innovators, many hold Ph.D.'s, or to a lesser extent, M.D.'s.

A number of patent-holders were members of well-known research teams or headed research departments of large firms. Lewis Latimer was a member of Thomas Edison's research team, the "Edison Pioneers." Lloyd A. Hall was chief chemist and director of research at Griffith Laboratories from 1925 to 1959, after having been chief chemist at the John Morrell Company, Boyer Chemical Laboratory, and the Chemical Products Corporation.[8] From 1936 to 1954, Percy Julian headed the research department at the Glidden (paint) Company, which was the first time a black person headed a major industrial laboratory in the U.S. In general, between approximately 1900 and 1950, there appear to be few cases of African American patent-holders who join firms that purchased their patents or large university departments where similar research was being done. I return to this observation below.

Some patentees created firms to which their patents were occasionally assigned. Granville T. Woods assigned at least 10 of his 45 patents to the Woods Electric Company between 1884 and 1891. In 1920, Elijah McCoy permitted a number of investors to form the Elijah McCoy Manufacturing Company in Detroit.[9] Percy Julian formed his own laboratory, which was sold for several million dollars in the

[7] Jenkins (1996), p. 97.
[8] Haber (1970), p. 104. Carroll Griffith was Hall's chemistry laboratory partner at Northwestern University (B.S., Pharmaceutical Chemistry, 1916).
[9] O. R. Sullivan, *Black Stars: African American Inventors*, New York: John Wiley & Sons, Inc., 1998, p. 30.

late 1950's. There are, however, limited data and not yet a clear pattern of ownership of other assets or of other entrepreneurial activity for all observations.

While 5.9 percent of all U.S. patents of U.S. origin can be attributed to women inventors between 1977 and 1998, women constitute 10.5 percent of African Americans holding utility patents.[10] Among their innovations are a nursery chair, signal generators, an illusion transmitter, a safety-window cleaning device, a torpedo launcher, an apparatus for ablating and removing cataract lenses, and an emergency escape apparatus.

Finally, biographical data on a number of these inventors suggest that at least some perceived and were motivated by the "patent race." Lewis Latimer was the draftsman responsible for preparing and submitting the patent for Alexander Graham Bell's telephone hours before Bell's chief rival submitted it. Reports of Jan Matzeliger suggest that he was committed to, if not paranoid about, becoming the first to patent the shoe-lasting machine, which revolutionized the industry by connecting the shoe upper to the sole. Not only did he assign the all of his non-working hours to the study of physics and with shoemakers, but he systematically hid his inventions from his employer (a shoe manufacturer) and died at 37 from tuberculosis contracted from overexposure to conditions in leather-producing and –manufacturing facilities in and around Somerville, Massachusetts. Stiff competition between Thomas Edison and the "Black Edison," Granville T. Woods (also supplier of patented inventions to Alexander Graham Bell), led to Woods suing Edison twice. When Woods represented himself and won, Edison offered

Woods a position in the Engineering Department of the Edison Electric Company, which Woods declined.[11]

Finally, as important as who did obtain patents is who did not. It is surprising to find that George Washington Carver, arguably the best known African American inventor, obtained only three patents. This seems to be a puzzle among Carver and history-of-science scholars, and competing theories have been offered about his low level of patenting activity relative to his general inventive and scientific-research activities. One theory is that plant varieties could not be patented until very late in his career, which is probable since his patents were granted between 1925 and 1927 and the U.S. started issuing plant patents in 1930. While such a debate is beyond the scope of this paper, it may be considered for future research (see Section 5). Another example is Madame C. J. Walker, the first African American millionaire and inventor of beauty products. She never obtained patents for her products and processes but instead relied upon trade secrets to protect her claims of novelty and usefulness.

Data Appraisal

The data file is not yet fully functional. Many inventors have been matched to patents, but not all. I estimate that the data set underestimates the number of patentees by approximately 25 to 50 percent. Henry Baker reports having verified 800 of the 1200 patents for which he received survey responses from patent

[10] Androgynous first names and initialed names are excluded from the count of black women patentees.

attorneys and agents between 1900 and 1913.[12] By this measure, if the average patenting rate were held constant, there should be a minimum of 717 patents added in the last 87 years, and the current total should be roughly 1517 patents. In a number of cases, biographers or editors give less reliable data concerning the total number of patents received (sometimes overestimates) and other patent characteristics (see above footnote). In these instances, the primary sources used by these authors or USPTO data must be consulted.

Particularly for the 1990's, it is difficult to know the magnitude of the potential omission of patentees. Unfortunately, this research cannot benefit from name-matching in the same way that a number of recent studies which take advantage of women's or "black" names. For instance, a 1999 USPTO study identifies women patentees by matching common women's names to the first-named inventor on a patent. Mullainathan and Bertrand (2002) and Levitt and Fryer (2003) take advantage of commonly-used "black" first names to perform tests of labor-market and life outcomes. As currently configured, the data show that conditional on being African American, the probability of obtaining a patent is 1.3 percent if an innovator is named Charles; 1.2 percent, George; 1.9 percent, Henry; 3.3 percent, James or John; 1.8 percent, Robert; and 3.0 percent, William. Initialed patentee names notwithstanding, there are no commonly-used "black" first names in the data. This finding may reflect the possible bias of the data set, which has better data on earlier rather than later periods when "black" names, as defined by the

[11] "Points to Ponder," The Patent and Trademark Museum, http://www.uspto.gov/go/kids/ponder7.htm and Asseng (1997), p. 71.
[12] Patent data between 1900 and 1913 are recorded by Baker in subsequent articles, rather than in the four-volume compilation of patents by African Americans.

aforementioned authors, may have been used more frequently. It may also reflect self-selection or criteria applied in the formation of patent teams. I return to this point in Section 5.

A third wave of the Baker-type survey of patent intermediaries and patentees would likely be useful to identify and address the missing-data problem. It would also likely be the most costly means of obtaining additional data. Interviews scheduled over the next few months with patentees, venture capitalists, industry groups, patent attorneys, and patent-generating firms will aid in this effort.

Another potential problem in the data is that there might be a structural undercount for the period during which African Americans relied heavily upon patent intermediaries. Baker encountered significant difficulty in verifying patentees, because there was a perception that their patents would be undervalued if race were a factor. This may account for the additional 400 patents that Baker could not verify.[13] This problem will be related to an hypothesis formed to explain patenting behavior in the next section and will be addressed formally in estimation.

A final problem is likely truncation. The Baker volumes include all patents from the period 1834 to 1913.[14] These are likely the most reliable data available,

[13] Similarly, Milton Friedman points out that the undercount might also be exacerbated by the problem of "passing." If Baker received information from a patent agent or attorney that a patentee was black, but the patentee did not claim the same race, the patent could not be verified as being held by a black person.

[14] The only known omission in the Baker data was that of the first patentee. He, like many, assumed that Henry Blair, who obtained a patent for a corn planter in 1834, was the first African American to receive a patent, because he was the first and only patentee to have "colored" to appear on his patent application. The dating of the first patent to an African American appears to have been corrected in the 1990's.

because Baker was an informed patent examiner, and his survey results are published in several places, including refereed journals. To my knowledge, the first significant compilation of patents matched to African Americans after Baker was assembled by the New York State Library in 1991 and is currently on the Internet. The person or algorithm compiling this list was limited to a maximum of three patent attributions per inventor. Initial indications are that patentees cited with three patents are roughly equally likely to have exactly three as they are to have more than three. Some coded with a "3", like Percy Julian, have over 100 patents, and the total patent count would be biased downwards. Subsequent lists, which are primarily on the Internet (and not scrutinized), appear to have extended this work by identifying more patentees, but no study systematically corrects this truncation problem.[15] Therefore, each name assigned three patents in this 1991 data set must be reconsidered for patent-count accuracy. Currently there are 43 such patentees under review in the data set.

The data set, once complete, will be comparable to both the NBER-Hall, et al. data file and to the Sokoloff-Khan-Lamoreaux data sets. For the post-1963 period, the data set should be very similar to the NBER-Hall, et al. data set. Series such as country of first inventor, state of first inventor (if not the state of the relevant patentee), main U.S. patent class, number of claims, measures of "generality" and "originality," forward and backwards citation lags, and self-citations will be omitted.

[15] The lists available on the Internet and in print also make systematic errors with respect to names, patent numbers, and the like. However, these infractions are relatively minor with respect to the truncation

Geographical data collected in this data set will likely be as refined as in Sokoloff (1988), which includes analyses related to navigable inland waterways, but will not be identical series nor time periods covered. Data on "great inventors" used in Khan and Sokoloff (1993) contain series that will be relevant for the analysis of innovative activity among African Americans, including education levels, occupations, and entrepreneurial activities. I discuss these data further in Sections 4 and 5.

The Lerner (2000a, 2000b, 2002) data sets emphasize international comparisons and interactions between patent-office officials and patentees (or their representatives) and are less relevant for this research than the NBER-Hall, et al. and Sokoloff-Khan-Lamoreaux data.

The next section focuses on the subset of data for 1821 to 1919 relevant for this paper's investigation.

III. The Period 1821 to 1919

Table 1 shows that there were three decades during the antebellum and Civil-War period in which there were triple-digit increases in overall patenting activity in the United States: the 1830's, the 1850's, and the 1860's. Sokoloff (1988) and Khan and Sokoloff (1988) find responsiveness of overall patenting activity to business conditions for the period 1790 to 1846. It begins from a very low base, but patenting activity among African Americans is, nonetheless, pro-cyclical during the

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problem.

first half of the 19th century. Six of the eight patents obtained up to 1846, for example, were obtained during periods of economic expansion, that is, between 1822 and 1837 and between 1843 and 1846.[16] Patenting activity exhibited, on the other hand, countercyclicality during the 1850's. I will return to this observation later in the paper.

Contrary to the findings of Sokoloff (1988) and Khan and Sokoloff (1988), most innovative activity during this period was not concentrated in New England but was almost equally divided among the mid-Atlantic, mid-western, and southern regions (see Table 2). New England and the West account for only 12 percent of inventions patented by blacks up to 1919. Similar to what Sokoloff and co-authors find, I find that patentees residing in, or at least applying from, New York constitute the majority of black patentees from the mid-Atlantic region and 18 percent of all patents to blacks during this period. Also consistent with the Sokoloff findings is the disproportionate contribution of certain regions and states. Although 90 percent of blacks lived in the South, only one-third of patents obtained by blacks originated from southern residents. Only three percent of blacks lived in the mid-Atlantic region, but their contribution to total patents held by blacks was 10 times their population share. Mid-western patentees exceeded their population share by a factor of five.

While the existence and persistence of inter-regional differentials is simply noted here, it will become important in explaining changes in patenting activity in Section 4.

[16] Unless otherwise specified, the term "patent" will be used throughout the paper to denote utility patents, which constitute over 95 percent of all patents granted African Americans.

Not surprisingly, a significant proportion of patents awarded, one-third, were in transportation, a major employer of African Americans in the late 19th and early 20th centuries. It is also surprising that many patents were obtained in manufacturing, since few blacks were employed in manufacturing or had non-trivial exposure to the manufacturing sector. Nonetheless, this finding is consistent with broader trends.[17] Even more striking is the observation that most African Americans were employed in agriculture between 1861 and 1919 when free and slave alike could obtain patents, but only eight percent of all patents related to agriculture. By contrast, roughly one-fifth of all U.S. patents derived from the agricultural sector at this time.

A few of the early innovators in the data set were not literate, although likely numerate, at the time their patent was granted. Some patent applications signed with an "X", which would suggest illiteracy. Judy W. Reed, who patented a machine for kneading and rolling dough and is thought to be the first African American woman to obtain a patent in 1884, was illiterate, as was the second black patentee, Henry Blair.[18]

Given that it was illegal for slaves to obtain patents from the U.S. government and that most blacks were slaves prior to emancipation, it will be useful to divide this period into sub-periods.

[17] Kenneth Sokoloff, "Inventive Activity in Early Industrial America: Evidence from Patent Records, 1790-1846," *Journal of Economic History*, Vol. 48, No. 4 (Dec., 1988), pp. 813-850.
[18] "Points to Ponder," The Patent and Trademark Museum, http://www.uspto.gov/go/kids/ponder7.htm, and Aaseng (1997).

The Antebellum and Civil-War Period (1821 to 1865)

In 1821 or 31 years after the U.S. began issuing patents, Thomas L. Jennings was the first known innovator of African descent to obtain a patent. His innovation was a method for dry-scouring clothes.

Only 10 patents are known to have been obtained by African Americans between 1821 and 1865. Patentees were both free persons and former slaves. One inventor, Norbert Rillieux returned to New Orleans after his engineering studies in France and patented two processes related to the sugar industry in 1843 and 1846. These methods are widely reported in the literature to have revolutionized the U.S. sugar industry. Some innovators were themselves former slaves, such as George Washington Carver, or the children of runaway slaves.

In 1858, Attorney General Jeremiah S. Black clarified U.S. Patent Office policy and ruled it illegal for either a slave or a slave-owner on behalf of a slave to own a patent for the slave's invention.[19] Before this clarification, not permitting slaves to hold patents was viewed to be consistent with the earlier Dred Scott case, whose implication was that the United States could not enter into contracts with non-citizens. While the data are limited, it appears that, despite the absence of intellectual-property-rights protection, slaves were engaged in a wide range of inventive activities, particularly related to agriculture and transportation. At least

[19] The terms "U.S. Patent Office" and "U.S. Patent and Trademark Office" will be used interchangeably in the text. Both names were used during the period studied.

two slaves who developed means of treating infectious diseases, smallpox and skin and venereal diseases, were freed and allowed to pursue careers in medicine.[20]

The extent to which patentable inventions were appropriated by slave-owners or their representatives to patent without the consent or participation of the slave-inventor is unclear. The cotton gin, for example, was believed to have been one such patented invention. Eli Whitney visited a Georgia plantation where a slave, Sam, was using his father's invention to separate the seeds from the rest of the cotton before patenting the cotton gin. It would be difficult to ascertain whether there was an agreement between Sam's (or his father's) slave-owner concerning the subsequent patent or in any such case.

While patents to slaves for their inventions were legislated by the 1861 Statutes-at-Large of the Confederate States of America, the preliminary evidence suggests that no such patent was granted under that regime.[21] Nonetheless, the inventive slave who provided the motive for Jefferson Davis, the president of the Confederacy, to advocate patent rights for slaves, Benjamin Montgomery, obtained a patent for his

[20] This paper will not address the debate articulated in Aufhauser (1974) and the rejoinder in Fleisig (1974), which centers on whether slave societies retarded technological progress, given profit and wage incentives. Rather, the current research assumes that the incentive for slaves to invent was largely to minimize the level and intensity of effort and that such innovations allowed technological advancement. This assumption seems reasonable, given the empirical evidence concerning freed slaves' withdrawal from the labor force following emancipation and concerning the evolution of the cotton gin. It is also consistent with evidence from the data set and from anecdotes that former slaves patented a number of their inventions, or formally added to the known stock of ideas, once free and able to maximize wages and profit.

[21] The response of southerners to the establishment of the Confederate Patent Office is the subject of a companion paper. See Section 5.

steamship propeller after the Civil War ended.[22] It is unclear whether other slaves, such as Hezekiah, a slave from Alabama who invented a cotton-cleaning machine in 1825, or Joe Anderson, who is reported to have provided the design for Cyrus McCormick's harvester, applied for patents through the Confederate Patent Office or through the U.S. Patent Office after the abolition of slavery.[23]

The Reconstruction Era (1866-1899)

The rate of growth in patenting slowed from 265 percent in the 1860's to 13 percent at the turn of the century. Figure 1 shows that patenting activity among African Americans followed a pattern similar to that of the larger population. In fact, the rate of increase was faster, but this was due to the low base from which the trend was starting in the 1860's.

Most patented innovation in the U.S. between 1880 and the early 20th century related to simple gadgets that increased efficiency. Inventive and patentable activity did not require specialized training in a technical field during that period (Sokoloff (1988)).

The agricultural and domestic-service sectors notwithstanding, innovations patented by African Americans closely reflected the industries in which they were employed, particularly in the railway industry in the 1880's. Of Elijah "The Real"

[22] My data and the sources I have consulted have not been able to corroborate this patent.
[23] Otha Richard Sullivan, *African American Inventors*. New York: John Wiley and Sons, Inc., 1998, p. 23.

McCoy's 28 patents, 21 were modifications of the lubricator cup, which was thought to have dramatically changed the method of lubricating train engines and, therefore, extended substantially the distance that trains could travel without fires and other mechanical disruptions. Household inventions, like lawn movers, ironing boards, serving devices, and cleaning devices, proliferated from the turn of the century when blacks increasingly became employed as domestic servants. Low levels of participation in patent-intensive industries among blacks will be included as a factor to be empirically tested below.

Sokoloff and Lamoreaux (2002) demonstrate that the role of patent intermediaries developed dramatically in this period. Patent agents and lawyers reduced information costs by matching buyers and sellers of patent rights. By analyzing assignment records, they find that patentees whose patent assignment contracts were intermediated by these specialists produced more patents over their careers, assigned a greater fraction of their patents, and were able to find buyers for their inventions faster than inventors who did not use their services.

It is suggested in the historical literature, particularly by Henry Baker, that patent agents and attorneys may have encouraged participation in the innovative process, especially among African Americans. Baker reports that his survey was difficult to execute, because African American patent-holders and their agents vigorously protected patent-holders' racial identities, since the Patent Office never required information about one's race.[24] Anecdotal evidence from inventors suggests that

[24] Only one person, Henry Blair, who received a patent 1834, is identified in the Patent Office data as being "colored." It is unclear why his racial identity was recorded.

the market value of the patent may have been, or perceived to be, negatively correlated with being of African descent. For example, it is reported that Elijah McCoy's lubricator cup, because of its significant cost-saving features, was adopted quickly in the railroad industry and used on most locomotives in the U.S. between 1872 and 1915. The cup was useless if installed improperly. Because of his formal training as an engineer, he insisted on installing the cup himself. Apparently, this caused tension among railway workers who where unaccustomed to an African American in this role, and the cup was labeled the "nigger" cup.[25] Certainly, no patentee wanted this label, which would likely diminish the value of current and future patented inventions. A more detailed and systematic analysis would be needed to ascertain whether an adverse shock to patent value was real or perceived.

A greater than 2000-percent increase in patenting activity among African Americans in the late 19th century suggests that they valued equally two new features of the market for invention: efficiency and anonymity. The race-neutral policy of the U.S. Patent Office already provided anonymity. But before the proliferation of patent agents and attorneys, the active market for patents depended critically on the inventor's marketing efforts, whose outcome was uncertain. The minimization of search and transactions costs increased the certainty of intellectual-property-rights protection, which, in turn, raised the expected utility of patenting and induced technical change. This outcome appears

[25] Aaseng (1997), p. 27.

less ambiguous than recent papers that have found few positive effects of patent protection.[26]

While the focus of this period has been the changes in inventive activity due to the protection of intellectual property, the argument is extended in the next section to show that changes in the protection of all forms of property may better explain the variation in technical change over time.

Early 19th Century (1900-1919)

Growth in patenting increased at an increasing rate (38 percent) between 1900 and 1909 and at decreasing but still positive rate (25 percent) between 1910 and 1919. We observe that technological innovation relied less on "know-how", became more specialized, and required more investment in education.

Although trends in the earlier periods are consistent between the U.S.-patent-holding population and its African American subset, this period is anomalous (Sokoloff and Lamoreaux (1999, 2002)). The number of patents African Americans obtained between 1900 and 1919 fell 111 percent from the number obtained in the 1890's. Not only has this collapse not been identified previously, no explanation for this collapse has been offered in the economic or historical literature.

[26] Josh Lerner, "Patent Protection and Innovation Over 150 Years," NBER Working Paper No. 8977, June 2002.

Hypotheses

One hypothesis appears to be particularly salient for this period. Features of industrial organization, post-Reconstruction institutional changes, and societal practices may have increased the riskiness of patenting. As a result, risk-averse agents may have selected out of the activity.

Property Rights Protection

Emancipation and reconstruction efforts allowed blacks to pursue employment and economic opportunities previously unavailable to them. The Bureau of Freedman, Refugees, and Abandoned Lands (Freedman's Bureau) came into existence in March 1865 and was charged with meeting shorter-term ("provisions, clothing, and fuel") and longer-term (health, education, land, and banking) activities of freed slaves.[27] Northern missionaries and other private groups visited the postbellum South and provided many resources for the immediate relief effort and for the rebuilding effort. With mobility came integration into industries, particularly in the West and North, albeit often at the lowest levels, relatively unknown to blacks. Land acquired through the Freedman's Bureau or other means was used, enjoyed, and protected from infringement of associated rights. Robert Margo's analysis of tax-assessment records between 1870 and 1910 demonstrates that the gap between

[27] "An Act to establish a Bureau for the Relief of Freedmen and Refugees," http://www.inform.umd.edu/ARHU/Depts/History/Freedman/fbact.htm.

black and white assessed (property) wealth in the South was closing rapidly.[28] Further, the effect on patenting rates was almost immediate. Within 10 years of the end of the Civil War, 26 African Americans had been granted patents, more than three times the number for the entire period since the first African American received a patent. That Granville T. Woods was able to challenge Thomas Edison twice and win during this period is a testament to the fact that intellectual property rights were relatively secure during this period.

In the South after Reconstruction ended (1877), a dramatic change in property-rights protection, not restricted to intellectual property, may have been a source of increased riskiness in patenting. Blacks had increasingly less access to political processes and the legal system after 1890 due to restrictions on voting and holding elected office. Without representation, blacks' confidence in the legal system to protect all property rights likely waned. Blacks in the South also faced a dramatic rise in race-related violence, particularly riots involving property destruction and lynchings, during this period. Lynchings were concentrated in the South, although present in the North, and peaked between 1890 and 1899 but peaked with respect to percent black victims (91.5 percent) between 1910 and 1919. In a recent paper by Darity and Price (2003) which uses 1930 census data, it is found that a significant number of lynching victims owned property, which was subsequently confiscated. Between 1898 and 1908, violence typically directed at individuals became targeted at communities, and major race riots broke out in North and South Carolina, Louisiana, New York, Ohio, Georgia, Indiana, Texas, and Illinois.[29]

[28] Margo (1984).
[29] Derrick Ward, "Urban Race Riots of the Jim Crow Era,"

The signal that risk-averse inventors likely received from these actions was that all property rights, including intellectual property rights, were less secure.

All property rights, physical and intellectual, matter simultaneously. The positive and adverse shocks to patenting activity between the end of the nineteenth and the beginning of the 20th centuries are striking. It is reasonable to believe that their source is common: property-rights protection. Patent-office policy with respect to race was held constant, but the market for patents and patentees changed. In the earlier period greater certainty resulted in higher rates of technical change, and in the latter period, less certainty resulted in diminishing rates of technical change. Both responses to changes in inventors' opportunity sets are consistent with expected-utility maximization.

The response to greater and less certainty will be formalized in the next section. Before that, it would be useful to entertain three alternative hypotheses related to changes in patenting rates among African Americans, since a number of variables were shifting during this period.

Right Place, Right Time

At this time, invention-intensive firms are increasingly internalizing their research activities. Simultaneously, other events were taking place that may have imposed

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http://www.jimcrowhistory.org/resources/lessonplans/hs_es_urban_race_riots.htm. There was also an unprecedented number of race riots between 1917, with 20 taking place between April and October 1919.

constraints on African American participation in the research-internalization wave. Race-based labor-market restrictions were growing in the South, as well as in parts of the North, and were reaffirmed by the Supreme Court's ruling in favor of "separate but equal" practices in the *Plessy v. Ferguson* case (1896). There is some evidence that blacks found it difficult to find jobs in invention- or research-intensive firms once it was known they were black. For example, American Bell Telephone Company, part owner of Western Electric Company based in Cincinnati, Ohio, purchased a patent for a mechanism for electric message transmission from Granville T. Woods in 1885. However, in 1916, Lloyd A. Hall, a young Northwestern University and University of Chicago graduate who ultimately patented over 60 inventions, was hired over the phone for a job at Western Electric but was denied the position when his racial identity became known when he came to work.[30] African Americans also became barred, often by unions, from activities that were previously the source of inventive activity, such as the early twentieth-century printing industry in Washington, D.C.

There are two possible outcomes from this change in industrial organization. First, the move by firms to incorporate patentees into newly-established research departments may have eroded the possibility of anonymity, which would have the effect of raising uncertainty and diminishing the incentive for African Americans, who were protected by intermediaries in the past, to patent. Percy Julian's appointment as Director of Research at the Glidden Company is considered a turning point in the acceptance of black scientists in industrial laboratories in the

[30] Haber (1970), pp. 104-105.

U.S.[31] Second, even if it is assumed that black and white inventors had roughly equal access to scientific and invention-related resources prior to this change, the gap between insider-inventors' and outsider-inventors' access to resources should have grown significantly, particularly if many of the externalities from industrial research groups were captured by the firm. One potential response to becoming an outsider may have been to continue patenting at the same or a higher rate, but this explanation is not consistent with the evidence.

Further, increasing formal race-based restrictions in the workplace and in everyday life may have limited blacks' access to two important activities. First, patent intermediaries may have become more scarce, and, therefore, their ability to register patents, to conduct patent searches, to defend their patents against infringement, and the like would have been more limited. Segregated residential and business districts may have also contributed to less access to patent intermediaries and to training to become such. Second, industry in the South developed asymmetrically along racial lines. Whites were employed in textiles, the source of significant patenting activity in the North, and blacks were employed in the steel industry, for example. Again, the uncertainty associated with patenting would increase, and risk-averse inventors would seek other opportunities.

Education

[31] Haber (1970), p. 94.

Patenting activity required increasingly specialized skills at the end of the 19th and beginning of the 20th centuries. If differences in education and training are observed, explanations related to the level and quality of education might be appropriate.

According to Ransom and Sutch (1977), in 1870, black males over the age of 20 were more than 90 percent illiterate, compared to 20 percent among white southerners in the same age group. It was a Herculean task for the Freedman's Bureau to provide schooling for former slaves, given the lack of extensive public-school systems for anyone. Expenditures by the federal government through any channel were largely not replaced by state spending after the Reconstruction era.

There appears to have been a dramatic increase in school quality among blacks relative to whites starting in 1915. The ratio of the average annual salary of white teachers to black teachers was 2.3 to 1 in 1915 and 1.45 to 1 in 1940. [32] If patenting activity were increasingly a function of tertiary education in the sciences, blacks might have become less prepared for graduate studies of any sort relative to their white counterparts.

Also, patent agents and attorneys are assumed to be primarily white during the period before 1913 when Henry Baker was conducting his research on African American patentees. However, if African Americans increasingly relied upon African American patent agents and lawyers, there might have been at least two possible outcomes that combine level and quality factors. First, a decline in the

quality of primary and secondary schooling would also affect those aspiring to become patent agents or attorneys. Also during this period the black-white earnings gap among the most educated was widening, which may have provided an incentive for aspiring African American attorneys to pursue other professions and limited the pool of available intermediaries.

This explanation suggests that safer activities or investment would include reduced effort, since more effort to acquire basic skills is likely required of individuals when there is a negative shock to education quality.

With respect to level of education, many factors were also changing. During Reconstruction, a number of colleges and universities began to admit black students. In addition, most of the historically black colleges and universities (HBCUs) were established, particularly by Northern missionaries, during this period. Spelman College, for example, is a women's college for former slaves and their daughters begun in 1881 by Sophia B. Packard and Harriet Giles, two Baptist missionaries from Boston who secured funding from John D. Rockefeller, Sr. to finance it. Few offered graduate degrees at inception, and only seven medical schools were established. With increasing specialization associated with patenting, there was greater demand for inventors seeking patents to possess graduate degrees in technical fields. African Americans only began obtaining such degrees, for the most part, in the 1910's, as is reported in Table 4. This list excludes Ph.D.'s obtained at foreign universities, but the magnitude of degree-granting activity abroad is not yet known.

[32] Card and Krueger (1992).

Finally, the 1910 report to the Carnegie Foundation for the Advancement of Teaching by Abraham Flexner, *Medical Education in the United States and Canada*, may have played a role in limiting the stock of human capital appropriate for patenting at this time. By 1910, the number of medical schools fell from 166 to 126 due to recommendations by the American Medical Association's Council on Medical Education, which was formed in 1904 to address problems associated with the over-production of physicians and the quality of medical education. The Flexner Report's recommendations were largely responsible for reducing the number to 96 by 1915 and to 76 by 1930. Among the medical schools closed were five of the seven black medical schools: Flint Medical College (New Orleans, LA); Leonard Medical School (Raleigh, NC); Knoxville Medical College (Knoxville, TN); Medical Department of the University of West Tennessee (Memphis, TN); and National Medical College (Louisville, KY).[33] While the effect on faculty, students, and aspiring students at the time is perhaps unknown, it is reasonable to suspect that this event constrained the number of black scientists in the short run.

Credit Constraints

Although some African Americans had degrees in engineering (mainly from European universities), it is likely that very few had the means to invest in a laboratory or other substantial infrastructure for research-intensive inventive

[33] Flexner (1910), p. 180. Howard University Medical School (Washington, DC) and Meharry Medical School (Nashville, TN) remained open.

activity. Elijah McCoy was able to finance his workshop through the sale of patents, but self-financing was likely rare for most inventors. Access to external finance may partially explain the variation in patenting relative to the earlier periods and to the overall population of innovators. Related to the factors associated with the changes in industrial organization aforementioned, financing constraints may have become binding for at least three reasons. First, in the absence of easy access to patent agents and attorneys, the value of future patents, which would be used to collateralize loans, would fall and borrowed funds would become limited. Second, firms that had already committed substantial sums to acquire productive innovators would limit their budgets to acquire outside technology. Again, outsiders lose. Further and related to the point above, owning property in an area where lynchings or property crimes were becoming more prevalent would have depressed property values and, therefore, the value of collateral used to secure external finance.

Now I turn to the basic framework that posits this relation between patenting activity and riskiness.

III. Theoretical Considerations

The inventor is an expected-utility maximizer. She must decide whether to apply for a patent to obtain exclusive rights to an invention and to its associated expected future cash flows. If this source of income becomes more risky, i.e., its

probability density function undergoes a mean-preserving spread, it can be shown that the expected utility to a risk-averse inventor will fall.[34]

Suppose an inventor has a strictly concave von Neumann-Morgenstern utility function U. She chooses x, a monetary sum, to maximize E[U(x, p)], where p is future cash flows from a patent and is a random variable. Short sales and borrowing at the risk-free rate to invest in p are prohibited. Otherwise, it is implicitly assumed that there is a perfect market (absence of taxes and transactions costs), perfect divisibility, and a competitive securities market.

Recall that the first- and second-order conditions are:

$$E[Ux(x,p)] = 0 \qquad (1)$$

$$E[Uxx(x,p)] < 0, \qquad (2)$$

where $Ux(x,p) = dU(x,p)/dx$. The second-order condition is satisfied by the assumption of risk aversion, $U''<0$.

Suppose changes in property-rights protection can shift the probability distribution of patent-licensing royalties. Let γ denote a parameter that represents a shock to the distribution of p, which preserves the mean but reduces the concentration of the weight around the mean. A choice function $x=x^*(\gamma)$ is given by (1). If γ changes, the values of x^* and of $E[Ux(x,p)]$ change, as well. Differentiating (1) with respect to γ gives

[34] The concept of "second-order stochastic dominance" was introduced in Rothschild and Stiglitz (1970) and extended in Machina and Pratt (1997).

$$\frac{\partial x^*}{\partial \gamma} E[Uxx(x,p)] + \frac{\partial}{\partial \gamma} E[Ux(x,p)] \equiv 0 \qquad (3)$$

If Ux(x,p) is a concave function in p, that is, marginal utility is decreasing in p, E[Ux(x,p)] will decrease as p is subject to a mean-preserving spread. Therefore, the second term in (3) is negative. By the second-order condition, E[Uxx(x,p)] is negative, and $\partial x^*/\partial \gamma < 0$.

For the risk-averse decision-maker the distribution of $p(\gamma=0)$ second-order stochastically dominates the distribution of $p(\gamma>0)$, and she will get higher expected utility when $\gamma=0$ and when there is no change in property-rights protection. That is, as uncertainty related to property-rights protection grows, the expected cash flows from a patent become more risky, and a risk-averse inventor's response will be to shift her investment away from patenting and toward relatively safer assets. The contrapositive is also true: if there is a reduction in "noise" and the probability distribution function becomes more concentrated around the mean, patenting activity should become relatively more attractive to the inventor. This comparative statics result is the basis of the empirical investigation that follows.[35]

IV. Estimation

[35] It will also be used to explain the collapse in patenting among African Americans in the 1980's and 1990's in a companion paper. Risk will be associated with human-capital accumulation in this instance.

The process of specifying an appropriate empirical model is in its initial stages and is an iterative one. The initial specification will, of course, be given by theory, but this specification should be refined by data-exploration techniques to better fit the data.

The basic equation to be estimated relates patenting activity to property-rights-related indicators (Li) and education, finance, and other explanatory variables in the vector X_i.

$$P_i = L_i\lambda + X_i\beta + \varepsilon_i, \qquad (4)$$

where P_i is a utility patent granted to individual i and ε_i is a stochastic error term.

Table 5 contains a summary of specification decisions to be made concerning the dependent and explanatory variables, which may include their functional forms. This table also summarizes anticipated results and data sources consistent with the foregoing discussion.[36] I will discuss a few of the regressors and their likely effects, in addition to some anticipated econometric issues.

Property Ownership and Protection

Consistent with the prediction of the model, property ownership may signal that the patentee interpreted her property rights as being secure. She would adjust her patenting activity to reflect changing conditions in overall property protection.

[36] One decision that is not summarized in Table 5 but will be considered is the timing of endpoints. Once the missing-data problem as described earlier in the paper is addressed, it will be determined whether the period 1821 to 1919 is the appropriate one.

The coefficient on property ownership is anticipated to be positive, while the coefficient on race-related or property-related violence is likely negative.

Right Place, Right Time

An appropriate explanatory variable would depend on whether a technological-field-specific dependent variable is used, i.e., P_{ik}. If P_i is used, a general indicator the degree to which labor-market restrictions existed would be an appropriate explanatory variable. State-level data on legislation will be required to determine the extent to which discrimination, particularly in labor markets, became legally sanctioned and influenced inventive activity. I would expect a negative coefficient on these restrictions. If P_{ik} is used, a weighted index of share black employment in the corresponding industry (technological category) and the share of that industry's contribution to patenting activity will be appropriate. I would expect a positive correlation between this index and patenting activity.

Education

The relation between patenting activity and education levels and quality will be tested. . The Card and Krueger (1992) data span 1915 to 1966 and would be useful for testing the school-quality hypothesis. They collected three state-level indicators of school quality: the ratio of students to teachers, average term length, and average annual teachers' salaries. Data on tertiary education for African

Americans are likely limited and are only available from the National Science Foundation from 1971. As aforementioned, earlier in the period, this effect might be small. However it should rise and be positively correlated with patenting output.

Access to Finance

Census records and biographical data may be helpful in determining the extent of access to external finance. Also, matching data on the existence of banks serving African Americans and the zip codes of the patentees may be useful, as well. It is supposed that the greater the access to external finance, the more likely it is that the decision-maker will choose in favor of patenting over time.

Some Econometric Issues

The data-appraisal section addressed the most immediate estimation-related problem, which is measurement error. Another set of issues may arise at the stage of econometric analysis. The first test in (4) is characterized as a binary-choice model with Pi representing the decision to patent or not, which would suggest implementing a probit model.[37] These models are particularly sensitive to

[37] To estimate this model, one would use the combined series of inventors who obtained patents and inventors who did not. This empirical strategy assumes that the residual from the matching exercise will be sufficiently large such that there is variation with respect to the patenting decision in the combined series of inventors.

specification errors, including omitted variables and heteroscedasticity. If an explanatory variable is omitted, the coefficients on the included variables will be inconsistent. If underlying regression's disturbances are heteroscedastic, the maximum likelihood estimators will be inconsistent, and the variance matrix will not be appropriate. While several specification tests are available, the Lagrange multiplier test is likely the best for these two potential problems.[38] Although techniques are available and will be used to reduce the importance of measurement and specification errors, the results will, of course, need to be interpreted with care once obtained.

V. Further Research

The objective of this paper is to elucidate the decision faced by inventor-decision-makers. Risk-averse agents will reserve patenting activity for periods when the distribution of expected returns to patenting is more concentrated around the mean. Changes in property- rights protection can shift the distribution of expected payoffs and reduce patenting activity. The specifications proposed allow alternative theories to be tested against this one.

Two companion papers address a number of questions related to but outside the scope of this paper. The first concentrates on 19th century patenting activity, but from another angle. The second focuses on explaining the inventor's decision to

[38] See Greene (1990).

patent in the second period that diverges from the overall trend, that is, the current period (1980-2000).

The Effect of New Property-Rights Protection

To date, economists have ignored a potentially informative "natural experiment" related to technical change. While economists have attempted to carefully measure patenting activity during the Civil War, they have never used data from the Confederate States of America patent records. This is a particularly egregious oversight, given the increase in patents granted by the U.S. Patent Office during the Civil War.

U.S. Patent Office policy and practice were unfavorable to Southerners prior to 1865. As aforementioned, slaves, nor slave-owners on their behalf, could obtain patents. A disproportionate number of Southerners were slaves and slave-owners, and patents held by Southerners were more likely to be infringed. Since the South lagged other parts of the country in inventive and patenting activity and since a patent office was established that would be more favorable to the South, a few first-order facts should be ascertained. First, and most importantly, under ostensibly more favorable conditions, did Southerners respond to the incentives consistent with patenting? That is, did patenting activity in the South rise relative to the antebellum period and relative to other regions? Further, was antebellum U.S. Patent-Office policy a disincentive for creativity, and did it thereby slow the rates of southern and national technological progress and economic growth? Did the architects of the Statutes of the Confederacy respond to a belief that the South

was falling behind technologically? Or was the ability of a slave to obtain a patent an implicit redemption program (on the Russian serf-emancipation model that had been implemented by the start of the Civil War) that could raise the slave's value and the price at which he or she would be redeemed? Second, did slaves respond to the new opportunity to become patent-holders?

Records of the Patent Office of the Confederate United States at the Library of the Museum of the Confederacy will be used to test whether technical change in the South was affected by this institutional change. Discussions among policymakers leading up to the creation of the Confederate Statutes should be found in the *Richmond Times-Dispatch* and the *Confederate Union* (Milledgeville, GA), among other newspapers and periodicals.

What Happened in the Recent Boom Years?

Overall patenting increased by 56 percent in the 1990's.[39] It is astonishing that, during the longest economic expansion in recent history, patenting rates among African Americans fell 12 percent, after having fallen 34 percent in the 1980's. As in this paper, it is appropriate to ask why there is such a dramatic deviation from the overall trend and from profit-maximizing behavior. Using the later portion of this data set, hypotheses to be tested may include team formation, technical specialization (see Jones (2002)), and external finance.

[39] Approximately 47 percent of U.S. utility patents were granted to foreign citizens in the 1990's. Changes in patents granted to U.S. citizens were consistent with overall trends during this period.

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Table 1. U.S. Utility Patents Granted, Including to African Americans By Decade,1821-2000

	Number	Percent Change, By Decade	Number, African Americans	Percent Change, By Decade
Total Utility Patents Granted	6,156,260		1132	
1820-1829	2,542	na	1	na
1830-1839	5,616	120.9	3	200.0
1840-1849	5,516	-1.8	4	33.3
1850-1859	19,661	256.4	0	-100.0
1860-1869	71,718	264.8	2	na
1870-1879	124,751	73.9	43	2050.0
1880-1889	195,214	56.5	123	186.0
1890-1899	221,251	13.3	218	77.2
1900-1909	304,726	37.7	48	-78.0
1910-1919	381,176	25.1	32	-33.3
1920-1929	414,872	8.8	52	62.5
1930-1939	442,852	6.7	97	86.5
1940-1949	307,631	-30.5	40	-58.8
1950-1959	425,988	38.5	65	62.5
1960-1969	567,858	33.3	120	84.6
1970-1979	690,428	21.6	126	5.0
1980-1989	708,472	2.6	83	-34.1
1990-1999	1,108,393	56.4	73	-12.0
'2000	157,495	na	2	na
20+ Patents	…	…	14	…
40+ Patents	…	…	7	…
Career Patentees	…	…	65	…

Source: U.S. Patent and Trademark Office, http://www.uspto.gov;
European Patent Office, http://ep.espacenet.com;
Great Lakes Patent and Trademark Center of the Detroit Public Library, http://www.detroit.lib.mi.us/glptc/aaid/index.asp;
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Note: "Career patentees" refers to patent-holders whose patenting career spans more than one decade. Utility patents and design patents are combined in the total U.S. series from 1836 to 1842.

Figure 1. U.S. Utility Patents Granted, African American and Total, 1821-2000

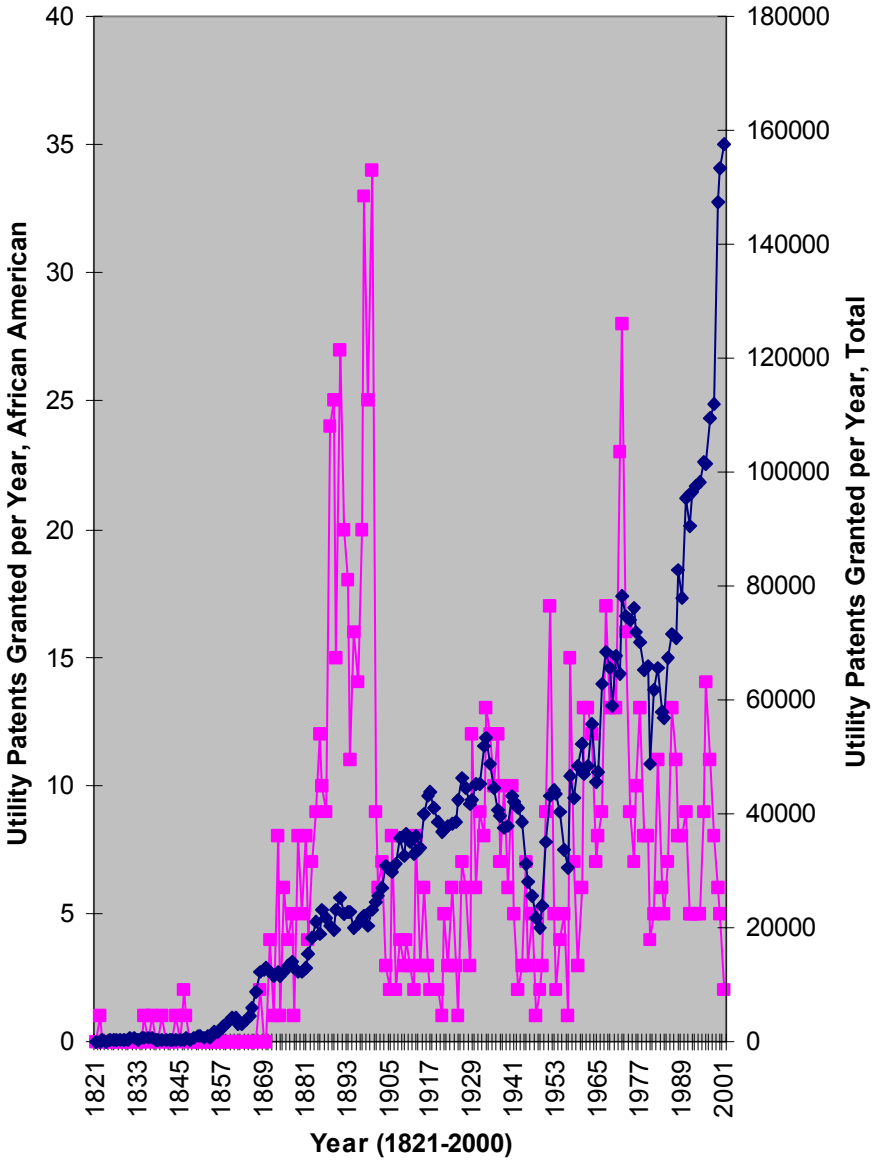

Table 2. Descriptive Statistics, African American Patentees, 1821 to 1919

Total U.S. Utility Patents Granted, 1821-1919	*1,332,271*
Total U.S. Utility Patents Granted to African Americans	*456*
Sectoral Distribution, African American Patents (%)	
Agriculture	7.7
Construction	2.4
Transportation	32.5
Railway	16.7
Manufacturing	30.7
Communications	2.0
Domestic	24.8
Geographic Distribution, Afircan American (%)	
Mid-Atlantic (NJ, NY, PA)	31.4
Mid-West (IA, IL, IN, KS, MI, MN, NE, OH)	29.8
New England (CT, MA, ME, RI)	9.4
South (AL, DC, FL, GA, KY, LA, MD, MO, MS, NC, SC, TN, TX, VA, WV)	26.5
West (CA, MT, NM, WA)	2.4
Non-U.S. (Canada, Haiti)	0.4
Average Patents/Patentee, African American	1.9
Patentees with 5 or More Patents	15
Patentees with 10 or More Patents	5
Patentees with 20 or More Patents	2

Source: www.uspto.gov; Cook patent database; author's calculations
Note: African Americans constitute 12.6 percent of the U.S. population on average during the period 1850-1920. In 1890, the geographic distribution of the African American population was as follows: Mid-Atlantic, 3%; Mid-West, 6%; New England, 1%; South, 90%; West, 0.4%; (Census Bureau Working Paper Series #56, http://www.census.gov/population/www/documentation/twps0056.html)
Mechanical home appliances are included in domestic; electrical home appliances, manufacturing. Mining patents are included in manufacturing. Total patents granted to patentees with five or more patents are reported. All but six patentees were granted all their patents before 1920.

Table 3. Patented Inventions by African Americans, Selected, 1821 to 1919

Year	Patentee	Invention	Location
1821	Thomas L. Jennings	Method of dry scouring clothes	New York, NY
1834	Henry Blair	Corn planter	Glen Ross, MD
1843	Norbert Rillieux	Improvement in sugar-works	New Orleans, LA
1867	Henry Lee	Improvements in animal traps	Oberlin,OH
1872	Elijah McCoy	Automatic lubricator cup	Ypsilanti, MI
1872	Turner Byrd, Jr.	Neck yokes for wagons, holder for reins	Williamsville,MI
1874	Edward H. Sutton	Improvement in cotton cultivators	Edenton, NC
1875	Alexander P. Ashbourne	Method of preparing coconut	Oakland, CA
1878	Benjamin H. Taylor	Improvement in rotary engine	Rosedale, MS
1880	Charles T. Christmas	Hand power attachment for sewing machine, bale band tightener	Riverton, MS
1881	Lewis H. Latimer	Carbon filaments for electric incandescent lamp	New York, NY
1883	Jan Earnst Matzeliger	Automatic method for lasting shoes	Lynn, MA
1884	Charles Lewis Mitchell	Device for aid in vocal culture	Boston, MA
1884	Judy W. Reed	Dough kneader and roller	Washington, DC
1885	Sarah E. Goode	Ironing board	Chicago, IL
1887	Alexander Miles	Elevator	Duluth, MN
1887	Enos W. Stewart	Machine for forming vehicle-seat bars	Kalamazoo, MI
1887	Granville T. Woods	Telephone system, electro-mechanical brake, railway telegraphy, polarized relay	Cincinnati,OH
1888	Frank Winn	Direct-acting steam engine	Dallas, TX
1888	William A. Johnson	Paint vehicle	Bangor, ME
1889	Daniel Johnson	Lawn mower attachment	KansasCity, MO
1890	Frank J. Farrell	Steam trap, apparatus for melting snow, valve	New York, NY
1890	Daniel McCree	Portable fire escape	Chicago,IL
1890	William B. Purvis	Paper-bag machine	Philadelphia, PA
1891	Henry Creamer	Steam water trap	New York, NY
1893	Elbert R. Robinson	Electric railway trolley	Nashville, TN
1894	George W. Murray	Fertilizer distributor, planter, cotton chopper	Sumter, SC
1895	Clatonia J. Dorticus	Machine for embossing photographs	Newton, NJ
1897	Andrew Jackson Beard	"Jenny" coupler (for train operators)	Eastlake, AL
1899	George F. Grant	Tapered golf tee	Boston, MA
1900	Eugene Burkins	Breech-loading cannon	Chicago, IL
1907	Clara C. Frye	Timing device	Tampa, FL
1910	Ned E. Barnes	Indicator or bulletin	Willis, TX
1913	David Baker	Railway signal appartus	Los Angeles, CA
1912	Oscar Robert Cassell	Flying machines	New York, NY
1914	Garrett A. Morgan	Gas mask	Cleveland, OH
1915	Samuel J. Hines	Life preserver	Plaquemine, LA
1916	Madeleine Turner	Fruit press	Oakland, CA
1918	Clarence Gregg	Machine gun	Pitt Bridge, TX

Source: Cook patent data (see text)

Table 4. First African Americans to Obtain Ph.D.'s in Selected Scientific Disciplines

Discipline	Ph.D. Recipient	Granting Institution	Year	Patents
Agronomy	Major Franklin Spaulding	Massachusetts State College	1935	0
Anatomy	Roscoe Lewis McKinney	University of Chicago	1930	0
Astronomy	Harvey Washington Banks	Georgetown University	1961	0
Bacteriology	Fredrick Douglass Patterson	Cornell University	1932	0
Bacteriology	Hildrus Augustus Poindexter	Columbia University	1932	0
Botany	Thomas Wyatt Turner	Cornell University	1921	0
Chemistry	St. Elmo Brady	University of Illinois	1916	0
Dairy Technology	Emmett Bassett	Ohio State University	1956	0
Embryology	Samuel Milton Nabrit	Brown University	1932	0
Engineering, Chemical	Harry James Green, Jr.	Ohio State University	1943	6
Engineering, Civil	George Maceo Jones	University of Michigan	1934	7
Engineering, Electrical	Percy A. Pierre	Johns Hopkins University	1967	0
Entomology	Charles Henry Turner	University of Chicago	1907	0
Geology	Marguerite Thomas Williams	Catholic University	1942	0
Mathematics	Elbert Frank Cox	Cornell University	1925	0
Metallurgy	Frank Alphonso Crossley	Illinois Institute of Technology	1950	6
Meteorlogy	Charles Edward Anderson	MIT	1960	0
Nutrition	Flemmie Pansy Kittrell	Cornell University	1936	0
Pathology	Robert Stewart Jason	University of Chicago	1932	0
Pharmacology	Arnold Hamilton Maloney	University of Wisconsin	1931	0
Physics	Edward Alexander Bouchet	Yale University	1876	0
Physiology	Julian Herman Lewis	University of Chicago	1915	0
Psychology	Francis Cecil Sumner	Clark University (MA)	1920	0
Public Health	Paul Bertau Cornely	University of Michigan	1934	0
Zoology	Alfred Oscar Coffin	Illinois Wesleyan University	1889	0

Source: Charles Drew, "Negro Scholars in Scientific Research," *Journal of Negro History* , Volume 35, Issue 2 (Apr., 1950), 135-149. Caldwell Titcomb, "The Earliest Ph.D. Awards to Blacks in the Natural Sciences," *Journal of Blacks in Higher Education* , Volume 0, No. 15 (Spring 1997), pp. 92-97; European Patent Office; Mitchell C. Brown, http://www.princeton.edu/~mcbrown/display/first_phds.html
Note: Degrees granted in U.S. only. George Maceo Jones likely has 7 patents, according to the preliminary matching exercise.

Table 5. Estimation Strategies

Dependent Variable	Principal Regressors	Expected Sign	Data Sources
(1) Presence of a patent, Pi, Pik, Pia, Pis	Physical property, collateral	+	Census, 1930 and before; bio
	Race-related violence (riots, lynchings) in area	-	Tuskegee University, Ida B. Wells, general
	Financing	+	Freedman's Bank; Census, 1930 and before; bio
(2) Number of Patents, Pi, Pik, Pia, Pis	Education level	0, +	Card and Kruger (1993); Census, 1930 and before; bio
	Education quality	0, +	Card and Kruger (1993); Census, 1930 and before; bio
	Occupation, previous occupation	+	Census, 1930 and before; bio
	Weighted index of (black to total employment)* share patents in given industry)	+', -	Census, 1930 and before
	Wage (measure of other opportunities)	+	Census, 1930 and before; bio; Historical Statistics
	Segregation status of occupation (law, custom)	0, -	BLS (?)
	Access to R&D resources	+	Assignment data, Census, 1930 and before; bio
	Patent intermediary (location of firm; likely ethicity)	+	USPTO, EPO
	Location (North, South; New England, New York; metro area)	+', -	USPTO, EPO; Census, 1930 and before
	Migration status	-	Census, 1930 and before; bio
	Discriminatory laws (restrictions on labor market, general)	-	State records
(3) Changes in patent count, pt, pkt	Mean land holdings	+	W.E.B. DuBois; Census, 1930 and before, state records
	Total riots, lynchings	-	Tuskegee University, Ida B. Wells, general
	Density of financial intermediaries serving blacks	+	State records
	Mean education level	0, +	Card and Kruger (1993); Census, 1930 and before; bio
	Mean education quality	0, +	Card and Kruger (1993); Census, 1930 and before; bio
	Per capita or student spending on schooling	+	Freedman's Bureau, state records
	Weighted index of (black to total employment)* share patents in average patent-intensive industry)	+', -	Census, 1930 and before
	Mean wage	+	Historical Statistics
	Year (segration high, low)	0, -	BLS (?)
	Density of patent intermediaries by state	+	USPTO
	Location (North, South; New England, New York; metro area)	+', -	General

Note: Pi denotes at least one patent granted to individual i; Pik denotes at least one patent granted individual i in technological field k; Pia denotes at least one patent granted to individual i that is wholly or partly assighed at date of patent grant; Pis denotes at least one single-inventor patent granted individual i; pt denotes change in number of patents granted in year t; pkt denotes change in number of patents in technological field k in year t.