The Electricity Revolution and the Stock Market: 1885 - 1928

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1 Project Description

It is widely believed that the U.S. economy is going through a technological transformation the scope of which we have not seen since the 1890-1930 period, when the nation switched from steam-powered to electrically-powered (and, to a lesser extent, diesel-powered) equipment. This paper examines the nature of technological change and its impact on the economy in this earlier period. To do this, we use an untapped source of information, namely the stock-market values of individual ¯rms from 1885 to 1928. David (1991) has already compared this era to the ongoing computer revolution and we agree with most of what he has to say, but we will be able to move well beyond his analysis because it rests largely on comparisons of aggregate and sectoral output, capital input and labor input. David did not have access to detailed stock-market information, and this is one gap that we ¯ll.

Since the CRSP data extend no earlier than 1928, part of the task has been to continue our development of a new database of stock prices, par values and capitalizations for the 1885-1928 period. The database currently includes all equities traded on the New York Stock Exchange (NYSE), and will also include prices of stocks traded on New York's Consolidated and Curb Exchanges. The latter exchange was \the NASDAQ of the electricity era" and was, hence, a vehicle for bringing new industrial ¯rms to the IPO stage { ¯rms that later would readily adopt electricity. This unique ¯rm-level information has until now been unavailable in electronic format.

Our paper analyzes this information and draws its implications for the development of the U.S. economy today. Jovanovic's earlier work with Greenwood and Hobijn indicates that the stock market can tell us a lot about events on the real side of the economy and that, in particular, the stock market's trough in the late 1970's and subsequent rise re°ect to some extent the information technology (IT) revolution. Certainly, the recent rise in stock prices has been highest in those sectors where IT investment was heaviest in the last twenty-¯ve years. In the early 1970's, however, it was in those very sectors that the stock market values of incumbent ¯rms fell the most, apparently because they could not adopt the new technology as easily as new entrants could. Moreover, it has been the IT-intensive sectors (and services especially) where IPO's have added the most value to the stock market, with new entrants playing an even bigger role in the recent stock-market rise of those sectors. The argument goes on to say that the takeovers of the early 1980's (and the greater prospect of takeover action later) forced the large firms into reorganizing – so much so that large firms have, since then, outperformed the smaller firms on the stock market.

1.1 The S&P 500 index: Then and now

Interpreting the stock market in light of an unique postwar event – a technological revolution – would be easier if similar events from other epochs can be called upon to provide independent evidence on the hypotheses being advanced. We shall ask if the electrification era corroborates the story. Corroboration does not imply that the time paths of the major stock-price indices behaved in roughly the same way as the two technological revolutions unfolded. If important differences between the two technologies exist, they should have caused a discrepancy in the responses of stock prices, as well as in patterns of firm entry and exit. Indeed, one would hope that it is these very differences that may render the current IT-driven rise in the stock market sustainable despite the fact that the rise of the late 1920's, which was at least partially fueled by electrification, ended in overvaluation and the great crash!

How similar were the two epochs? Aggregate indices shed some light on this question. The solid line in Figure 1 is the S&P index since 1878, deflated by the CPI. The dashed line is the hindsight-endowed value of actual dividends paid and the 1996 value of the index.[1] A casual look reveals striking parallels between the run-up of stock prices since 1985 and the years preceding the crash of 1929. There is, however, a major difference in that the current rise began when IT investment was well under way, but by no means over. In fact, even though the share of IT in total equipment investment was already about twenty percent by 1985, the computerization of the workplace remains incomplete to this day. On the other hand, the stock-market rise of the 1920's took place towards the end of the electrification era – by then, U.S. firms were just about done replacing their steam-powered equipment with electrically-powered machines. Nor does the first run-up in stock prices at the end of the 19th century provide an exact parallel to the rise in stock prices that we have witnessed since 1985. In particular, the rise in the stock market that accompanied the first important commercial applications of electricity around 1893 happened before

[1] That is,

$$P_t^* = \sum_{s=t}^{1996} \beta^{s-t} D_s + \beta^{1996-t} P_{1996},$$

where $\beta = 0.96$. Our choice of a 4% discount rate and assumption of no real-interest rate variation do not affect the substance of the conclusions.

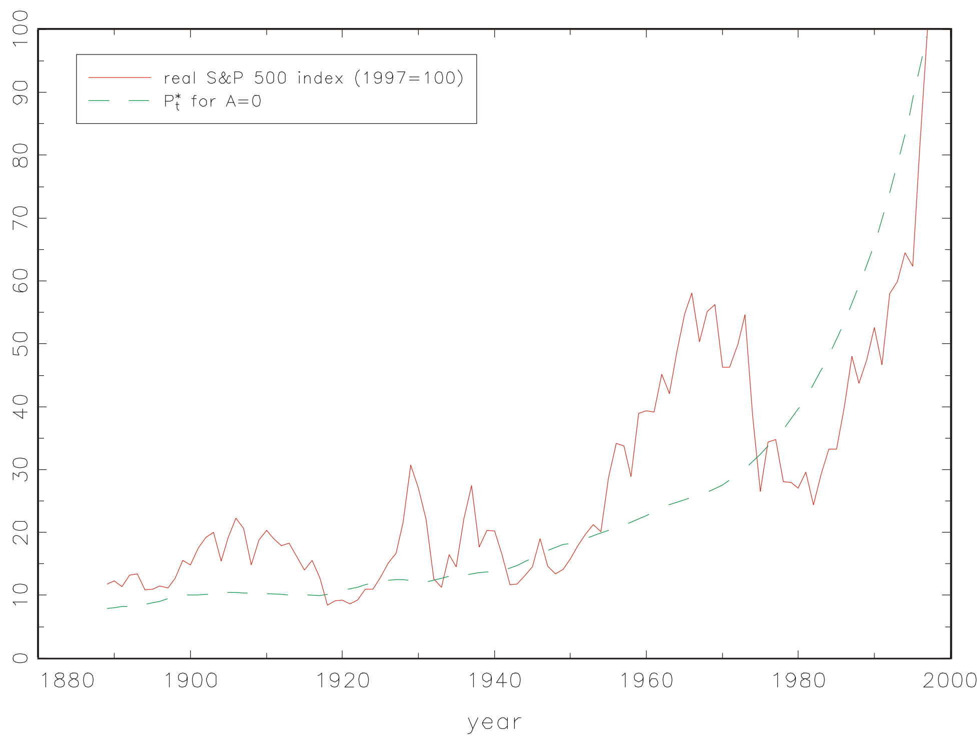

Figure 1: The S&P index and the \Perfect Foresight Price" $P_t^{¤}$

investments in electri¯cation were in full swing. Nevertheless, of the two upswings, the one of the mid-to-late 1890's appears to match more closely what is going on today.

We also observe a ten-fold increase in annual trading activity between 1896 and 1901 that coincided with the ¯rst merger wave. This is paralleled by the more recent wave of mergers and acquisitions starting in the early 1980's. What motivated the mergers? Was it, as Gort (1969) would argue, a rise in uncertainty and a greater dispersion of valuations caused by major technological change? Or was it a need to weed out ine±cient ¯rms and re-organize them? Did performance then improve with the entry of new ¯rms and the adoption of electricity by surviving older ¯rms? Certainly, the stock-market's rise accelerated when widespread networks for electricity distribution came on-line in the early 1920's. On the face of it, the aggregate index during electri¯cation shows a striking parallel with the S&P over the past forty years, with growth in the 1960's, a decline in the 1970's, a merger wave in the early 1980's, and a gradually accelerating rise thereafter. But the run-up of the 1920's was brief { about seven years { compared to the run-up that started in 1983 and that, as this paper is being written, still continues. Why the di®erence in these patterns? To answer questions like these we will use more detailed data.

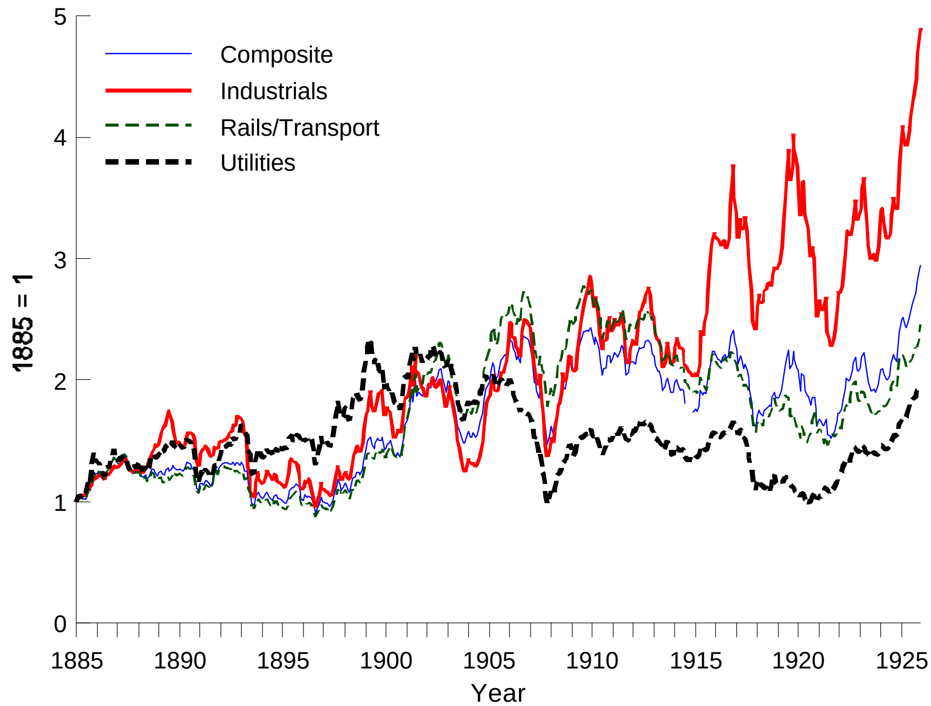

Figure 2: Sectoral Stock Price Indexes, 1885-1925. Source: Cowles et al. (1939).

1.2 Sectoral Stock Performance, 1885 - 1928: How did the heavy electricity-using sectors fare?

The sectoral sources of index growth show the following parallel between the electri-¯cation and IT revolutions: Sectors that used the new technology most intensively recorded, in both eras, the largest initial drop and the most dramatic subsequent recovery. Figure 2 presents monthly price indices from Cowles et al (1939) for the composite and the industrial, railroad/transport, and utility sectors from 1885 until 1925. The industrial sector made the most extensive use of electricity in the earlier decades and declined sharply in the mid-1890's only to recover slowly in the midst of mergers and the subsequent slow adoption of direct drive systems. It is only after 1915, when secondary motors began to receive widespread usage, that industrials took o® to outperform both the composite and rails. This is broadly similar to the recent and more compressed pattern of decline, merger, and gradual acceleration in IT-intensive industries since 1985, except that the IT-intensive industries are the service industries, not manufacturing.

Located to a large extent in New England factory towns, textile ¯rms readily adapted to new technology by using an electric motor rather than steam to drive the shafts which powered looms, spinning machines and other equipment (see Devine

1983). This early (though partial) adoption of electricity corresponds to a rise in the Cowles index for textile ¯rms (not shown here) that preceded the rise for the industrial sector generally. The rise in the industrials index was probably delayed by lags in the distribution of the new power, lags that made it more costly to fully electrify a new industrial plant, and by the investments that many industrial ¯rms had made in obsolete production techniques. Overall, the period of decline associated with electri¯cation was considerably longer than that experienced after IT emerged, probably because electricity took longer to spread than the computer has.

1.3 Individual ¯rm valuations 1885 - 1928

We study the evolution of listings, overall market value, and price performance of traded ¯rms as electrical technologies gained widespread use, focusing on subsets of the market as de¯ned by ¯rm size and sector. Since the NYSE was the leading exchange for the trading of national securities throughout the period of our study, we ¯rst examine activity on this exchange. Just as any study of IT must consider the rise of trading in technology stocks on NASDAQ, however, our analysis must examine, to the degree possible, activity on the New York Curb Market, where smaller industrials traded actively throughout the sample period.

Our continuing challenge of collecting price and capitalization observations for individual ¯rms that traded in the half century preceding the 1929 crash has not been seriously taken up since the 1930s, when the Cowles Commission built price indices for NYSE stocks from 1871. Since this was well before electronic data storage became possible, we return to the original source of the Cowles data, The Commercial and Financial Chronicle, to recover annual prices and par values for NYSE-listed ¯rms. Since The Chronicle does not include the book capitalizations of individual ¯rms, we collect these from three other sources: Bradstreet's for 1885-1896, The New York Times for 1897-1911, and The Annalist for 1912-1928. These additional sources make it possible to ¯ll in many price observations that are missing from The Chronicle. By combining book capitalizations with par values and prices, a view of the market values of various sectors and aggregates will emerge.

Since Rousseau, both alone and with Atack, has identi¯ed New England as the nation's premier market in industrials until about 1900 and as a central player in its continued industrialization thereafter, we also examine the sustained development of the industrial market in Boston. Since, as mentioned above, the Cowles study suggests a modest advance in the prices of textile ¯rms during the early phases of electri¯cation, we might also expect to see New England's industrials maintain their market values prior to 1915 in a way that the NYSE ¯rms could not. Data on prices, capitals, and par values for individual New England ¯rms (including plants in the burgeoning Fall River, MA) are available from the worksheets of contemporary Boston brokers Joseph Martin and, later, Frank A. Ruggles.

We now summarize some of the data that we have collected so far for the NYSE

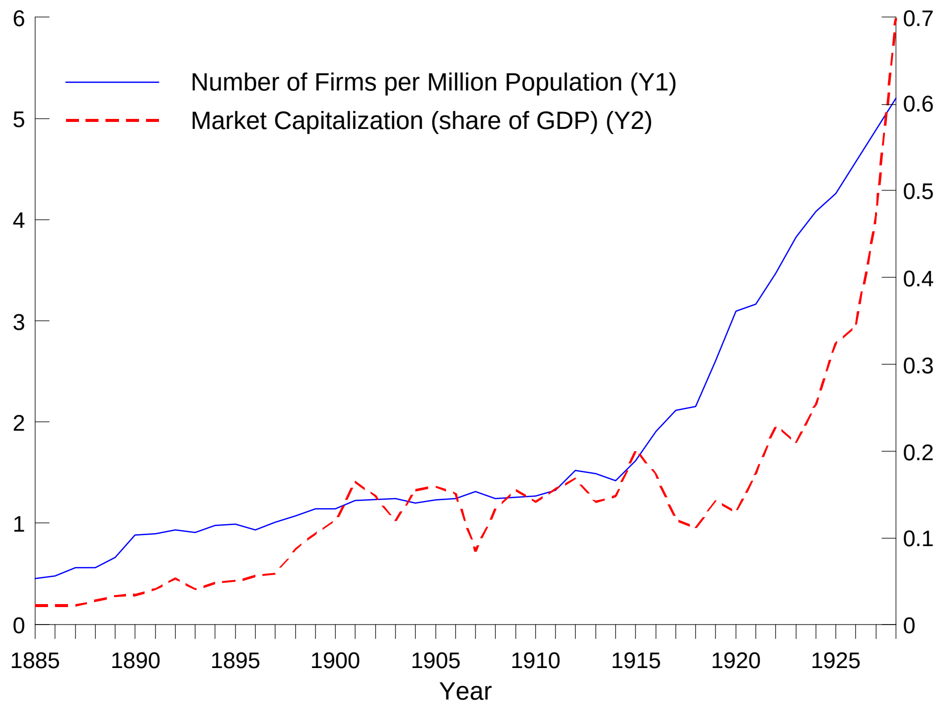

Figure 3: Number and Market Capitalization of Non-Railroad Firms Listed on the NYSE, 1885-1928. Sources: The Annalist, Bradstreet's, The Commercial and Financial Chronicle, and The New York Times various issues.

with respect to market size and ¯rm survival, and relate the patterns that arise to electri¯cation.

Figure 3 plots the number of non-railroad ¯rms that listed stock on the NYSE per million of population between 1885 and 1920, as well as their aggregate market value as a percent of GDP (population and GDP ¯gures are taken from Friedman and Schwartz, 1982). Consistent with a delay in the adoption of electricity, the market capitalization ¯gures rise prior to 1902, only to wander trendlessly for another ¯fteen years. The number of non-rail listings rises only very gradually before 1915. Nelson (1959) attributes the °atter appearance of total NYSE listings in the decade surrounding the turn of the century to the o®setting e®ects of new industrial entries and the exit of many industrials and rails via merger. Our ¯gures support at least the ¯rst part of this interpretation, with both series rising sharply around 1915 and at the same time that price performance in the industrial sector signi¯cantly improves.

1.3.1 The role of the small firm in electrification

Early on, the IT revolution was led by small firms, many of which have since grown into large ones. Was this also true of electrification? In asking this, we should remember that one hundred years ago, the financial playing field favored the large, established firm much more than it does today. The rise of smaller firms later on may have been due partly to changes in the law (such as the Sherman antitrust act of 1890 and the transparency forced on the market by the Securities Act of 1933) but it probably stemmed much more from a profound and gradual change in the technology and in the growth of expertise with which business is financed. The capital market was not nearly as deep even in the 1920's as it is today — some 50 percent of Americans own stock today, whereas only three or four percent owned stocks in the 1920's, and even less in the 1890's. Moreover, Wall Street's financial expertise was concentrated in a few large banks. The market was thus less well prepared to float shares of smaller firms, and the big bankers of the era as a rule shied away from new issues by unknown companies.

Navin and Sears (1955), for example, discuss the formation of the industrial market in New York around the turn of the century, and find that only large firms and combines were usually able to capture the attention of the nation's early financiers. Nelson (1959) notes that only 19.6 percent of all consolidations during the first merger wave traded on the NYSE sometime in the next three years. In addition, between 1897 and 1907 the total value of cash issues to the general public ($392 million) was only 11.6 percent of the value of securities that were exchanged for the assets and securities of other companies. It appears, then, that the small company had a harder time a century ago. Other, less direct evidence, suggests this too. New products are often created by new companies, and Agarwal and Gort (1999) give evidence that a new product diffuses through the economy much faster today than it would have one hundred years ago, leading us to expect a more protracted playing out of events in the electricity era. And Gates (1999, p. 118) provides evidence that computers are penetrating the household sector faster than electricity did — not least because computer prices have declined at a much faster rate since 1970 than electricity prices did after 1890. As size-related barriers to public listing were more formidable for small firms at the turn of the century than they are today, it is likely that entrants could replace the missing market capital only at a much later stage of electricity's adoption.

Our data will allow us to calculate the relative contributions of stock-market entrants (i.e., IPOs) in terms of value. For now, however, our preliminary calculations suggest that it was not until about 1920 that new entrants and surviving firms of slightly older vintages succeeded in replacing the market's capital. Figure 4, for example, shows that entry started to dominate exit only after 1915. In addition, when entry began to surge in the early 1920s, exits increased sharply, suggesting that the new technology brought with it a rise in both the flow of new ideas and the rate

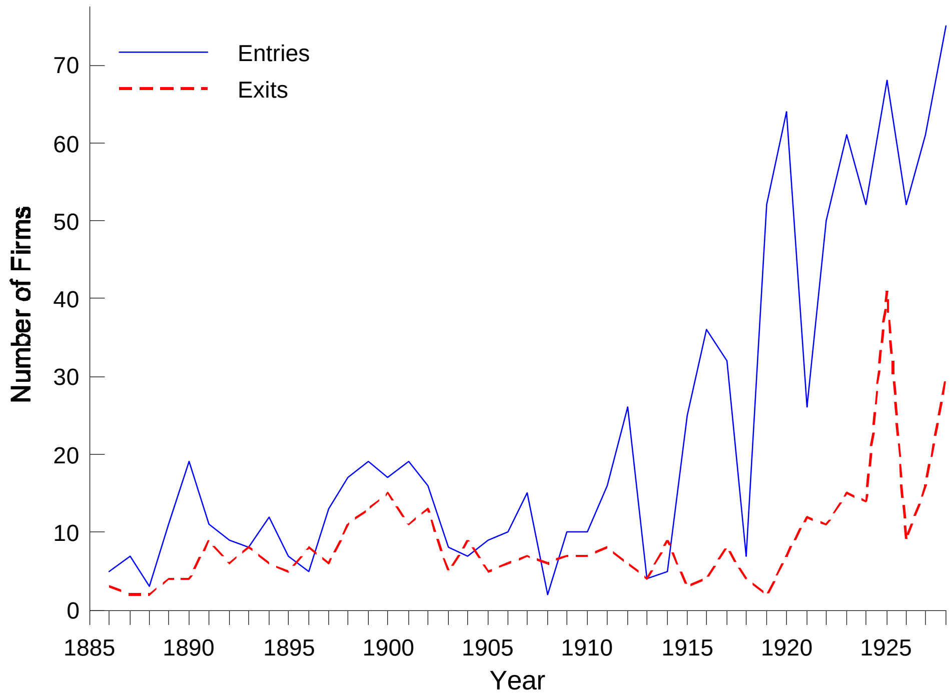

Figure 4: Number of Annual Entries and Exits of Non-Railroad Firms from the NYSE, 1885-1928. Source: The Commercial and Financial Chronicle, various issues.

of firm replacement.

Figure 5 shows the share of market capitalization held over time by those non-railroad firms (incumbents) that were listed on the NYSE at five-year benchmarks. The striking feature is that the shares of all incumbent vintages prior to 1915, and particularly those of the earliest vintages, were unable to maintain market share as electrical technologies diffused. Even more importantly, the patterns in Figure 5 indicate that new entrants attempted to replace the missing capital between 1905 and 1915, but were not very successful in doing so.

Our data also show that the small firm had a more difficult time early on in the era of electrification. In particular, Table 1 presents the five-year survival rates of non-railroad firms that entered the NYSE listings in each five-year segment from 1885 to 1920, as well as from 1921 to 1923.

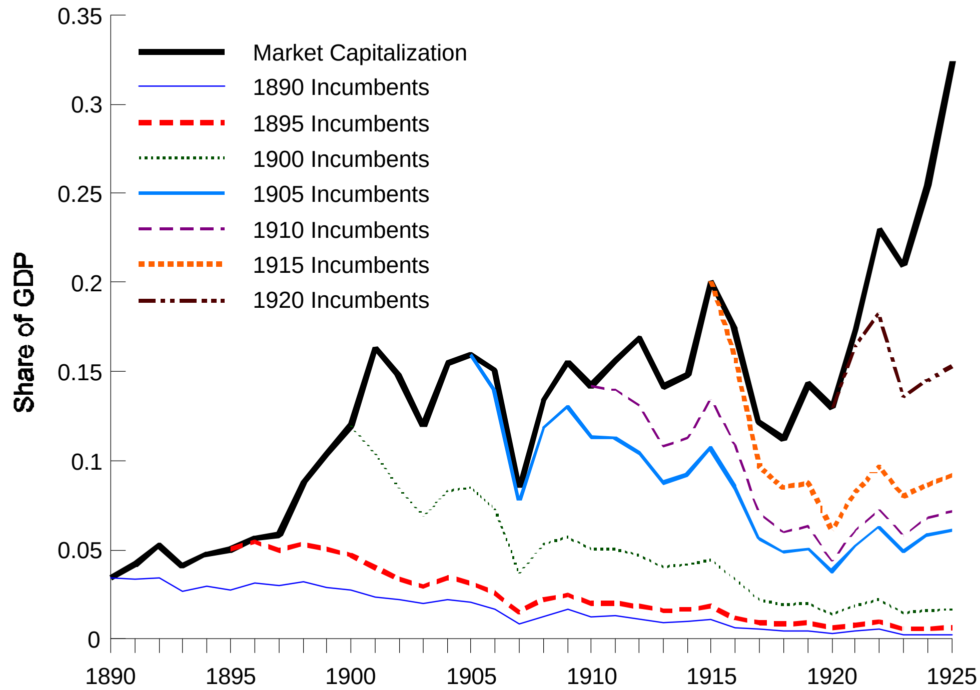

Figure 5: Shares of Five-year Cohorts of Non-Railroad Firms in NYSE Market Capitalization, 1890-1925. Sources: The Annalist, Bradstreet's, The Commercial and Financial Chronicle, and The New York Times, various issues.

Table 1: Five year survival rates of entrants (percent)

1886-1890	51.1
1891-1895	46.8
1896-1900	43.7
1901-1905	64.4
1906-1910	68.1
1911-1915	88.2
1916-1920	85.8
1921-1923	83.2

The early decades of the sample were clearly not good ones for stock market entrants, with ¯ve-year survival rates beginning to exceed 75 percent only with the 1911-1915 entrants. This suggests that if small and innovative new ¯rms did adopt the technology in the early years of the electrical revolution, they were either not very successful or not well represented on the NYSE.

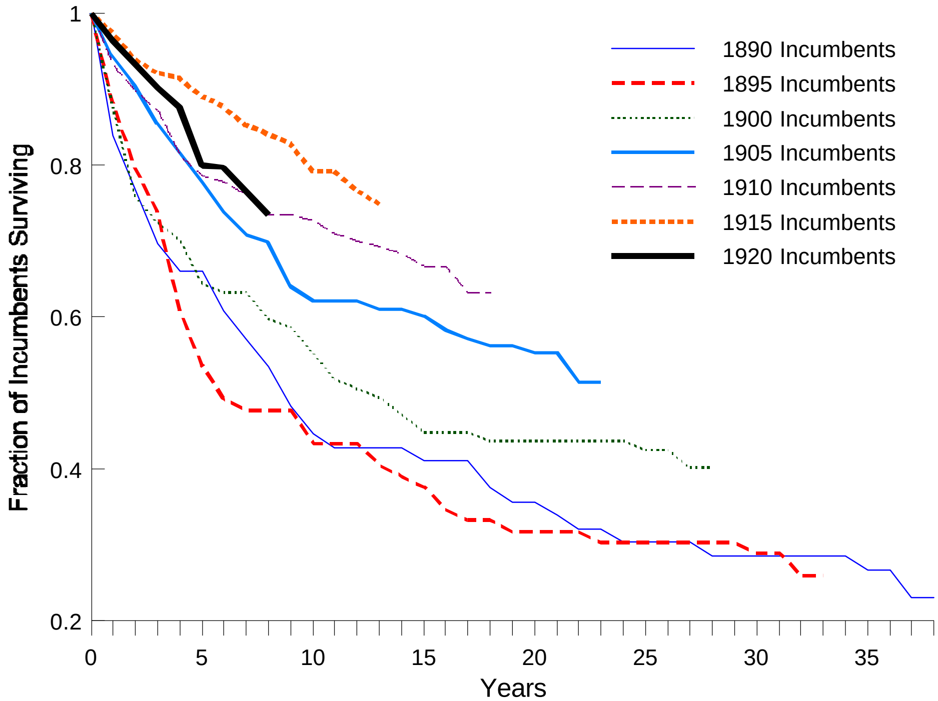

Figure 6: Fractions of Incumbents of Five-Year Vintages Surviving in Subsequent Years. Source: The Commercial and Financial Chronicle, various issues.

1.3.2 The survival of the large ¯rm: Was the 1899-1900 merger wave a disciplining device?

The IT revolution was bad news for the stock-market incumbents of the early 1970's. Was the same thing true at the dawn of the electri¯cation era? Again, one has to note some structural di®erences between then and now. We noted that the ¯nancial system had made it harder for a small ¯rm to enter using a costly new technology. A reduced threat of entry made it easier for ine±cient incumbent ¯rms to survive and easier for them to resist the new electricity-based technology. Directly and indirectly, then, the barrier to entry slowed down the di®usion of electrical technology, and this is one reason why electricity spread more slowly than the computer is spreading today.

Not having to worry about entrants, an ine±cient incumbent ¯rm would, however, still have faced the threat of takeover. This may be one explanation for the turn-of-the-century merger wave. Our ¯rm-level data will show if the merged ¯rms improved their performance or not. The aggregate data suggest that the turn-of-the-century merger wave was less successful than the wave of the 1980's which was followed by a strong recovery in the relative stock-market performance of large ¯rms. Did the market decline over the ¯rst two decades of the century because (as the experience

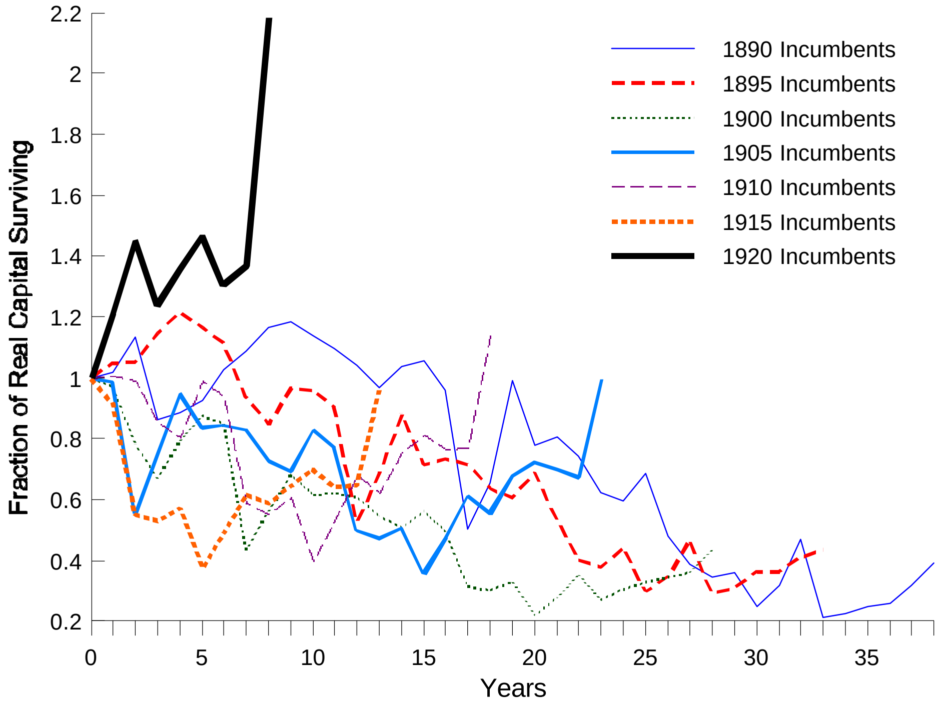

Figure 7: Fractions of Real Market Capitalization Retained by Incumbents of Five-Year Vintages in Subsequent Years. Sources: The Annalist, Bradstreet's, The Commercial and Financial Chronicle, and The New York Times various issues.

of the early 1970's suggests) older ¯rms were slow to adopt the new technology? If this was indeed the reason for the decline, the mergers that occurred around 1900 probably failed as a disciplining device.

Figure 6 presents the fractions of non-railroad NYSE incumbents of ¯ve-year vintages from 1890 to 1920 that retained their listing status in subsequent years. Here, the improved survival rates of new entrants after 1910 were clearly not accompanied by widespread improvements in the survival of ¯rms in the market as a whole. In fact, while the incumbents of 1905, 1910, and 1915 fared better than those of previous vintages, the 1910 incumbents had a lower survival rate than 1905 incumbents! The weak performance of incumbents between 1895 and 1910 is further re°ected in Figure 7, which presents the fraction of real (i.e., IPD adjusted) market value retained by ¯rms of each vintage. Here only the 1920 incumbents see their market capitalizations rise consistently, although the 1905, 1910 and 1915 incumbents begin to recover some of their deteriorating market values after 1920 as well. Figure 8 shows the shares of total non-rail market capitalization retained by the same incumbents. The sharp declines in these shares to some extent re°ect the growth of this market via entry,

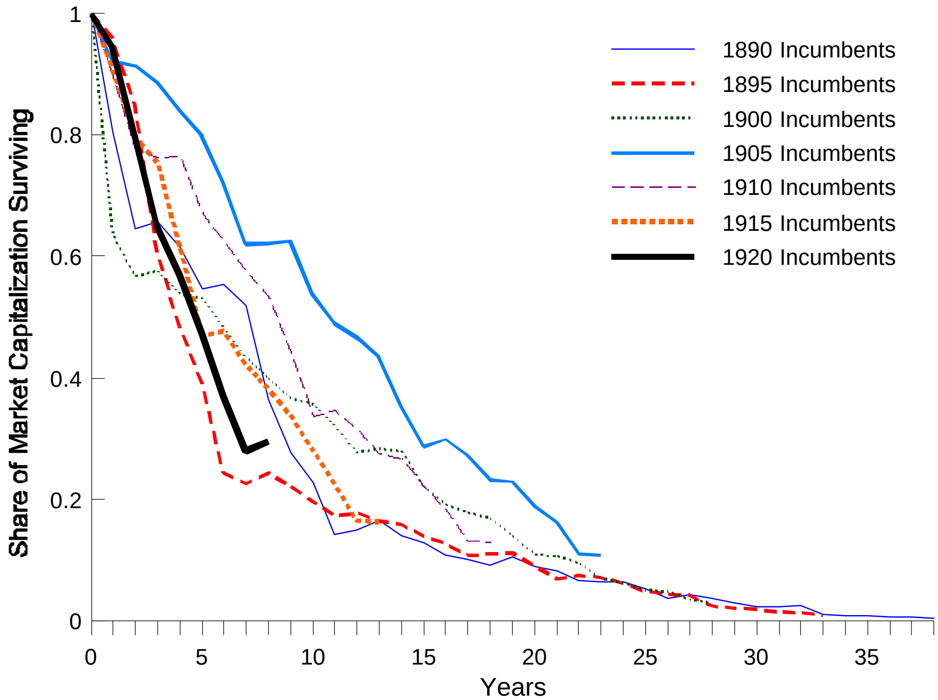

Figure 8: Shares of Total Market Capitalization Retained by Incumbents of Five-Year Vintages in Subsequent Years. Sources: The Annalist, Bradstreet's, The Commercial and Financial Chronicle, and The New York Times various issues.

especially after 1915, but also suggest that the rise of the 1920's can be attributed largely to ¯rms that entered after 1920.

Interpreting the plots in Figures 6, 7, and 8 requires some care because the speed with which the incumbent loses stock-market share depends not just on how e±cient he is compared to the entrant, but also on how hard it is for the entrant to have his IPO on the stock market. IPOs became easier during the electri¯cation era and, indeed, they have been getting easier since (and to a large extent because of) the advent of the computer. At the very least, however, the preliminary evidence leaves open the possibility that the ¯rst merger wave, which was necessary to improve ¯rm e±ciency as electri¯cation took hold, was an inadequate policing device because it took the market the better part of two more decades to remove the underperformers. The \discipline" hypothesis holds that mergers take place in order that the targets will reorganize. Since Nelson shows that the majority of mergers involved food and kindred products, chemicals, petroleum products and primary metals, which would have involved increasing electri¯cation, the merger movement seems to have failed as an attempt to impose this discipline on those sectors. More generally, we will study how the merger movement may have a®ected the spread of electricity.

1.3.3 Was electri¯cation less skill-biased than IT?

Today's computer user must be able to read and write. Not so for an operator of a newly electri¯ed machine in 1900. Whatever barriers there were early on to the adoption of electricity probably had more to do with management than with the workforce. Moreover, at the dawn of the electricity era, the potential bene¯ts of electri¯cation should have been more transparent to managers of ¯rms than the bene¯ts of information technology were to managers in the early 1970's. It is also likely that the conversion of certain types of equipment simply meant replacing steam-powered shafts and belts with an electric connection to an otherwise similar machine. Even the assembly line technology that was introduced in the early part of the twentieth century was compatible with steam-powered drive from a single main source in the factory. If this were all there was to the electri¯cation process, then one would not call the technology skill-biased for the worker, and only moderately so for management. Resistance on the part of established interests would then be weaker than it apparently was for the IT revolution.

However, electri¯cation o®ered the potential for important changes in the organization of work. It enabled the use of smaller hand-held equipment like powered drills, and machinery became easily movable. Moreover, it enlarged the range of products that could be invented, making routinized research more pro¯table { the mode of competition shifted more towards product innovation. As all homes became electri¯ed, a whole range of electrically-powered consumer products was developed. To survive, ¯rms had to focus more on product development. The role of skill in new product introduction is one reason why the return to skill was as high early in the century as it is today (Goldin and Katz 1999). Another reason, of course, is that the U.S. labor force had relatively few skilled people a hundred years ago.

1.4 Theory

Consensus is still forming on \the" right way to study the e®ects of major technological change. Three well-known vintage-capital growth models { Atkeson and Kehoe (1997), Greenwood and Yorukoglu (1997), and Hornstein and Krusell (1996) { imply that the value of old capital changes when a new technology arrives. In these models, two things prevent a ¯rm from switching to the better technology immediately. First, the ¯rm's old capital has been paid for whereas the new capital hasn't. Second, output is lower while the ¯rm learns to use the new technology. Another model that we can use is that of Helpman and Trajtenberg (1998) in which ¯rms, though they do not use physical capital, still choose not to adopt the new technology until the research sector has come up with complementary inventions. The model of Parente (1994) has only human capital, and a delay in adoption arises because of learning costs. These models share the property that the economy su®ers an upheaval and productivity loss following the arrival of good news and following the adoption of a better technology.

Another class of models explains the upheavals with bad news. Boldrin and Levine (1999) and Zeira (1999) stress that a market crash occurs when agents get bad news about the growth-prospects of the incumbent technology. In the model of Jovanovic and Rob (1990), bad news about the incumbent technology prompts search for a new one and, as in the Boldrin-Levine model, precedes a technological switch. These three models predict that we should see upheavals after getting the bad news that the existing technology has \played itself out."

These are all theories about the lifetime of capital and how the value of that capital depends on technological shocks. They are not models of the life-cycle of ¯rms. The stock-market data suggest, however, that old ¯rms are wedded to old technologies and that new technology is brought in largely by new ¯rms, especially at the outset. The data also suggest that the established ¯rm's resistance to technological change exceeds the inertia that its technology-speci¯c investments alone would induce. Well-known examples from the early microcomputer era indicate that an employee who gets a major new productive idea will want to leave his employer and develop that idea on his own, probably because his employer would otherwise grab too large a share of the rents from that idea. This suggests that we should look at models of the life-cycle of not just technologies, but also of ¯rms or organizations.

2 Conclusion

The technological transformation { some call it the third industrial revolution { that we are now undergoing will be easier to understand and its remaining course will be easier to predict if we can draw the appropriate parallels between the previous two revolutions and the current one. We are gathering a wealth of stock market data on the general-purpose technology { electricity { that provided the spark for the second industrial revolution. The preliminary results that are summarized in this proposal suggest some interesting parallels between the IT and the electri¯cation eras, and we look forward to learning more as we delve more deeply into the data.

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