Stock Market Swings and the

Value of Innovation, 1908-1929

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Introduction

A recurrent theme in the modern literature on the economics of financial markets is the extent to which stock market swings reflect changes in the present discounted value of expected future earnings or the ‘animal spirits’ of investors. For example, the rapid acceleration in stock prices during the 1990s can be explained both by changes in expected investor payoffs in response to the accumulation of intangible capital by firms (*e.g.*, Hall, 2001), and by behavioral phenomenon that caused a speculative bubble (*e.g.*, Shiller, 2001). Whether swings in the stock market are driven by the diffusion of new technologies or by periods of irrational exuberance is an important question in the economics of innovation and finance.

While this question is central to the debate over the causes of the recent stock market boom and bust it is also important to a fuller understanding of another major event in the American stock market – the run-up in equity prices during the 1920s and the Great Crash of 1929. While Irving Fisher famously reported on the eve of the Crash that stock prices would remain permanently higher than in past years due to the arrival of new technologies and advances in managerial organization that created positive expectations about future profits and dividend growth, retrospective analysis has indicated the presence of a ‘bubble’ (DeLong and Shleifer, 1991; Rappoport and White 1993, 1994). The speculative bubble hypothesis has become orthodox in the literature given that the S&P

Composite Index fell by more than 80 percent from its September 1929 peak to its level in June 1932. The Great Crash is the canonical example in American financial history of market prices diverging significantly from fundamentals.

Despite the conventional wisdom that stock market prices were unrealistically high during the 1920s, we know little about the types of assets that investors are said to have been overvaluing. In particular, evidence on the relationship between innovation and the stock market is sparse. How rapid was the growth of intangible capital during this period? Did the stock market encourage investment in innovation? Did a technological revolution lead to higher stock market valuations? This article attempts to answer these questions using a rich dataset of balance sheets, stock prices and patent citations for 121 publicly traded corporations between 1908 and 1929. The aim is to determine whether movements in stock prices can be correlated with the intangible assets of firms, and why it matters whether markets in the 1920s got valuations right.

The new data leads to at least two advances over the current literature. First, it introduces a robust measure of intangible capital based on the patenting activity of firms during the 1920s. Although patents are a noisy measure of innovation, citations to patents in the current data set in patent grants between 1976 and 2002 significantly enhance the signal-to-noise ratio. Aside from McGratten and Prescott (2005) who present estimates of intangible capital for U.S. corporations during the 1920s, there is no systematic data on the intangible capital of firms for this period. Moreover, McGratten and Prescott are only able to measure intangibles indirectly using equilibrium relations from a growth model. In this study, patents and their citations capture intangibles directly at the micro-level.

Second, it is well known that the predictability of U.S. stock returns is an increasing function of time (Fama and French, 1992; De Long and Barsky, 1990), yet most studies of the stock market in 1929 concentrate on relatively short intervals, in particular the 'bubble period' from early 1928 to October 1929 (*e.g.*, Rappoport and White, 1993, 1994). With over 20 years of data prior to the Great Crash this article is able to track firm-level innovation over major swings in financial markets, and to correlate these swings with changes in investor forecasts about the value of fundamentals.

The main finding of this study is that intangible capital growth was substantial in 1920s America, investors realized it, and they integrated this information into their market pricing decisions. Between 1920 and 1929 the *United States Patent and Trademark Office* (USPTO) granted the 121 firms included in this study 19,948 patents, 4,215 of which were subsequently cited in patent grants between 1976 and 2002. Insofar as these citations represent flows of knowledge from one generation of inventors to the next, this was a major epoch of technological progress. Using historical patent citations as a proxy for the intangible capital of firms, patent market value regressions reveal that a one percent increase in the firm's stock of cited patents is associated with a 0.26 percent increase in market value during the 1920s. The returns to intangible capital were approximately three times larger during the 1920s compared to the 1910s reflecting large changes in the configuration of company assets between these decades. Moreover, as the ratio of the coefficient on intangibles to the coefficient on tangible capital is bigger for the 1920s, there appears to have been a major shift in investor psychology towards intangibles during the stock market boom. One implication of these findings is that investors were not only more responsive to intangible capital at this time, but through triggering large stock market payoffs for innovation they also encouraged its growth.

Intangible Capital and the Financing of Innovation

The finding that during the 1990s stock market run-up unmeasured intangible capital was an important element of a firm's market value (*e.g.,* Hall, 2000, 2001) makes an historical perspective on this issue appealing. Parente and Prescott (2000) have commented that, "unmeasured investment is big and could be as much as 50% of GDP". McGrattan and Prescott's (2001) calculations suggest that the growth of intangible capital may explain the postwar increase in the ratio of total market capitalization to GNP from around 0.5 in 1950 to 1.8 in the first half of 2000.

Unlike the literature on the modern period, however, intangible capital is often omitted from discussions of financial markets during the 1920s. This is a surprising omission, to the extent that intangibles are likely to be significant in stock market valuations. For example, McGratten and Prescott (2005) estimate that the stock of intangible corporate capital was at least 60 percent of the stock of tangible corporate capital in 1929. In their model, the stock market is overvalued only if the value of intangible capital is zero. With more moderate estimates of the value of intangibles they conclude that prices of stocks were too low in 1929, and therefore Irving Fisher was right!

Additional evidence supports the view that the 1920s was an extraordinary period of technological progress and intangible capital growth. Several firms formed during the great merger wave in American business (1897-1904) built up separate research and development laboratories, shifting innovation away from individual inventor-entrepreneurs and towards firms (Lamoreaux, 1985). The centralized R&D lab became a focal point for innovation, and was perhaps the most significant organizational change to influence the structure of American business in the early twentieth century. In 1921 General Electric had five labs in four different states.[1] By 1927 AT&T had more than 2,000 research staff working in a 400,000 square feet 13 story building on West Street in New York (National Research Council, 1927). Through vertical integration firms avoided some of the contracting problems associated with market-based exchange, and managerial hierarchies facilitated the coordination of resources for innovation. Mowery (1983) shows that investment in research and development was positively correlated with firm survival rates between 1921 and 1946. Scientific knowledge became increasingly exploited as firms developed larger stocks of organizational capital. Within firms, star scientists played central roles in the commercialization of basic science, though unlike their counterparts in the life sciences today few went on to start their own enterprises. Irving Langmuir spent more than four decades at General Electric, his experiments leading to the invention of the gas filled incandescent lamp and a Nobel Prize for chemistry in 1932. At Du Pont's research center during the 1920s, Wallace Carothers' investigations into the molecular structure of polymers led to the discovery of neoprene, and nylon which were commercialized in the early 1930s (Hounshell and Smith, 1988). At Eastman Kodak, Kenneth Mees and Samuel Sheppard significantly advanced the science of photography; by reducing the width of photographic film Kodak's research scientists permitted ever smaller lighter weight cameras to be introduced. The institutionalization of innovation also extended beyond the boundaries of the firm as science in universities began to influence the direction of technological change in industry (MacGarvie and Furman, 2005). Science and technology also complemented larger stocks of human capital in the economy. David (1990) reveals how falling prices for electrical capital goods after the First World War encouraged electrification of the mass production economy, which in turn increased the demand for skilled, literate, and educated labor (Goldin, 2001).

It is a reasonable *a priori* assumption that complementarities between innovation, organizational changes and human capital impacted the stock market during this epoch in much the same way as researchers have discovered they do today (Bresnahan, Brynjolfsson, and Hitt, 2002). The large early twentieth century American corporation was the principal agent of organizational and technological change according to Chandler (1990). White (1990) suggests that General Motors was attractive to investors during the 1920s because its more advanced management and organization facilitated smooth transitions from one production run to the next. Klepper and Simons (2000) show how firms with the favorable mix of innovation and complementary assets (such as marketing channels) were more likely to survive the shakeout of producers in the tire industry.

Intangible capital growth was also encouraged as markets developed to finance innovation, and investors became responsive to holding equities. According to Peach (1941) the public became more willing to hold different types of securities issued by corporations following their successful experiences with Liberty Bonds during the First World War. O'Sullivan (2004) documents a major financing role for the 1920s U.S. stock market as companies increasingly utilized external sources of finance. According to Rajan and Zingales (1998) financial development is positively correlated with the allocation of capital to areas of highest value. Nicholas (2003) shows for the 1920s that bond and stock issues by companies were positively correlated with their propensity to innovate. This finding is consistent with Schumpeter's (1942) contention that a developed and efficiently functioning capital market extends the frontier of technological progress.

Historical Balance Sheets and Patents

In order to empirically track the development of intangible capital and stock market value at the firm-level during the early twentieth century, I collate data on company financials and historical patent citations. The approach is similar to studies of the modern period which, given limited disclosures by companies concerning expenditures on intangibles, utilize indirect measures of intangible assets. For example, Bond and Cummins (2000) use R&D and advertising outflows to proxy for investment in intangibles, while Brynjolfsson, Hitt and Yang (2000) infer that computer related intangibles are substantial because the coefficient on the stock of computer capital in market value regressions is much larger than other types of productive assets.[2] Although patents are an imperfect proxy for intangible assets, when combined with historical citations statistics they provide a valuable source for tracing the dynamics of technological progress.

Company Financials

Before discussing the data on intangibles, as measured by patents and historical citations, it is helpful to describe the company financial data. The main sources on financials are *Moody's Manual of Industrials* for company balance sheets, and the *Commercial and Financial Chronicle* for end-of-year share prices. The sample includes every firm with at least four years of continuous data, giving a total of 121 firms with a time series dimension running from 1908-1929. The main period of interest is the 1920s, but data going back to 1908 illustrate long-term swings in the relationship between intangible capital and the stock market. The company financial data detail major 'Chandlerian' corporations of the time such as General Electric, E. I. Du Pont, Eastman Kodak and General Motors, as well as companies that possessed a more moderate level of assets than the set of firms studied by Chandler (1990) (See Figure 1a). While there is still a slight skew towards larger firms, by market value my data closely approximates the population of companies collated by the *Chicago Research Center in Securities Prices* (see Figure1b).

The main financial variables used in this analysis are calculated using the methodology proposed by Lindenberg and Ross (1981). The market value of the firm is measured as the product of common equity and year-end market price, plus the book value of outstanding debt and the value of preferred stock (which is assumed to be a perpetuity discounted at the average industrial bond yield reported by *Moody's*). Capital assets (k) are estimated using the recursive formula $k_t^{rc} = k_{t-1}^{rc}[(1+i)/(1+\rho)] + (k_t^{bv} - k_{t-1}^{bv})$ where i is the GNP implicit deflator, ρ is the depreciation rate at an assumed five percent and the subscripts *rc* and *bv* denote replacement value and book value respectively. Inventory is estimated at replacement cost by adjusting for inflation through the wholesale price index from *Historical Statistics of the United States: 1790-1950*. Tobin's q is then calculated as the ratio of the firm's market value to the replacement cost of its tangible assets. Descriptive statistics on these variables are given in Table 1.

Historical Patent Citations

Table 1 also includes summary data on patenting. Patent data were assembled from the USPTO and the *European Patent Office* (EPO) for each firm in the sample. Over 35,000 patent grants were assigned to the 121 firms between 1908 and 1929, with 19,948 being assigned between 1920 and 1929. Figure 2 illustrates the level of patenting activity by firm year. High frequency patenting firms like Westinghouse, which peaked at 564 patent grants in 1929 are included alongside lower frequency patenting firms like Otis Elevator, which peaked at 26 patent grants in 1928. Twenty-one firms in the sample did not patent at all.

Patent counts are commonly used to proxy for innovation, but this measure is prone to error because not all inventions are patented, and the quality of patents varies widely (Griliches, 1990). To improve the quality of the patent measure, I use citations to 1920s patents in patent grants between 1976 and 2002. The assumption is that citations distinguish the frontier of knowledge regardless of how far back in time they go. It can be argued that inventors and patent examiners habitually cite patents from the past without regard to prior art. However, if innovation is cumulative, as suggested by Scotchmer (1991), and citations come from the frontier, these references will reflect knowledge transfers between generations of inventors.

Of the 19,948 patents granted to firms between 1920 and 1929, 21 percent are cited in patents granted between 1976 and 2002. Of the 4,215 patents cited, 2,548 receive one citation while 1,667 receive two or more citations, with the maximum number of cites for a patent being 27. This is a notable number of citations given that citations fall off sharply a decade after the patent's grant date (Caballero and Jaffe, 1993). To show how large this proportion is, I collected data on 132 successful grants by the USPTO between 1910 and 1930 to the great inventor-entrepreneur Thomas Edison. Great inventors were typically entrepreneurial figures who developed important inventions in response to market demand (Khan and Sokoloff, 1993). Forty-two (31.8 percent) of Edison's patents are cited in patents granted between 1976 and 2002. Although this proportion may be inflated if patent examiners have a propensity to "cite the classics" I use Edison's patents as a benchmark for the upper tail of the patent quality distribution. This comparison suggests that the proportion of citations observed for the firms in the sample is both large and significant.

Patents as Intangibles

Recent research suggests that the 1930s was the most technologically progressive decade of the twentieth century. And the significance of productivity growth during this period may be attached to technological "larder-stocking during the 1920s and earlier, upon which measured advance built" (Field, 2003). Insofar as the patent citation data reveal that the 1920s was a major epoch of technological innovation, how far can patent rates be used to measure the stock of intangible capital in the economy?

It is important to note at the outset that this measure is imperfect. Although 21 firms in the sample did not patent, their stock of intangible capital was undoubtedly greater than zero. Innovations in food processing, for instance, are much less likely to be patented compared to innovations in machinery (Moser, 2005). Thus, companies like Coca Cola and Quaker Oats developed intangibles through branding, secrecy and distribution networks even though their intangibles are effectively put at zero for this study. Nevertheless, an insight into the significance of patents as intangible assets can be gained from the financials detailed by *Moody's*. Numerous companies found intellectual property rights to be so important in their portfolio of assets that they reported patents directly in financial statements. J. I. Case Threshing Machine Company, the Wisconsin agricultural machinery manufacturer, reported $1.04 million in patents between 1922 and 1928. American Bosch Magneto Corporation, which manufactured devices for internal combustion engines, valued its patents at between $594,176 and $633,356 from 1924 to 1929, equivalent to around one-third of the total assets of the company.

More generally, patents were critical for appropriability during the 1920s. Extrapolating backwards from Cohen, Nelson and Walsh (2000) 'discrete' industries such as chemicals in which patent protection is deemed to be important were cornerstones of industry structure in the early twentieth century. Mokyr (1990) puts innovations in chemicals at the heart of the second industrial revolution. Patents not only increased the effectiveness of research and development activities, but they also enhanced the market power of incumbents. Lerner, Strojwas and Tirole (2003) argue that patent pools were a principal means through which firms during the early twentieth century used intellectual property rights to foster collusion. For example, the American conglomerates Du Pont, Standard Oil, Allied Chemicals, the English firm I.C.I. and I.G. Farben of Germany captured a commanding share of the fertilizer market through 1,800 patents relating to the synthetic nitrogen process (Comer, 1942, p.161).

Perhaps the most compelling evidence that patents were an important component of a firm's portfolio of intangible assets can be gained from Figures 3, 4 and 5. Figure 3 plots indexes of total patents granted by the USPTO and those granted to the firms in the sample for comparable years. A striking result to emerge from this figure is the growth of patenting activity by firms over time. This growth in firm-level patenting activity is consistent with what we know about the role of the early twentieth century industrial research laboratory in increasing the rate of innovation within firms (Mowery, 1995)

Using the means from Table 1, Figure 4 plots trends in patenting and market value over time. The logarithmic scale allows a more informative comparison of large (market value) and small (patent count) values because an equal percentage change is shown as an equal amount of space on the graph. It is noticeable to observe during the 1920s how closely the growth rate of patents, and especially of patent citations, is aligned with the growth rate of market value.

Figure 5 illustrates that patents as intangible capital were important in the context of the stock market for several of the companies considered. AT&T, General Electric and Westinghouse pushed out the frontier of productivity enhancing electrification technology. Eastman Kodak created a market for amateur motion pictures during the 1920s with the introduction of 16mm reversal film on cellulose acetate. General Motors developed lighter metal casings for motor vehicles, while Firestone and Goodyear introduced advanced methods of rubber vulcanization increasing the longevity of tires. Although the association between patenting and q is weak for some of the companies illustrated (Du Pont and Ingersoll-Rand) the fact that the correspondence is close for others warrants a more systematic investigation of the links between financial markets and the intangible assets of firms.

Estimating the Market Value of Intangibles

To analyze the data more systematically, I use an empirical approach developed from a simple model that relates patents to market value. The market value model of Griliches (1990) assumes an efficiently functioning financial market where the value of a firm (v) depends on the evolution of its cash flows, which firms attempt to maximize from their mix of tangible (k) and intangible (g) assets. This gives a value function of the form (1) where γ is the market premium or discount over tangible assets and π represents the relative shadow value of intangibles. Using a standard linear approximation of this value function yields (2) where q is the ratio of the firm's market value to the replacement cost of its assets. The coefficient α_1 measures the value of intangible assets relative to the tangible assets of the firm. If the value of the firm exceeds its replacement cost, the intuition behind this model is that the difference can be explained by the presence of intangibles (*i.e.*, $\alpha_1 > 0$).

$$v_{it}(k_{it}, g_{it}) = \gamma_t(k_{it} + \pi g_{it}) \tag{1}$$

$$\log(q)_{it} = \log(v/k)_{it} = \alpha_0 + \alpha_1 (g/k)_{it} + X'_{it} + u_{it} \quad (2)$$

$$\begin{aligned} \log(v)_{it} &= \theta_0 \log(k)_{it} + \theta_1 \log(g/k)_{it} + \theta_2 (g=0)_{it} \\ &+ \theta_3 AGE_{it} + \theta_4 AGE_{it}^2 + \sum_{j}^{j-1} \theta_5 E_{tj} \cdot \log(g/k)_{it} + u_{it} \end{aligned} \quad (3)$$

Although the logarithm of *q* is commonly used as a dependent variable, I prefer a specification (3) with the logarithm of market value on the left-hand side because changes in stock prices -- which are incorporated into the numerator of *q* -- explain the largest component of the variation in *q* during the 1920s. Intangible capital is given by the firm's stock of patents, which is constructed using the declining balance formula $g_{it} = (1-\delta) g_{it-1} + pat_{it}$ with a depreciation rate δ =0.15. I weight each patent by the number of citations it receives, therefore summing the total number of citations for each firm, each year. Both the stock of patents and citation-weighted patents (g_c) are normalized on the firm's capital assets. A dummy variable for when $g = 0$ is added to partial out the effect of adding one to the patent stock as a precondition of taking its logarithm. I use a logarithmic specification for g because it moderates extremes in the data and lessens the effect of outliers. Thus, θ_1 has an elasticity interpretation.

An additional variable AGE is calculated as time *t* minus the year of the firm's incorporation, and included in the regressions (with a polynomial) to determine how far a firm's vintage affects its stock market capitalization in the manner of Hobijn and Jovanovic (2001). Since variation over time in the value of intangible capital is also of interest, interactions of E_{j-1} year dummies the with the firm's normalized stock of patents are also included. To analyze the returns to intangible capital over major swings in the stock market and to obtain more refined estimates with citation data, which I have for 1920-1929, equation 3 is estimated for two panels, 1908-1918 and 1919-1929.[3]

Results

Referring back to the descriptive statistics in Table 1, and the plots in Figures 3 and 4, it is clear that as the market value of companies grew during the 1920s the patenting activity of these firms also increased. The aim of this section is to determine whether anything more systematic can be concluded from the relationship between these variables.

Before discussing the results themselves it is important to consider an issue that has a wider bearing on the interpretation of the findings -- the direction of causality between patenting and *q*. Taking a cue from the empirical literature on the *q*-model of investment, authors such as Barro (1990) find that the stock market predicts investment, while others such as Blanchard Rhee and Summers (1993) find that it does not. Theory suggests that the relationship between innovation and market value is also endogenous. Incumbents have incentives to pre-emptively innovate if the expected payoffs exceed the rents from maintaining the current technology (Gilbert and Newbery, 1982). Equally stock market runups can be driven by technology-push. Equation 3 does not identify the direction of causality. While the standard solution to this problem is an instrumental variables estimator, there are also alternative strategies. For example, Brynjolfsson, Hitt and Yang (2000) use a test motivated by Granger's concept of causality, finding that the lagged stock of computer capital predicts market value, while lagged market value has little predictive power for investment in computers.

For the overall interpretation of the current results the simultaneous association between innovation and market value is not so problematic. After all, the central argument is that investors were both alert to the opportunities presented by companies with stocks of intangible capital, which also encouraged further investment in innovation: both effects fed of each other concurrently, and access to external sources of corporate finance probably played a mediating role (Nicholas, 2003). However, a related issue still remains -- measuring and interpreting the size and significance of the relationship between patenting and market value.

To address this issue differences in parameter estimates between periods are used. The regressions for 1908-1918 serve as a benchmark for the 1920s regression results. Changes in the stock market returns to intangible capital are captured by differences in the coefficient θ_1 between 1908-1918 and 1919-1929. Through θ_5 this effect can be measured for sub-periods of the 1920s (*i.e.*, interactions of the year dummy and $\log(g/k)$ measure changes in the relationship between stock market value and patenting relative to a baseline). Any change in investor attitudes towards intangible capital, will be revealed by the ratio of the coefficient on intangibles (θ_1) to the coefficient on tangible capital (θ_0).

Table 2 contains the regression results. The first point to note is that the coefficient on the log of the capital stock (*k*) is surprisingly low with fixed effects; under the assumption of linear homogeneity in the market value model of Griliches (1990) the coefficient should be exactly one. The results from the first two columns of Table 2 imply that for a 1 percent increase in the capital stock, market value increases by only 0.31-0.38 percent. In an OLS specification without controls for unobserved heterogeneity the estimates on (*k*) at the 95 percent confidence interval are larger at between 0.83 and 0.89, but they are still significantly different from unity. Possible explanations for the deviation include large fixed capital adjustment costs or measurement error bias. A corrective approach would be to impose unity in the empirical specification, but since this has the effect of biasing downwards the other coefficients in the model, the current model without parameter restrictions is preferred.

With respect to intangibles, the results reveal a strong and significant relationship between patenting and stock market value. Columns I and II report comparable estimates on the patent stock variable for the period 1908-1918 and 1919-1929. During the 1920s the elasticity of the firm's normalized stock of intangibles (g/k) with respect to market value is 0.12, approximately three times larger than the estimate for 1908-1918. Comparing columns II and III the elasticity estimate increases from 0.12 to 0.26 when citation weighted patents are introduced. This is important because cited patents are more likely to be commercially viable than their un-cited counterparts. As the estimates show a higher value on quality patents, the results suggest that investors were integrating expectations of future growth from innovation into their assessment of market prices.

Why are the parameter estimates on the patent stock variables so different between periods? To the extent that firms were accumulating substantial stocks of intangible capital during the 1920s this is exactly what we would expect if investors perceived that these intangibles would have a positive impact on expected future earnings. Investors would have been increasingly aware of important new inventions because widely distributed publications such as the *Scientific American* kept readers apace with technological breakthroughs. The *Official Gazette* of the USPTO published lists of patents assigned to companies, which investors could easily track.[4] If investors were uncertain about how innovation would contribute to the dividend growth rate, the effect would have been to increase the firm's fundamental value. Pástor and Veronesi (2005) incorporate uncertainty about the firm's future profitability into a stock valuation model that can reject the hypothesis of a bubble in the Nasdaq at its late 1990s peak. In their model as uncertainty increases, the price of a stock can be justified with a significantly lower expected growth rate of earnings. The high trading volume on the New York Stock Exchange during the 1920s is consistent with high levels of uncertainty. Since no-one knew what RCA's dividend trajectory looked like (because it didn't pay a dividend) the firm had some probability of failing and some probability of becoming a market leader, and therefore became extremely valuable to investors in much the same way that Nasdaq stocks had some probability of failing, but also some probability of becoming the next Microsoft in the Pástor and Veronesi framework.[5] Relative to the 1910s, the 1920s was a much more uncertain epoch concerning how technology would influence the future profitability of firms since the technological change taking place was so far reaching.

Retrospectively we also know that technological revolutions are characterized by diffusion lags so the large differences between the 1910s and the 1920s in the valuation of intangibles is comprehensible in this context. According to Hobijn and Jovanovic (2001) the process of innovation and delayed stock market reaction caused a lull in the stock market during the 1970s as organizations adjusted to new information and communications technology (ICT) and old capital became gradually displaced. The boom in the stock market during the 1990s was then a response to a more efficient new vintage of capital that revolved around the implementation of ICT. By this time investors had a much clearer idea of which firms had adapted to the new technological environment and which firms had not. New capital became more valuable as old capital faded away; innovation did not cause a bubble in the 1990s stock market.

Inasmuch as the 1990s was a decade of ICT, the 1920s was a decade of electrification and a similar diffusion lag was evident. David (1990) argues that the 1920s productivity acceleration occurred because manufacturing plants had developed complementary capabilities to exploit electrical power transmission inventions that dated back to the 1880s. Beyond electricity the inverted-U relationship between market value and AGE shown in Table 2 is consistent with models of innovation and the stock market that associates new capital value creation with old capital value destruction.[6] Many dominant firms lost market share during the 1920s as rivals embraced newer technologies. For example, United States Steel overcommitted resources to producing steel for rail lines and ignored opportunities for profit created by steel skeletal construction for skyscrapers and bridges. Bethlehem Steel, on the other hand, innovated in this market and by the early 1920s had gained significant market share from U.S. Steel. Old firms did not fall away altogether, but rather the threat of creative destruction encouraged preemptive innovation to prevent the dissipation of industry profits. A buoyant industrial sector (Klepper, 2002, p.646, reports that more than 500 firms entered the automobile industry in its first twenty years) meant that new firms seized opportunities ignored by inefficient incumbents.

The 1920s was probably the first period in history when investors began to assess the intangible assets of companies. This would have required a major shift in investor psychology towards the bundle of assets that comprise a firm, and a favorable assessment of the equity risk premium. The nuts and bolts of the railroad corporation were much easier for investors to value than the intangible assets of the 1920s technology firm. The results in Table 2 provide an indication of the change in investor attitudes. The coefficient on intangibles (*i.e.*, the patent stock variable) is much larger relative to the coefficient on tangible capital when comparing columns I and II. The results in the final column of Table 2 show that the relationship between patenting and market value is stronger for years closer to the 1929 Crash, contrary to what would be predicted if this was a phase of unrestrained speculation by uninformed investors. The baseline period in this regression is set at 1920-1925 where the elasticity of patenting with respect to market value is 0.18. In 1926 the elasticity rises to 0.26 (*i.e.*, 0.1849 + 0.0777), in 1927 to 0.25, in 1928 to 0.33 and in 1929 to 0.42. At this level of aggregation there is not enough variation in the data to pick out the pre and post Crash valuation of intangibles -- the coefficient for 1929 is a point estimate for the entire year. Nevertheless, the coefficients for 1926-1928 provide enough evidence to support the view that stock market appreciation during the run-up to the Crash was connected to expectations about the intangible capital embodied in firms.

Discussion and Conclusions

Intangible capital growth was substantial in 1920s America, investors realized it, and they integrated this information into their market pricing decisions. Recall that *q* is computed using tangible capital, and therefore *q* can exceed unity as intangible assets become a larger fraction of total assets. The most important source of variation in *q* during the 1920s was the change in stock market prices. Table 1 shows that average *q* was very low in 1920 (0.49) but by 1929 had risen to 1.25. What explains this drastic change in the market value of firms relative to the replacement cost of their assets? While conventional wisdom suggests that unrestrained speculation created a divergence between share prices and fundamentals, this article has offered a new perspective: the interaction between innovation and changes in investor attitudes towards intangible capital fomented large stock market payoffs for innovating firms. Consequently, the run-up to the Crash was not an epoch of irrational exuberance as is often claimed, rather investors linked rational (positive) expectations about fundamentals to the market value of firms.

The basic assumption underlying this analysis is that the value of intangible assets can be inferred from the gap between *q* and the replacement value of capital derived from the firm's balance sheet. A common criticism of this approach is that market participants do not accurately observe intangibles and therefore the market value regression may recover an inefficient estimate of intangible value (Bond and Cummins, 2000). Yet, the evidence here supports the hypothesis that investors were receiving information about intangible capital during the 1920s. I measure their response to fundamentals by the value attached to citation weighted patents. The fact that cited patents have substantial explanatory power (even over and above un-weighted patents) in the market value regressions shows that investors placed a premium on firms that pushed out the frontier of knowledge. Furthermore, the estimates in Table 2 show the parameter on the patent stock variable is much larger during the 1920s than the 1910s. Therefore, the results are consistent with a major change in the psychology of investors during the stock market boom. The 1990s run-up in the stock market has been interpreted as a response to an increase in the amount of organizational capital (Hall, 2001). Similarly, the 1920s stock market boom can be seen as a response by investors to the growth of intangibles in the economy.

Technological change does trigger booms in the stock market. The 1920s was a remarkable decade of technological progress and intangible capital growth. By 1920 electricity had surpassed steam as a source of power for manufacturing, and by 1929 accounted for 78 percent of total capacity (Devine, 1983). A chemicals invention during this epoch -- Percy Bridgman's method for growing crystals and purifying crystalline substances (patent number 1,793,672 filed February 16th 1926) -- paved the way for what David (1990) describes as a "breakthrough event" in the computer revolution almost half a century later, namely Intel's silicon microprocessor. The organization of production along 'Taylorist' lines improved workplace learning and performance (Hounshell, 1984). As the threat of creative destruction in product markets increased the marginal benefits from investing in search for new technologies, firms that innovated received sizeable stock market payoffs (Nicholas, 2003). As capital markets became increasingly liquid due to the entry of additional investors, innovation could be financed by access to external sources of credit. Investors both financed innovation directly, and indirectly they encouraged investment in technological development by inducing stock market rewards for innovation. One argument is that the change in fundamentals during this period may have caused 'informational overshooting' (Zeira, 1999) as market participants had different expectations about how long technological change would keep dividends growing. However, retrospectively we know that productivity growth did persist, so there was no *ex ante* constraint on the profits and payouts of firms. General Electric, for example, was profitable throughout the depression years (O'Sullivan, 2004). Productivity growth during the 1930s was marked (Field, 2003). It is plausible that investors were driving up equity values in the twenties on expectations of productivity growth a decade later.

None of these reasons, which suggest that stock prices in 1929 were warranted *ex ante*, is meant to deny instability in financial markets on the eve of the Crash. Neither do the findings detract from the real consequences of the precipitous decline in the stock market from 1929-1933. Not for the first time in the history of financial markets did investors begin to appreciate the downside of stock market risk. As Galbraith (1987) put it, "to an extraordinary degree this is a game in which there are many losers". Rather, the aim of the exercise has been to illustrate the significance of intangible capital growth during the 1920s, and to highlight that the positive correlation between market value and innovation arose because of a change in investor attitudes towards the composition of assets within a firm. The evidence here suggests that soaring stock market prices during the 1920s made sense insofar as they were correlated with the growth of intangibles in the economy. Determining how market participants responded to firms with large stocks of intangibles during the Crash, and after, should further our understanding of interactions between intangible capital, investor behavior and the stock market.

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Endnotes

[1] Schenectady, NY; Lynn, MA; Pittsfield, MA; Harrison, NJ; Cleveland, OH. See further, (National Research Council, 1921).

[2] They estimate a market value specification in which the coefficient on information technology (IT) capital is around 10. According to their interpretation, the stock market does not value $1 of IT capital at $10. Rather for every $1 of IT capital there are $9 of related intangibles.

[3] The first year of data drops off in the construction of the capital stock at replacement cost. Therefore the panel regressions are run for 1909-1918 and 1920-1929 respectively.

[4] An investor tracking Westinghouse, for example, would have been able to see that the firm was assigned more than 4,000 patents during the 1920s, approximately double the number of assignments during the 1910s.

[5] Pástor and Veronesi (2004), p.1.

[6] However, it should also be noted that the coefficients on AGE and AGE^2 are not precisely estimated over the two time periods.

TABLE 1. DESCRIPTIVE STATISTICS

	Market Value ($m)	*k* ($m)	*q*	Patents	Patent Citations
1908	69.35	53.37	0.72	13.70	.
	(174.58)	(180.43)	(0.30)	(52.28)	.
1909	77.75	51.04	0.83	15.23	.
	(199.46)	(173.01)	(0.31)	(53.52)	.
1910	72.20	49.08	0.82	13.74	.
	(183.70)	(163.32)	(0.29)	(48.81)	.
1911	71.52	44.57	0.74	17.08	.
	(181.38)	(153.92)	(0.28)	(59.61)	.
1912	70.36	44.75	0.82	16.77	.
	(179.80)	(148.33)	(0.35)	(61.77)	.
1913	64.60	42.36	0.77	17.18	.
	(168.88)	(140.80)	(0.32)	(57.21)	.
1914	61.80	41.28	0.78	20.00	.
	(157.78)	(135.07)	(0.43)	(65.65)	.
1915	66.47	38.03	0.81	21.45	.
	(170.88)	(125.88)	(0.31)	(65.60)	.
1916	70.97	41.25	0.72	18.92	.
	(183.29)	(137.41)	(0.26)	(59.39)	.
1917	65.55	52.30	0.51	18.43	.
	(168.64)	(169.35)	(0.18)	(59.42)	.
1918	70.95	56.70	0.51	16.87	.
	(173.03)	(185.18)	(0.18)	(58.18)	.
1919	66.85	39.84	0.68	13.74	.
	(159.26)	(149.43)	(0.30)	(49.26)	.
1920	55.65	47.00	0.49	11.83	3.79
	(142.50)	(165.29)	(0.18)	(41.83)	(12.34)
1921	59.09	37.95	0.66	13.46	4.70
	(150.13)	(133.26)	(0.27)	(41.32)	(11.93)
1922	70.63	34.14	0.76	13.09	4.68
	(171.14)	(116.22)	(0.37)	(38.29)	(13.45)
1923	73.87	35.81	0.74	13.55	4.88
	(178.26)	(118.75)	(0.36)	(40.26)	(12.60)
1924	88.86	35.13	0.84	16.26	6.37
	(208.09)	(116.66)	(0.41)	(51.39)	(19.75)
1925	108.55	34.91	1.01	20.94	8.86
	(249.68)	(115.10)	(0.63)	(69.91)	(32.02)
1926	139.24	37.79	1.07	21.86	8.90
	(368.52)	(113.54)	(0.64)	(62.41)	(23.77)
1927	161.94	39.43	1.25	21.46	10.54
	(401.17)	(114.28)	(0.82)	(65.02)	(32.86)
1928	250.22	44.44	1.58	28.31	10.45
	(581.75)	(116.52)	(1.13)	(82.73)	(30.69)
1929	234.27	51.16	1.25	29.61	13.30
	(569.41)	(115.19)	(0.92)	(90.50)	(36.59)

Note: standard deviations in parentheses

TABLE 2. MARKET VALUE REGRESSIONS

	Dependent Variable log(v)			
	I	II	III	IV
log (k)	0.3817	0.3087	0.2843	0.2677
	(0.0299)	(0.0345)	(0.0354)	(0.0353)
log (g/k)	0.0465	0.1245		
	(0.0286)	(0.0394)		
g=0	-0.0598	0.0970		
	(0.0298)	(0.0405)		
log (g_c/k)			0.2565	0.1849
			(0.0507)	(0.0553)
g_c=0			0.0897	0.0777
			(0.0426)	(0.0426)
1926·log(g_c/k)				0.0777
				(0.0536)
1927·log(g_c/k)				0.0621
				(0.0536)
1928·log(g_c/k)				0.1448
				(0.0573)
1929·log(g_c/k)				0.2327
				(0.0651)
AGE	0.0307	0.1266	0.0421	0.1610
	(0.0060)	(0.0096)	(0.2405)	(0.0127)
AGE^2	-0.0006	-0.0008	-0.0009	-0.0010
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Period	1908-1918	1919-1929	1919-1929	1919-1929
Firm Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
F	20.00	66.30	52.81	53.82
R^2 within	0.29	0.48	0.45	0.46
between	0.65	0.18	0.46	0.11
overall	0.66	0.20	0.43	0.12
Observations	781	1077	964	964

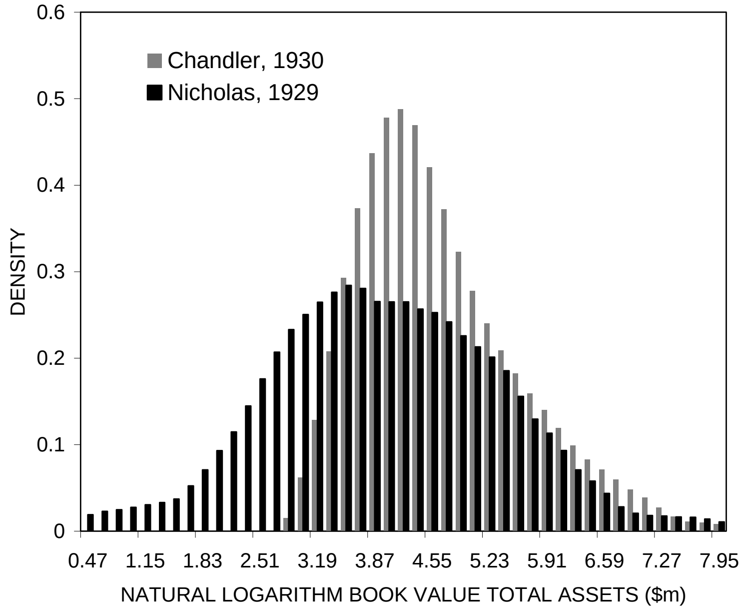


FIGURE 1a. COMPARING THE DISTRIBUTION OF FIRMS AGAINST CHANDLER'S LISTING OF THE 200 LARGEST COMPANIES

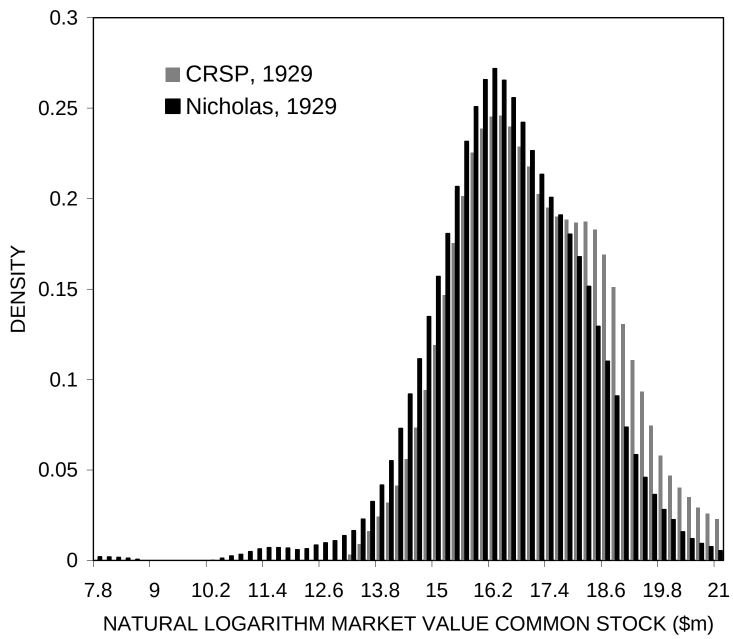


FIGURE 1b. COMPARING THE DISTRIBUTION OF FIRMS AGAINST THE POPULATION OF CRSP INDUSTRIAL FIRMS

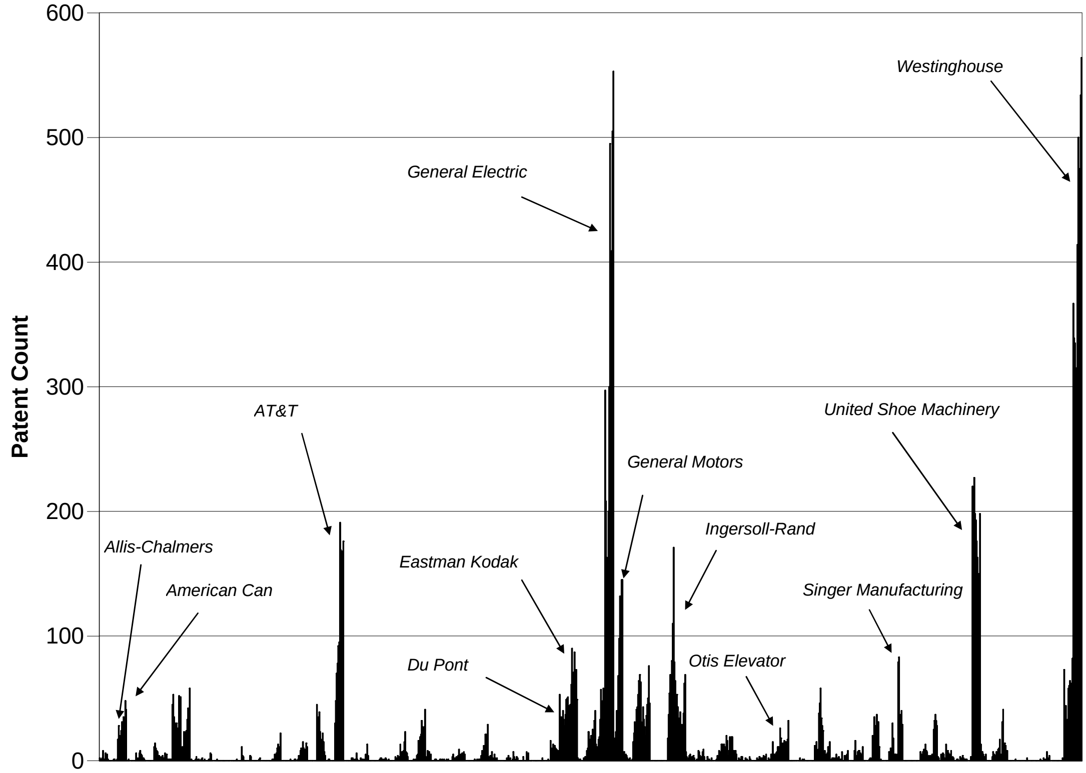


FIGURE 2. PATENT COUNTS (PER YEAR) FOR THE

FIRMS IN THE SAMPLE, 1920-1929

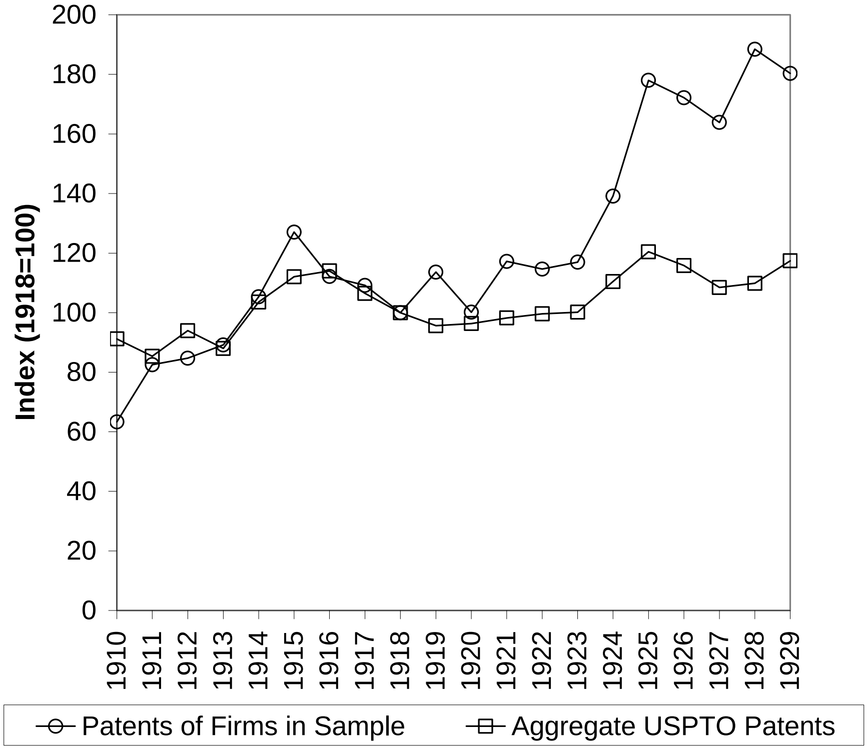


FIGURE 3. INDEX OF PATENTS FOR FIRMS IN THE

SAMPLE AND AGGREGATE USPTO PATENTS

FIGUIRE 4. MARKET VALUE AND PATENTS, 1908-1929

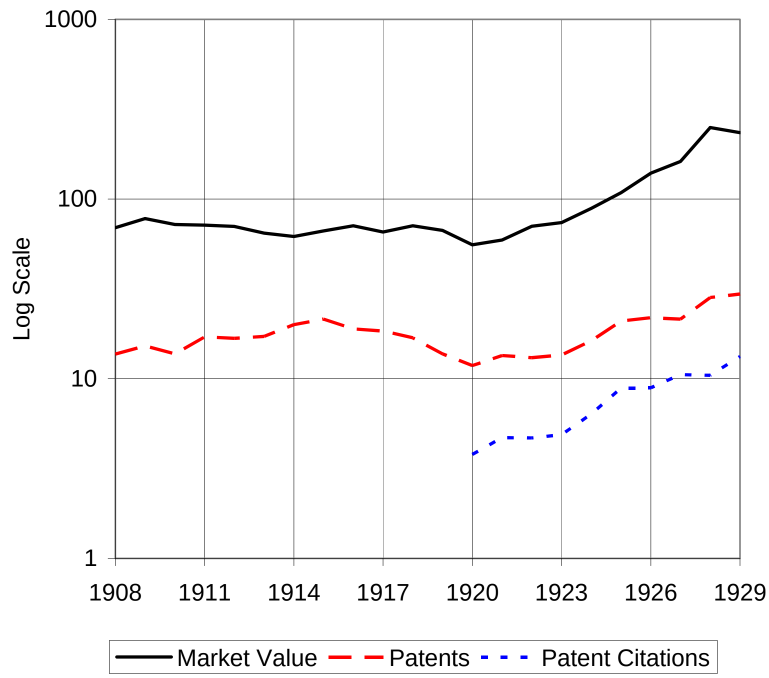
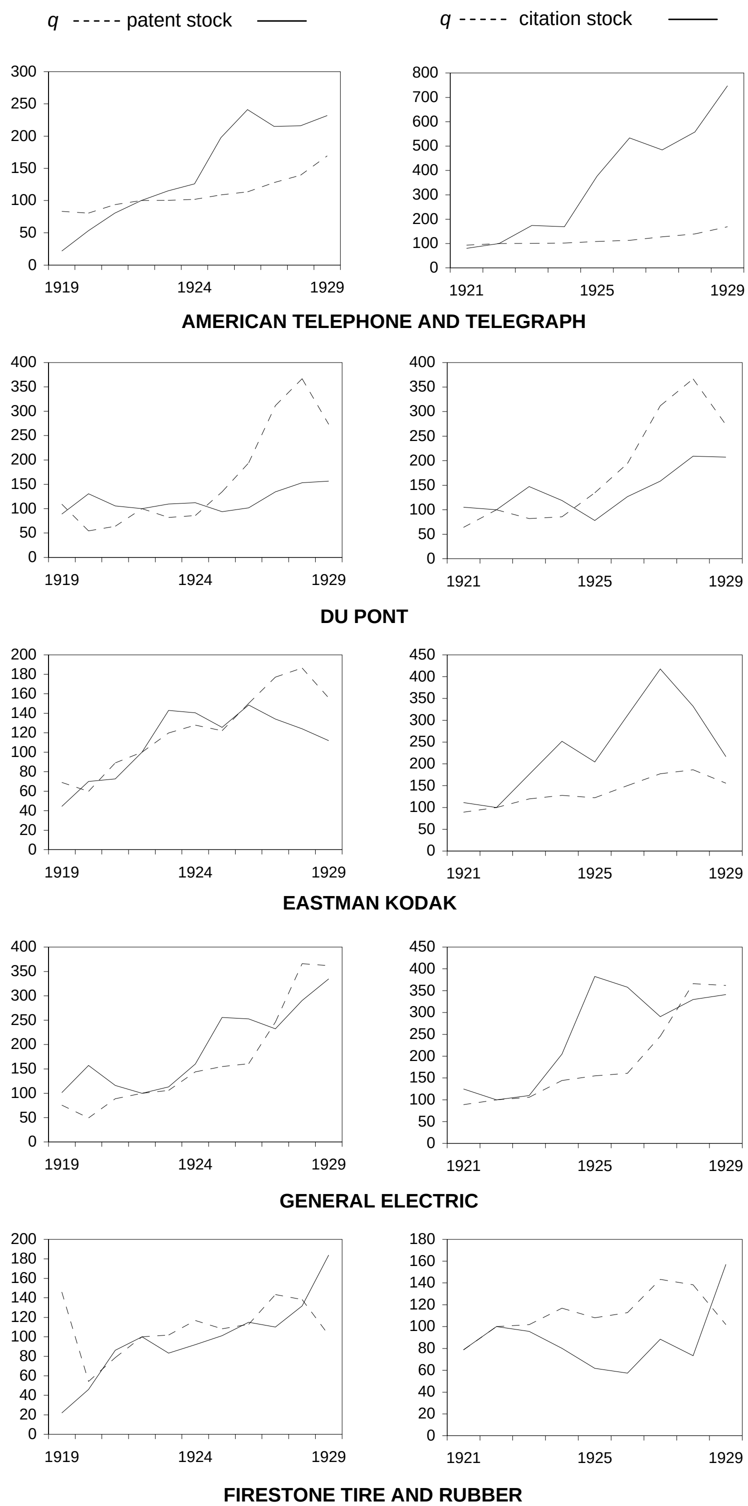
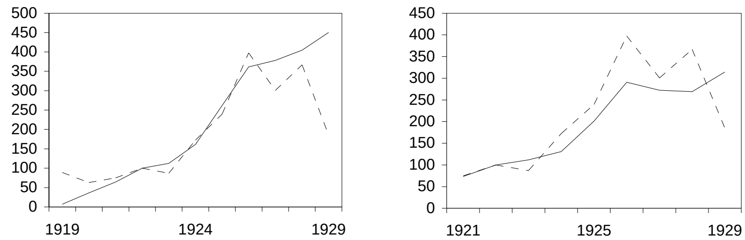
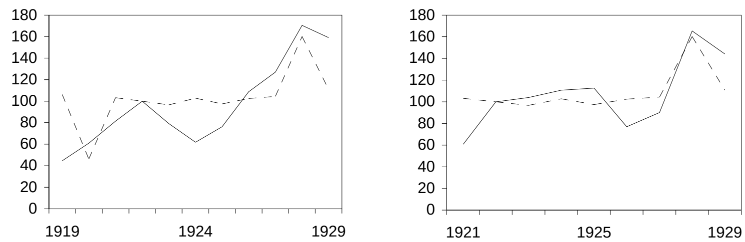


FIGURE 5. INDEXES OF PATENTING AND TOBIN'S *q*, 1919-1929

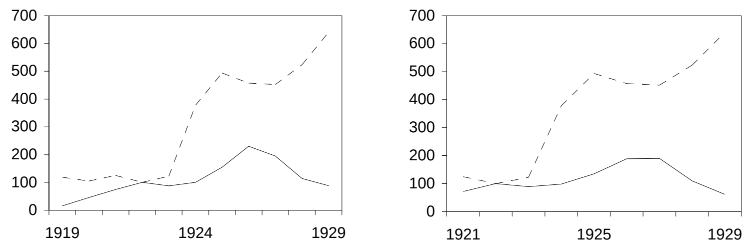




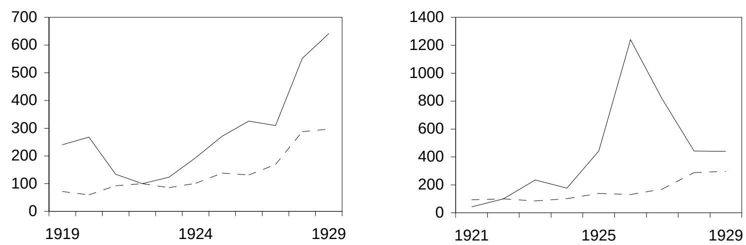
GENERAL MOTORS



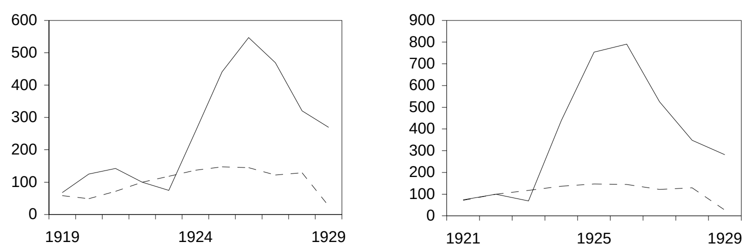
GOODYEAR TIRE AND RUBBER



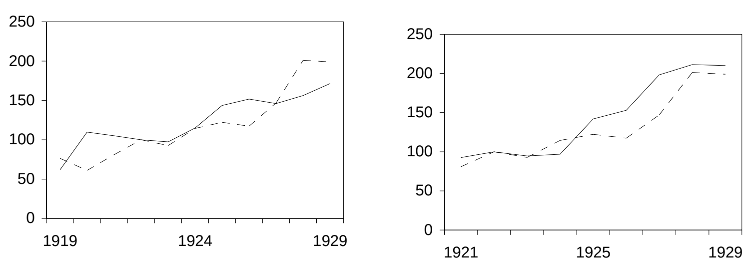
INGERSOLL-RAND



OTIS ELEVATOR



PITTSBURGH PLATE GLASS



WESTINGHOUSE ELECTRIC AND MANUFACTURING