Risk, variety and volatility: growth, innovation and stock prices in early industry evolution

Journal Item

Risk, Variety and Volatility: Firm Growth Rates and Stock Prices During Early Industry Evolution

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Abstract

The paper studies the patterns of volatility in firm-specific growth rates and stock prices during the early phase of the life-cycle of an old economy industry, the US automobile industry from 1900-1930, and a new economy industry, the US PC industry from 1974-2000. Strikingly similar patterns of volatility are discovered in the early phases of the two industries. The comparison sheds light on the *co-evolution* of industrial and financial volatility and the relationship between this co-evolution and mechanisms of Schumpetarian creative destruction. Results also provide insight into the debate on whether firm growth rates follow a random walk (e.g. Gibrat's Law).

Keywords**: industry life-cycle, technological change, risk, stock price volatility**
JEL Classification: L11 (Market Structure: Size Distributions of Firms), 030 (Technological Change), G12 (Asset Pricing)

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I. Introduction

The paper studies the patterns of volatility in firm-specific growth rates and stock prices during the early phase of the life-cycle of an old economy industry, the US automobile industry from 1900-1930, and a new economy industry, the US PC industry from 1974-2000. The comparison sheds light on the *co-evolution* of industrial and financial volatility and the relationship between this co-evolution and mechanisms of Schumpetarian creative destruction. It also illustrates the strikingly similar patterns of volatility in the early phases of old and new industries—suggesting that some of the patterns that are associated with the "new economy" are simply patterns that relate to early industry evolution in an economy with many new industries.

After reviewing data sources in Section II, Section III studies industrial volatility in both industries by focusing on the statistical properties of firm-level growth rates. Both absolute and relative growth rates are explored, with the latter being more central to an evolutionary analysis of change. Descriptive statistics and unit root tests are performed on the growth rates where the null hypothesis for the latter is that firm growth rates follow a random walk. In Section IV, these same statistical methods are used to study the volatility of firm-level stock prices and dividends. Results indicate that, for most firms, stock prices are the most volatile during the same decades in which relative growth rates (e.g. market shares) are the most volatile. In Section V, innovation dynamics in the two industries are used to interpret these patterns of volatility: in both industries the decades in which relative growth rates and stock prices were the most volatile were the same decades in which innovation was the most radical and competence-destroying (Tushman and Anderson, 1986). Building on this result, Section VI uses panel data analysis to test whether firm level stock prices are related to variables describing industrial instability (as opposed to traditional fundamentals), and whether this relationship is stronger in the early or mature phase of the industry life-cycle. The firm-level results confirm the industry level results in Mazzucato (2002) where changes in industry structure (e.g. number of firms, entry/exit rates, concentration, etc.) and innovation are related to changes in industry level stock prices.

II. Data

The study focuses on the US market for automobiles and personal computers (including both domestic and foreign producers). The firm-level and industry-level data is annual. Sales are measured in terms of annual units of automobiles (cars and trucks) and personal computers (all microcomputers, e.g. desktops and notebooks) produced. In both industries, units produced follow the same general qualitative dynamic as that of net sales in dollars but is preferred due to its greater precision (sales figures are affected by idiosyncratic accounting items).

Automobiles: Individual firm units and total industry units from 1904-1999 were collected from annual editions of *Wards Automotive Yearbooks* (first editions, reporting data starting in 1904, are published in 1924). Although firm-level units were collected for only 8 domestic firms and 5 foreign firms (the first foreign firms entered in 1965), the *total* industry sales include the units shipped by all existing firms (e.g. in 1909 that includes the output of 271 firms). Firm-specific stock prices, dividends, and earnings/share figures were collected from annual editions of *Moody's Industrial Manual*. Industry-specific per share data were collected from the *Standard and Poor's Analyst Handbook*[i] (the firms included to calculate that index are listed in the footnote below). However, since all financial data, except stock prices, only goes back to 1946 for the automobile industry, the data for the pre-war period was aggregated from the firm-specific data gathered from Moody's[ii]. The first year the auto firms went public was 1918, with Ford following only in 1956 (see footnote i for exact dates for each firm).

PCs: Annual firm-level data on the total number of personal computers produced from 1973-2000 was obtained from the International Data Corporation (IDC), a market research firm in Framingham, Massachusetts. Although this database is very rich (including brand, form factor, processor speed, region and customer segment), for the purpose of this study firm-level units were aggregated across models and brands produced by the firm. Firm-level stock price, dividend, and earnings per share data were obtained from *Compustat.* Industry-level financial variables were obtained, as for the post-war auto industry, from the Standard and Poor's *Analyst's Handbook* (2000). The firms which define this index are all included in the firm-level analysis, except for Silicon Graphics and Sun Microsystems (the only two firms in the

S&P computer index which don't produce personal computers)[iii]. Hedonic prices were obtained from the Bureau of Economic Analysis (BEA). An index measuring quality improvements was obtained from Filson (2001).

The data is analyzed during the first 30 years of each industry's history. This represents the "early" phase in the industry life-cycle, i.e. the phase that encompasses the introductory phase when the product first emerges and the initial growth phase (Gort and Klepper, 1982). The data for the "mature" phase of the automobile industry's life-cycle is also analyzed to gather some insight into what might lie ahead for the PC industry. The depression years, 1929-1933, are omitted from the sample (although results for relative growth rates are not altered when these years are included). To control for movements in the general market, analysis was also done on the units data divided by GDP and on the financial data divided by the S&P500 equivalent (e.g. GM stock price divided by the S&P500 stock price).

III. Firm Growth Rates

When studying the statistical properties of firm growth, the "law of proportionate effect", or Gibrat's law, is often used. *Gibrat's Law of Proportionate Growth,* states that firm growth rates are i.i.d. random variables independent of firm size (Gibrat, 1931; Ijiri and Simon, 1977). The size of a firm at time *t+1* is taken to be a function of its size at time *t* subject to random variation. Taking x_i to denote firm size, the size of firm *i* is governed by the following equation:

$$x_i(t) = \alpha + \beta_i x_i(t-1) + \varepsilon_i(t) \qquad (1)$$

where $x_i(t)$ is the log size of firm *i* at time *t,* and α is a growth component common to all firms. Gibrat's law assumes that ε is an i.i.d random variable and for all *i,* and β_i=1 (i.e. that the expected rate of growth is independent of the present size). The principal result in such models is that although firms might begin ex-ante with equal growth prospects, differences in initial conditions and the presence of random events cause firms to soon diverge in size and market shares, causing a skewed size-distribution (log-normal) to emerge. The empirical evidence on Gibrat's Law is mixed, with some studies showing that growth rates and their variance tend to fall with size and age (Hall, 1987; Evans, 1987) and others which find evidence for the law by focusing on the large percentage of exits. Geroski and Machin (1993) claim that Gibrat's Law is better suited to describe the growth process of relatively large firms[iv].

Gibrat's law is difficult to reconcile with those studies which find that there are *persistent* and *cumulative* patterns in firm profits and innovation (Mueller, 1990). While the random story suggests that there is some kind of reversion to the mean, the persistence story suggests that there are strong positive feedback mechanisms at work. Positive feedback may arise from learning by doing in which firm growth depends on cumulative output, or from more complex reasons related to the dynamics of absorptive capacity (Cohen and Levinthal, 1990), and the way that firm-specific capabilities develop (Teece, Pisano and Shuen 1990). Geroski and Mazzucato (2002) find that Gibrat's law is better suited to describe firm growth during the early phase of the industry life-cycle when technological opportunity is greater and concentration is lower. This result is returned to in the discussion of the results below.

Gibrat's law can be tested for in various ways. As is well known, testing for the beta coefficient in Equation (1) contains a bias towards accepting the random walk hypothesis (Geroski and Mazzucato 2002). Testing for a unit root (for each firm), using different variations of the Dickey-Fuller method (Dickey and Fuller, 1979), can provide an alternative way to test for the random walk hypothesis. If a time-series has a unit root then it shows a *systematic* pattern in its movement (a stochastic trend), but such movement isn't predictable because it is the effect of random shocks on a long-memory process. Dickey-Fuller testing strategies are generally addressed for discriminating between the trend-stationary processes and the difference-stationary processes. They can be modeled in many ways, depending on the consideration of drifts (deterministic component), trends, and the number of augments of the lagged dependent variable (ADF: Augmented D-F tests). It has been observed that the size and power properties of the ADF test are sensitive to the number of lags (Agiakoglou and Newbold 1992). There are two main approaches: 1) the general to specific technique (Hall 1994) which starts with a large number of lagged terms which are iteratively reduced until a significant statistic is encountered, and 2) the model selection information criteria (Akaike Information Criterion - AIC and the Schwarz Bayesian Information Criterion –SBC). Information Criterion methods based on small values can, in the presence of MA errors, result in size distortions (Maddala

1998). General to specific approaches tend to define higher dimensions, but this can produce important losses of power, especially in small sample sizes. The large (and increasing) number of unit root tests is a consequence of the fact that there is no uniformly powerful test of the unit root hypothesis. Given the moderate sample dimensions in the data used here, the Schwarz Bayesian Information Criterion (SBC) is used to handle the tradeoff between fit and parsimony.

Results: Tables 1-4 contain the standard deviations, means and unit root tests on firm-level and industry-level units and market shares, where the latter are taken as proxies of *relative* growth rates (results for firm level growth rates divided by industry growth rates were qualitatively the same as those for market shares). To maximize the degrees of freedom, the unit root tests were done on the entire 30 years of the "early" phase of industry history (or the maximum number of years that the firm existed), while the descriptive statistics were (also) done on the three individual decades (as well as the entire pre-war and post-war periods). When unit root tests identified a trend, the descriptive statistics were also performed on the detrended data. But since no qualitative difference was found in the different periods between the detrended and the non-detrended series (after the logs and differences were taken), for purposes of consistency, statistics only for the non-detrended data is reported here. Data is presented for the top 8 firms in the automobile industry: GM, Ford, Chrysler, American Motors, Studebaker, Packard, Hudson, and Nash (with unit root tests also presented for the foreign firms), and the top 10 firms in the PC industry: Apple, Compaq, Dell, Everex, Gateway, Hewlett-Packard, IBM, NEC, Toshiba, and Unisys

Automobiles. Table 1 indicates that firm-level units contain a unit root only in the pre-war period, i.e. they follow an I(1) process in the pre-war and an I(0) process in the post-war period. This is true for all firms except for Ford which does not contain a unit root in either period, most likely due to its stable dominance of the industry in the pre-war period (and the general stability of the industry in the post-war period). The same result holds for relative growth rates (market shares) and whether or not auto units were divided by GDP. As regards the different decades, Table 2 indicates that firm-level and industry-level units were most volatile in the period 1918-1941, with most volatility occurring between 1918-1928. Studebaker was the only exception, with its most volatile period after World War 2.

Personal Computers. Table 3 indicates that the growth rates of all firms, except Apple and Dell, contain a unit root. The descriptive statistics in Table 4 indicate that all firms experienced higher mean growth in the most recent decade (1990-2000) but more volatile growth (standard deviation) in the first decade (1970-1980) or the second decade (1980-90). Relative growth, unlike absolute growth, was the most volatile in the last decade. The industry results diverge from the firm-level results, suggesting an aggregation problem: total units experienced both higher average growth and more volatile growth in the first decade 1970-80. This is most likely because in some years the aggregation may dampen inter-firm heterogeneity and volatility while in other years it may enhance it, depending on how the different series interact. Nevertheless, it appears clear in both the firm-level and industry-level data that the last decade was the least volatile in terms of absolute growth but the most volatile in terms of relative growth and market shares.

Hence, Tables 1-4 indicate that the first 30 years in the auto and PC industry were characterized by volatile growth rates. The auto industry experienced the most volatile growth, in both absolute and relative terms in the first decade of its existence, while the PC industry experienced the most volatile absolute growth in the first decade (when entry rates were highest) and the most volatile relative growth in the third decade. After looking at the statistical properties of stock prices, Section III will interpret these results in terms of innovation dynamics in both industries.

IV. Stock Price Volatility

In this section the volatility of growth rates is compared with the volatility of stock prices. Research into this question can benefit by linking two literatures that do not often talk to each other: the (dynamic) industrial organization literature that looks at factors that determine industrial *instability*, for example the rise and fall of firm numbers and market share instability (Hymer and Pashigian, 1962; Gort and Klepper, 1982), and the finance literature that looks at the factors that determine stock price *volatility* (Shiller, 1989; Braun et al. 1995, Campbell et al. 2000). The connection between the two literatures lies in how "risk" and uncertainty evolve over the industry life-cycle—i.e. the dynamics of a time-varying (industry) risk premium—and how this risk is both a cause and an effect of the mechanisms that create differences and inequality between firms. The presence of uncertainty is what generates opportunities for firms to differentiate themselves while the resulting inter-firm differences result in a riskier more uncertain environment (for the individual firm and for a potential investor). It is this non-linearity that led the pioneer of the economics of risk to state: "*Without uncertainty it is doubtful whether intelligence itself would exist*." (Knight, 1921, p. 268).

Tables 5-12 contain the standard deviations, means and unit root tests on firm-level and industry-level stock prices and dividends. Results are also included for the aggregate industry data, i.e. the average industry stock price and dividend *per share* computed by the S&*P Analyst Handbook*. To control for movements in the general market, analysis was also done on the firm-level data divided by the S&P500 equivalent. The results for these deflated (by the S&P500) values are found in italics. However, in both industries no qualitative differences were found between results for units that were not deflated and those that were.

Automobiles. The results in Tables 6, and 10 indicate that firm-level and industry-level stock prices and dividends were the most volatile precisely in the same period that units and market shares were: the period 1918-1941, with most volatility of stock prices occurring between 1918-1928 and the most volatility of dividends in the period 1933-1941 (units were even more volatile in the period preceding 1918 but firms were not quoted on the stock market yet). This holds for all the firms, except for Studebaker which instead experienced more volatility of both units and stock prices in the post-war period (1948-1970) but more volatility of dividends in the pre-war period. Division by the S&P 500 indices does not alter any of the qualitative results between the two periods (i.e. the earlier period is still much more volatile), except again in the case of Studebaker, whose dividends were more volatile in the post-war period when divided by the S&P500 and vice versa when not divided.

Whereas Table 2 indicates that firm-level units and market shares follow an I(1) process in the pre-war and an I(0) process in the post-war period, most of the stock prices and dividends follow an I(1) process in both periods (as does the S&P500 stock price index as well). This suggests the possible presence of "excess volatility" in both periods: that stock prices are much more volatile than the underlying fundamentals. However, using the efficient market model as a benchmark against which to compare the volatility of actual stock prices, Mazzucato and Semmler (1999) and Mazzucato (2002) find that degree of excess volatility was highest during the early stage of the auto industry.

Table 6 indicates that the average relative automobile stock (i.e. the average auto industry stock price divided by the S&P500 stock price) grew much less than the economy average in the post-war period. This is also the period when the average industry sales growth began to fall (the mean growth rate both at the firm and industry level is negative after 1970). As regards the last three decades, stock prices—like units and market shares—were most volatile in the decade1970-1980 than the following two decades.

Personal Computers.

Table 7 indicates that all firm stock prices, except for Unisys and Gateway, contained a unit root, consistent with Shiller's finding that stock prices tend to move like a random walk (Shiller, 1989). Table 8 illustrates that in the PC industry, firm and industry stock prices were most volatile in the *last* decade (especially in the *early* 1990's). However, since at the industry level dividends were the most volatile in the last decade (not true for several firms), this does not mean that there is more "excess volatility". Stock prices were the most volatile in the same decade that relative growth rates were the most volatile. Units instead were the most volatile in the first decade when entry rates into the industry were highest (Mazzucato, 2002).

V. Innovation

Table13 summarizes the above results using aggregate volatility figures: market share instability (as defined in Hymer and Pashigian, 1962)[v], the standard deviation of the growth of total units, the standard deviation of the growth of stock prices and dividends, and the latter two divided by the S&P 500 equivalents. It is clear that in both industries stock prices were the most volatile in the period when market share instability was the highest. This section documents (qualitatively) that in both industries this was also the period in which innovation was the most radical, i.e. had a greatest impact on the production process.

In the auto industry, the period in which growth rates and stock prices were the most volatile was also the period in which entry rates were the highest, and technological change was the most radical. In an early work, Epstein (1928) attributed the large change in firm numbers, entry/exit patters and the fall in prices to technological change. Abernathy et al. (1983) confirms this point by documenting (through an in depth innovation survey where each innovation is weighted by its impact on production) that the innovations that impacted the production process the most in the auto industry all occurred before 1935! Falling prices were caused by changes in technology, the diffusion of mass production, and the general expansion of the market. Between 1906 and 1940 the real price of automobiles fell by 51% and given that the CPI at the same time rose by 59%, the inflation adjusted prices dropped almost 70% (Raff and Trajtenberg, 1997, p. 77). Using the hedonic price index that they created, Raff and Trajtenberg (1997) illustrate that most of the real change in automobile prices between 1906-1982 occurred between 1906-1940, and within that period most of the change occurred between 1906-1918. Between 1906-1940 hedonic prices fell at an average annual rate of 5%. Filson's (2001) "quality change" index— derived by dividing the BEA actual price index by the hedonic price index created by Raff and Trajetenberg (1997)— confirms these results indicating that most of the percentage change in quality occurred between 1895-1908 (25% annual rate of change compared to 3.1% in the period 1909-1922 and 3.2% in the period 1923-1929).

Unlike in the auto industry, in the PC industry the period of initial market expansion and high entry rates (causing high absolute growth rates), was not the period with the most radical technological change. Entry/exit rates were highest in the first decade, 1974-1984, but it took almost two decades for new firms to challenge the main industry leader, IBM, and hence to challenge the status quo both in terms of technology and market shares (causing high relative growth rates). Whereas the innovations introduced in the 1970's and 1980's were controlled by IBM (since everything had to be IBM compatible), the quality changes in the 1990's disrupted the status quo, principally because power shifted from IBM to Microsoft and Intel (Bresnahan and Greenstein, 1997)[vi]. Filson's (2001) "quality change" index indicates that most of the percentage change in the personal computer industry occurred in the first and third stage: 34% between 1975-1986 (the years when the industry first emerged encompassing the introduction of Intel's 386 processor), and 38% in the period 1993-1999 (soon after Windows 3.0 was introduced), with only 17% in the middle stage. Hence the last decade in the PC industry has witnessed not only the most quality change but also the most volatility in market shares. The uncertainty caused by the changing technology and market shares caused stock prices to be most volatile in the period 1994-2000, precisely the period referred to as the "new economy".

As in autos, prices of personal computers were driven by technological advance. Prices began to drop significantly after Intel's introduction the 32-bit 386 processors in 1985 and the introduction of Windows 3.0 in 1990. The latter allowed the production of PCs to be standardized and "commoditized" (via cloning of the IBM PC). The rise of the internet also has increased sales and decreased prices. In recent years quality-adjusted prices have fallen at an average annual rate of 24% (BEA, Survey of Current Business, 2000). Berndt and Rappaport (2000) find that between 1983-89 PC prices fell by an average of 18%, between 1989-94 by 32%, and between 1994 and 99 by 40%.

Hence in both the auto and PC industry, relative growth rates and stock prices were the most volatile in the period in which technological change was the most radical. While in the auto industry this occurred in the very early years of industry evolution (hence coinciding with the period of high absolute growth rates), in the PC industry it had to wait almost two decades until the new entrants broke their chain of dependence on IBM.

VI. Panel Data Analysis: Inter-Firm Heterogeneity

To better understand the degree to which stock price dynamics follow the patterns of industrial instability, panel data analysis is used here to regress the rate of change of firm stock prices on life-cycle variables like changes in: firm numbers, market share instability, market concentration, and also on more traditional fundamentals at both the firm, industry and economy wide level (e.g. firm dividends, industry dividends, S&P 500 stock price, etc.). Given the results already obtained, the goal is to see whether in the early phase of industry evolution stock prices are more related to variables defining industrial instability than they are to variables in the mature phase, and whether in the mature phase they react more to changes in fundamentals than they do in the early phase.

Due to the low number of firms and the long time period, Seemingly Unrelated Regression estimations (SURE) are used (Zellner, 1962, Smith, 2000). Wald tests are used to test for inter-firm heterogeneity, both in terms of the differences between firms with respect to a single regressor (Wald test type 1) and the differences between firm-specific coefficients for all the single regressors (Wald test type 2). That is, it tests for joint restrictions for homogeneity (the Fixed Effect hypothesis). If the null hypothesis of homogeneity is rejected then the correct estimator is the Unrestricted SURE (which controls for the likelihood ratio test between the sum of the OLS equations). If instead the hypothesis of homogeneity cannot be rejected on the whole set of parameters and it is not possible to reject the restrictions for homogeneity of the firm-specific coefficients for the single regressors, then this means that the correct estimator is the Restricted SURE.

Firm-level stock prices were regressed on firm-level dividends, firm market share, the S&P500 index stock price, the S&P500 index dividends, the number of firms in the industry and the level of concentration. Other variables were also included but since no convergence occurred of the Maximum Likelihood (ML) algorithm, they had to be omitted. For reasons of convergence, multicollinearity and parsimony, different specifications were tried for the PC industry, where each specification includes a different sub-set of firms. The t-statistics in the SURE analysis are often very large due to the convergence procedure. Due to space limitation, only the tables for the restricted case are included below, the unrestricted case which requires comparison with single equation OLS estimates are treated verbally.

Automobiles (1918-1941, 1948-2000). In Table 14-15 Wald tests state that in the pre-war period the joint restrictions for homogeneity (the Fixed Effect hypothesis) and the restrictions of the firm-specific coefficients for the single regressors can both be rejected. In the post-war period we *cannot* reject this restriction on the whole set of parameters and we can also not reject the restrictions for homogeneity of the firm-specific coefficients for all the single regressors. This means that in the post-war period there is more homogeneity between firms in how stock prices are affected by the different variables. In the pre-war period, the rate of change of firm stock prices are significantly affected by changes in market shares, the number of firms and the herfindahl index. Neither the firm level, industry level not market level fundamentals seem to be significant in this early period. In the post-war period there is increased significance of the fundamentals (both at the firm level and at the general market level) and no significance of the industrial dynamics variables (market shares, number of firms and herfindahl index).

Personal Computers (1975-1999). In each of the different specifications, the results were similar to that which emerged in the *pre-war* period for automobiles: rejection of the joint restrictions for homogeneity of the whole set of parameters (Fixed Effect panel hypothesis) and non-rejection of the restriction for homogeneity of the firm-specific coefficients for most of the single regressors. This means that the correct estimator is the *partially* restricted SURE estimator (only for homogeneity on those regressors for which restriction on homogeneity was rejected). As in the pre-war auto industry, the most significant variables in this early stage of evolution are changes in market shares, the number of firms and the herfindhal index. The financial fundamentals both at the level of the firm and at the level of the general market were less significant.

These results indicate that in both industries stock price dynamics in the early phase of the industry life-cycle are affected significantly by the turbulence in market structure: changing number of firms, rising concentration and market share dynamics. On the other hand, firm level and market level fundamentals (dividends, earnings per share) have a greater effect on stock price dynamics in the mature phase than in the early phase. Furthermore, in the early phase of both industries it is easier to reject the joint restrictions for homogeneity of the whole set of parameters, indicating that in this phase, unlike in the mature phase (for automobiles at least), there is more heterogeneity between firms. The fact that there is more heterogeneity between firms in the early period and the fact that firm level stock prices react to changes in industrial turbulence supports the cointegration results in Mazzucato (2002) that there is a larger idiosyncratic nature to stock prices in the early life-cycle phase (i.e. more firm-specific risk)[vii].

VII. Conclusion

The paper began by considering the literature on firm growth rates and the "random walk" hypothesis embodied in Gibrat's Law of Proportionate Growth. Unit root analysis and descriptive statistics on firm-specific growth rates (both absolute and relative) in the early auto and PC industry found that the Gibrat hypothesis better describes the statistical process of firm growth during the *early* phase of industry evolution. This is most likely because this early phase is characterized by higher rates of entry and exit, rapidly evolving technology and a general expansion of the market (creating opportunities for some and disadvantages for others). Once changes in technology and demand settle down and concern shifts more towards economies of scale and process innovation, firm growth rates tend to be more stable and structured. While one can clearly see these different patterns in the early and mature phase of the auto industry (e.g. the unit root hypothesis cannot be rejected for most firms in the early phase while it can be rejected in the mature phase), one can only wait for the pattern to show up in the PC industry—perhaps not too long given that the industry is beginning to experience slower growth and much less product innovation ("Personal computer shipments suffer first fall in 15 years", *The Financial Times*, July 21/22, 2001).

The statistical analysis of stock price volatility for firms in both industries found that stock prices were most volatile precisely in the decades that relative growth rates were most volatile. While in the auto industry this coincides with the period in which absolute growth rates were also the most volatile, in the PC industry absolute growth rates were most volatile in the first decade (1974-1984) while relative growth rates were most volatile in the third decade of industry evolution (the 1990's). This is because in the auto industry the phase of initial market expansion with new firm entry and exit (causing volatility in absolute growth rates) was also characterized by radical innovation, causing a shake up in market shares during the very early years (Epstein, 1926). In the PC industry, the initial phase of expansion and entry was not characterized by radical technological change since IBM dominated the growth of the industry and the innovation process. Only in the 1990's—the decade of the "new economy"—did innovation become free from IBM's dominance (due to radical changes in processor speed, dominance of the Wintel platform, and the rise of the internet), allowing the firms that had entered a decade (at least) before to finally compete for market share.

A look at the innovation data (e.g. through the "quality change index") confirms that the periods in which relative growth rates and stock prices were the most volatile in both industries were also the periods in which innovation impacted the production process the most. This suggests that both types volatility are related to the mechanisms of Schumpetarian creative destruction, or in the words of modern strategy theory, to the mechanisms of "competence-destroying" innovations— as opposed to "competence enhancing" ones that serve to fortify the advantages of incumbents (Tushman and Anderson, 1986).

An analysis which links volatility in firm growth rates, stock prices and innovation provides a different view of the "new economy" and of the stock price volatility which has characterized this era (continues today). Unlike the claim that stock prices are driven by "animal spirits" (and other random factors) and that the new economy was a period in which stock prices were less related to underlying performance criteria due to the greater importance placed by investors on future growth potential of firms (due to the characteristics of knowledge underlying the IT sector), this analysis had tried to portray how stock price volatility is fundamentally linked to the *real* structure of technological change during industry evolution. While this may not be used for predicting the dynamics of specific stocks (allowing the author to become rich), it does provide us with an alternative, Schumpetarian-based, structural framework to understand stock price volatility.

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TABLE 1

Analysis of the statistical properties of the series (processes) of units produced by US and foreign firms: DF and ADF tests

Firm	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Chrysler	1925-1941	SBC	ADF(1)+drift+t	-2.6184	-3.7612	I(1)
	1948-1998	SBC	DF+drift	-3.1572	-2.919	I(0)
Ford	1904-1941	SBC	DF+drift	-4.0172	-2.9446	I(0)
	1925-1941	SBC	ADF(1)+drift	-3.3364	-3.0522	I(0)
	1948-1998	SBC	DF+drift	-3.3243	-2.919	I(0)
GM	1909-1941	SBC	DF+drift	-1.6327	-2.9591	I(1)
	1925-1941	SBC	DF+drift	-2.0393	-3.0522	I(1)
	1948-1998	SBC	DF+drift	-3.1688	-2.919	I(0)
Hudson	1910-1926	SBC	ADF(1)+drift	-3.6729	-3.7612	I(1)
	-	-	-	-	-	
Nash	1917-1926	SBC	DF+drift+t	-2.1548	-4.1961	I(1)
	-	-	-	-	-	
Packard	1904-1926	SBC	DF+drift+t	-2.4551	-3.6454	I(1)
	-	-	-	-	-	-
Reo	1905-1928	SBC	DF+drift+t	-2.3108	-3.6331	I(1)
	-	-	-	-	-	
Studebacker	1911-1941	SBC	DF+drift	-1.8746	-2.9665	I(1)
	1925-1941	SBC	DF+drift	-1.5779	-3.0522	I(1)
	-	-	-	-	-	
American	-	-	-	-	-	-
	-	-	-	-	-	-
	1948-1985	SBC	ADF(1)+drift	-2.5329	-2.94	I(1)
Total units (US)	1899-1941	SBC	ADF(1)+drift	-2.3311	-2.9339	I(1)
	1925-1941	SBC	DF+drift	-1.9753	-3.0522	I(1)
	1948-1998	SBC	DF+drift	-4.2927	-2.919	I(0)
Honda	1971-1998	SBC	DF+drift	-6.7257	-2.9798	I(0)
Mazda	1985-1998	SBC	DF+drift	-1.2576	-3.1485	I(1)
Mitsubishi	1985-1998	SBC	DF+drift	-2.6298	-3.1485	I(1)
Nissan	1965-1998	SBC	DF+drift	-4.9077	-2.9558	I(0)
Toyota	1966-1998	SBC	DF+drift+t	-6.174	-2.9591	I(0)
Volkswagen	1965-1998	SBC	DF+drift	-1.4288	-2.9558	I(0)

note:
DF = Dickey-Fuller Test, drift stands for intercept, t for trend
ADF = Augmented Dickey-Fuller Test, drift stands for intercept, t for trend
SBC = Schwarz Bayesian Criterion (based on ML)
I(1) = Integrated process of order 1, or Difference Stationary (DS)
I(0) = Stationary process, or Trend Stationary (TS)

TABLE 2

Descriptive statistics of units (logs of differences) in the US auto industry

		1904-18	1918-28	1918-41	1948-00	1948-70	1970-00	1970-80	1980-90	1990-00
gm	st. dev	0.1650	0.1745	0.1548	0.0798	0.0933	0.0732	0.1114	0.0502	0.0229
	mean	0.1001	0.0597	0.0579	0.0052	0.0153	-0.0088	-0.0029	-0.0158	-0.0162
ford	st. dev	0.2382	0.2734	0.2307	0.0837	0.1045	0.0572	0.0735	0.0683	0.0359
	mean	0.1722	0.0011	0.0173	0.0072	0.0283	-0.0103	-0.0277	-0.0054	-0.0161
chrysler	st. dev		0.1035	0.1415	0.0897	0.1149	0.0615	0.0717	0.0708	0.0536
	mean		0.1019	0.0654	0.0006	0.0130	-0.0089	-0.0210	-0.0090	-0.0155
amc	st. dev			0.2039	0.1067	0.1136	0.0913	0.0673	0.1288	
	mean			0.0971	0.0021	0.0182	-0.0192	-0.0135	-0.0197	
studeb	st. dev		0.1565	0.1639	0.3023	0.3023				
	mean		0.0409	0.0470	-0.1038	-0.1038				
packard	st. dev	0.2096	0.1936							
	mean	0.1460	0.0262							
hudson	st. dev		0.2549							
	mean		0.1178							
nash	st. dev		0.1784							
	mean		0.1169							
industry	st. dev		0.1569	0.1500	0.0638	0.0759	0.0523	0.0768	0.0428	0.0231
	mean		0.0305	0.0378	0.0070	0.0172	-0.0034	-0.0050	-0.0054	-0.0088

TABLE 3

DF-ADF tests for logs of units produced in the US PC industry

Firm	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Apple	1979-2000	SBC	DF+drift	-7.127	-3.004	I(0)
Hewlett-Pack	1979-2000	SBC	ADF(1)+drift+t	-2.725	-3.633	I(1)
IBM	1979-2000	SBC	ADF(1)+drift	-2.101	-3.004	I(1)
NCR	1979-2000	SBC	DF+drift+t	-0.16	-3.659	I(1)
Unisys	1979-2000	SBC	ADF(1)+drift	-2.628	-3.012	I(1)
Commodore	1979-1994	SBC	DF+drift+t	0.169	-3.735	I(1)
Compaq	1985-2000	SBC	DF+drift+t	-2.045	-3.735	I(1)
Dell	1987-2000	SBC	ADF(1)+drift+t	-6.435	-3.792	I(0)
Gateway	1986-2000	SBC	ADF(1)+drift	-1.586	-3.082	I(1)
Toshiba	1983-2000	SBC	DF+drift	-1.747	-3.04	I(1)
Wang	1979-1993	SBC	DF+drift	-1.228	-3.082	I(1)
Wyse	1986-1994	SBC	DF+drift+t	-1.686	-4.081	I(1)
All firms	1979-2000	SBC	DF+drift	-3.358	-3.004	I(0)

note:
DF = Dickey-Fuller Test, drift stands for intercept, t for trend
ADF = Augmented Dickey-Fuller Test, drift stands for intercept, t for trend
SBC = Schwarz Bayesian Criterion (based on ML)
I(1) = Integrated process of order 1, or Difference Stationary (DS)
I(0) = Stationary process, or Trend Stationary (TS)

TABLE 4

Descriptive statistics of units (logs of differences) in the US PC industry

		1970-00	1970-80	1980-90	1990-00
apple	st. dev	0.7958	0.6847	0.4118	0.1132
	mean	5.7186	4.1964	5.7176	6.2251
compaq	st. dev	0.6717		0.3192	0.4843
	mean	5.9325		5.3333	6.3406
dell	st. dev	0.8999		0.4933	0.6501
	mean	5.6426		4.7283	6.0815
everex	st. dev	0.2038		0.2768	0.1932
	mean	4.7409		4.6979	4.7762
gateway	st. dev	1.5397		0.9631	0.5243
	mean	4.9947		3.3857	6.0170
hpackard	st. dev	1.1976	0.4852	0.3910	0.7145
	mean	4.7415	3.2614	4.8468	5.8018
ibm	st. dev	1.3390	0.4552	0.8164	0.1464
	mean	5.3104	3.3484	5.6838	6.3037
nec	st. dev	0.3437			0.3437
	mean	6.1557			6.1557
toshiba	st. dev	1.1964		1.0799	0.3587
	mean	4.9549		4.0701	5.7926
unisys	st. dev	0.6569	0.3242	0.4711	0.6040
	mean	4.1503	3.3528	4.3014	4.4822
industry	st. dev	0.1758	0.2062	0.1884	0.0357
	mean	0.1504	0.2432	0.1450	0.0646

TABLE 5

Analysis of the statistical properties of the series (processes) of the real stock prices (logs) by US firms: DF and ADF tests

Firm	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Chrysler	1925-1941	SBC	DF+drift	-1.6451	-3.0819	I(1)
	1948-1997	SBC	DF+drift	-1.2896	-2.9202	I(1)
Ford	-	-	-	-	-	-
	-	-	-	-	-	-
	1956-1998	SBC	DF+drift	-1.0184	-2.9339	I(1)
GM	1918-1941	SBC	DF+drift	-1.85	-3.0039	I(1)
	1925-1941	SBC	DF+drift	-1.4806	-3.0522	I(1)
	1948-1998	SBC	DF+drift	-1.5644	-2.919	I(1)
Hudson	1922-1941	SBC	DF+drift+t	-2.4929	-3.6921	I(1)
	1925-1941	SBC	ADF(1)+drift+t	-3.747	-3.7119	I(0)
	-	-	-	-	-	-
Nash	1922-1941	SBC	DF+drift+t	-4.2651	-3.6921	I(0)
	1925-1941	SBC	DF+drift+t	-3.9201	-3.7119	I(0)
	-	-	-	-	-	-
Packard	1917-1941	SBC	ADF(1)+drift+t	-5.1512	-3.6592	I(0)
	1925-1941	SBC	ADF(1)+drift+t	-4.7759	-3.7119	I(0)
	-	-	-	-	-	-
Studeback	1920-1941	SBC	ADF(1)+drift	-3.516	-3.0199	I(0)
	1925-1941	SBC	ADF(1)+drift	-3.2718	-3.0522	I(0)
	1948-1966	SBC	DF+drift	-2.2482	-3.0294	I(1)
American	-	-	-	-	-	-
	-	-	-	-	-	-
	1954-1986	SBC	ADF(1)+drift+t	-2.9128	-3.5615	I(1)
Industry	1918-1941	SBC	DF+drift	-1.4876	-3.0039	I(1)
	1925-1941	SBC	DF+drift	-2.8846	-3.0522	I(1)
	1948-1998	SBC	ADF(1)+drift	-2.181	-2.919	I(1)
S&P500	1913-1941	SBC	DF+drift	-2.3482	-2.975	I(1)
	1925-1941	SBC	ADF(1)+drift	-3.0079	-3.0522	I(1)
	1948-1998	SBC	DF+drift	-0.083576	-2.919	I(1)

note:

DF = Dickey-Fuller Test, drift stands for intercept, t for trend

ADF = Augmented Dickey-Fuller Test, drift stands for intercept, t for trend

SBC = Schwarz Bayesian Criterion (based on ML)

I(1) = Integrated process of order 1, or Difference Stationary (DS)

I(0) = Stationary process, or Trend Stationary (TS)

TABLE 6

Descriptive statistics of stock prices (logs of differences) in the US auto industry

		1918-28	1918-41	1948-00	1948-70	1970-2000	1970-1980	1980-1990	1990-2000
gm	st. dev	0.170964	0.147147	0.095173	0.080395	0.107536	0.096764	0.147021	0.038757
	mean	0.055331	0.043339	0.006101	-0.000395	0.00716	-0.017501	0.016151	0.01551
ford	st. dev			0.107571	0.08662	0.116013	0.125156	0.096478	0.128755
	mean			0.006197	0.008201	0.004956	-0.040533	-0.000331	0.036639
chrysler	st. dev	0.469634	0.248602	0.14847	0.08969	0.187895	0.154917	0.215675	0.185247
	mean	-0.080296	-0.000182	-0.001796	-0.016302	0.001725	-0.084603	0.03748	0.018132
amc	st. dev			0.170042	0.19818	0.13688	0.092815	0.188094	
	mean			-0.001156	0.020099	-0.027492	-0.020019	-0.038167	
studeb	st. dev	0.206597	0.195977	0.280321	0.280321				
	mean	-0.006913	-0.007087	0.011368	0.011368				
packard	st. dev	0.223114	0.187234	0.107029	0.107029				
	mean	0.057746	0.011162	-0.041811	-0.041811				
hudson	st. dev	0.200407	0.186195	0.098529	0.098529				
	mean	0.095105	0.010527	-0.01907	-0.01907				
nash	st. dev	0.390304	0.316962						
	mean	0.028112	0.017133						
industry	st. dev	0.145861	0.139372	0.079111	0.067126	0.088107	0.08955	0.088704	0.081875
	mean	0.093952	0.062004	0.029882	0.033595	0.024391	-0.019957	0.030865	0.045813

auto stock prices divided by the S&P500 stock price

		1918-28	*1918-41*	*1948-00*	*1948-70*	*1970-00*	*1970-80*	*1980-90*	*1990-00*
gm	st. dev	*0.213194*	*0.172266*	*0.05879*	*0.066352*	*0.051239*	*0.044026*	*0.072389*	*0.02192*
	mean	*0.003571*	*0.002638*	*-0.01278*	*-0.02173*	*-0.00648*	*-0.00982*	*-0.00759*	*-0.00803*
ford	st. dev			*0.050352*	*0.046057*	*0.052478*	*0.063024*	*0.052042*	*0.045389*
	mean			*-0.0074*	*-0.00587*	*-0.00717*	*-0.02108*	*-0.0123*	*0.001149*
chrysler	st. dev	*0.444806*	*0.243829*	*0.065299*	*0.040836*	*0.079745*	*0.064677*	*0.097673*	*0.073517*
	mean	*-0.18241*	*-0.05268*	*-0.01673*	*-0.0318*	*-0.00736*	*-0.04255*	*0.007565*	*-0.00414*
amc	st. dev			*0.095735*	*0.120111*	*0.064283*	*0.042164*	*0.088971*	
	mean			*-0.00584*	*0.00264*	*-0.01593*	*-0.01062*	*-0.02475*	
studeb	st. dev	*0.207561*	*0.167586*	*0.18901*	*0.18901*				
	mean	*-0.04401*	*-0.03154*	*-0.01761*	*-0.01761*				
packard	st. dev	*0.187661*	*0.145828*	*0.07082*	*0.07082*				
	mean	*0.020267*	*-0.01436*	*-0.04794*	*-0.04794*				
hudson	st. dev	*0.188132*	*0.130295*	*0.079557*	*0.079557*				
	mean	*-0.0045*	*-0.0456*	*-0.0423*	*-0.0423*				
nash	st. dev	*0.392557*	*0.312088*						
	mean	*-0.08453*	*-0.10006*						
industry	st. dev	*0.125784*	*0.108988*	*0.035248*	*0.037218*	*0.033578*	*0.040372*	*0.038819*	*0.027427*
	mean	*0.061789*	*0.035215*	*-0.00204*	*0.000273*	*-0.00369*	*-0.01134*	*-0.00555*	*-0.00424*

TABLE 7

DF-ADF tests for the logs of real stock prices in the US PC industry

Firm	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Apple	1983-2000	SBC	DF+drift	-2.333	-3.04	I(1)
Hewlett-Pack	1979-2000	-	-	-	-	-
IBM	1979-2000	SBC	ADF(1)+drift	-1.822	-3.003	I(1)
NCR	1979-2000	-	-	-	-	-
Unisys	1979-2000	SBC	ADF(1)+drift+t	-3.855	-3.633	I(0)
Commodore	1979-1993	SBC	DF+drift	-2.071	-3.081	I(1)
Compaq	1985-2000	SBC	DF+drift	-2.117	-3.066	I(1)
Dell	1990-2000	SBC	DF+drift+t	-1.746	-3.927	I(1)
Gateway	1995-2000	SBC	DF+drift+t	-4.683	-4.581	I(0)
Toshiba	1992-1997	SBC	ADF(1)+drift	-1.498	-3.551	I(1)
Wang	1979-1998	SBC	DF+drift	-2.613	-3.019	I(1)
Wyse	1986-1988	SBC	DF+drift	-0.393	-4.706	I(1)

note:
DF = Dickey-Fuller Test, drift stands for intercept, t for trend
ADF = Augmented Dickey-Fuller Test, drift stands for intercept, t for trend
SBC = Schwarz Bayesian Criterion (based on ML)
I(1) = Integrated process of order 1, or Difference Stationary (DS)
I(0) = Stationary process, or Trend Stationary (TS)

TABLE 8

Descriptive statistics of stock prices (logs of differences) in the US PC Industry

						stock prices divided by the S&P 500			
		1970-00	**1970-80**	**1980-90**	**1990-00**	***1970-00***	***1970-80***	***1980-90***	***1990-00***
apple	st. dev	0.209303		0.238666	0.19128	*0.083065*		*0.09724*	*0.073131*
	mean	0.043676		0.064494	0.005768	*0.009145*		*0.020582*	*-0.00922*
compaq	st. dev	0.225305		0.230429	0.218546	*0.089324*		*0.099345*	*0.078982*
	mean	0.091429		0.135991	0.068572	*0.032226*		*0.057387*	*0.018271*
dell	st. dev	0.370061		0.694571	0.350854	*0.138582*		*0.281417*	*0.131854*
	mean	0.201428		0.190106	0.247106	*0.072183*		*0.086022*	*0.089015*
everex	st. dev	0.239683		0.296755	0.104951	*0.09334*		*0.117415*	*0.034097*
	mean	-0.129761		-0.052906	-0.199099	*-0.05629*		*-0.02735*	*-0.08481*
gateway	st. dev	0.337883			0.337883	*0.107928*			*0.107928*
	mean	0.080564			0.080564	*0.019431*			*0.019431*
hpackard	st. dev	0.132265	0.134861	0.135744	0.150659	*0.059641*	*0.070197*	*0.061558*	*0.063048*
	mean	0.043979	0.025972	-0.000603	0.081044	*0.011006*	*0.013164*	*-0.0052*	*0.019333*
ibm	st. dev	0.122494	0.098844	0.103189	0.147733	*0.054581*	*0.053856*	*0.056612*	*0.052748*
	mean	0.027457	0.005942	0.022224	0.050709	*0.001435*	*0.004051*	*-0.00277*	*0.004831*
nec	st. dev	0.265431	0.307358	0.295656	0.171236	*0.123413*	*0.152363*	*0.140936*	*0.056444*
	mean	0.050035	0.275437	0.019097	0.007448	*0.015864*	*0.1347*	*-0.00042*	*-0.00681*
toshiba	st. dev	0.298498			0.298498	*0.119026*			*0.119026*
	mean	0.077906			0.077906	*0.02701*			*0.02701*
unisys	st. dev	0.237456	0.090132	0.262856	0.353007	*0.093811*	*0.054849*	*0.108797*	*0.133124*
	mean	-0.013906	-0.040914	-0.092654	-0.000323	*-0.01384*	*-0.01852*	*-0.05017*	*-0.00969*
industry	st. dev	0.090528	0.070891	0.066299	0.119646	*0.034966*	*0.029413*	*0.032475*	*0.044552*
	mean	0.02582	-0.004754	0.015488	0.058539	*-0.00383*	*-0.00399*	*-0.01369*	*-0.0003*

TABLE 9

Analysis of the statistical properties of the series (processes) of the real dividends (logs) by US firms: DF and ADF tests

Firm	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Chrysler	1925-1941	SBC	DF+drift	-1.5616	-3.0819	I(1)
	1948-1997	SBC	DF+drift+t	-3.0655	-3.5005	I(1)
Ford	-	-	-	-	-	-
	-	-	-	-	-	-
	1956-1998	SBC	DF+drift+t	-3.1455	-3.5217	I(1)
GM	1918-1941	SBC	DF+drift	-4.368	-3.0039	I(0)
	1925-1941	SBC	DF+drift	-3.5828	-3.0522	I(1)
	1948-1998	SBC	DF+drift+t	-4.1592	-3.4987	I(0)
Hudson	1922-1941	SBC	ADF(1)+drift+t	-2.0859	-3.6921	I(1)
	1925-1941	SBC	ADF(1)+drift+t	-2.9512	-3.7119	I(1)
	-	-	-	-	-	-
Nash	1918-1941	SBC	DF+drift+t	-2.1926	-3.6921	I(1)
	1925-1941	SBC	DF+drift+t	-1.8594	-3.8731	I(1)
	-	-	-	-	-	-
Packard	1917-1941	SBC	ADF(1)+drift	-2.6589	-2.997	I(1)
	1925-1941	SBC	DF+drift	-2.0046	-3.0522	I(1)
	-	-	-	-	-	-
Studeback	1920-1941	SBC	DF+drift+t	-2.6264	-3.6746	I(1)
	1925-1941	SBC	DF+drift+t	-2.5698	-3.7119	I(1)
	1948-1966	SBC				

note:
DF = Dickey-Fuller Test, drift stands for intercept, t for trend
ADF = Augmented Dickey-Fuller Test, drift stands for intercept, t for trend
SBC = Schwarz Bayesian Criterion (based on ML)
I(1) = Integrated process of order 1, or Difference Stationary (DS)
I(0) = Stationary process, or Trend Stationary (TS)

TABLE 10

Descriptive statistics of dividends (logs of differences) in the US auto industry

	gm	ford	chrysler	studeb	packard	hudson	nash	industry
1918-1928								
mean	0.014397		0.110924	-0.023247	0.066026		0.013197	0.028383
sd	0.482548		0.019819	0.536553	0.467959		0.248424	0.323424
1918-1941								
mean	0.033447		0.076592	-0.013561	0.042445	0.037086	0.013197	0.033497
sd	0.390041		0.293965	0.454954	0.421882	0.605477	0.248424	0.260793
1948-2000								
mean	-0.009355	-1.35E-18	-0.007187	0.117701	0.174293	0.0546		-0.008183
sd	0.236352	0.183059	0.283631	0.41256	0.501824	0.316417		0.166783
1948-1970								
mean	0.002363	-0.001266	-0.024958	0.117701	0.174293	0.0546		0.000777
sd	0.217482	0.115859	0.302836	0.41256	0.501824	0.316417		0.166347
1970-2000								
mean	-0.018327	0.000633	-0.011149					-0.021017
sd	0.249796	0.2078	0.284339					0.169351
1970-1980								
mean	-0.013752	0.027978	-0.027366					-0.00438
sd	0.17152	0.121243	0.415832					0.135948
1980-1990								
mean	0.02803	0.02128	0.070741					0.040017
sd	0.300927	0.276309	0.253263					0.141594
1990-2000								
mean	-0.039131	-0.045216	-0.008671					-0.066232
sd	0.300438	0.185551	0.163264					0.238726

dividends divided by S&P500 dividends

	gm	*ford*	*chrysler*	*studeb*	*packard*	*hudson*	*nash*	*industry*
1918-1928								
mean	*-0.20397*		*-2.97376*	*0.002687*	*-0.38466*	*-1.85289*	*-1.43912*	*-0.53587*
sd	*1.970619*		*1.351719*	*2.158434*	*1.807524*	*1.927482*	*2.179365*	*1.351978*
1918-1941								
mean	*-0.24482*		*-1.03621*	*1.1693*	*0.554859*	*-1.85289*	*-1.12314*	*-0.14841*
sd	*1.783283*		*3.996167*	*3.064914*	*2.807317*	*1.927482*	*1.935122*	*2.216052*
1948-2000								
mean	*0.038245*	*0.021935*	*0.153166*	*-1.55441*	*-2.30179*	*-0.75077*		*-0.08632*
sd	*3.860647*	*0.260755*	*2.010349*	*8.667584*	*31.47605*	*2.343213*		*1.120368*
1948-1970								
mean	*0.137328*	*0.064747*	*0.280318*	*-1.55441*	*-2.30179*	*-0.75077*		*-0.1759*
sd	*6.268709*	*0.309609*	*2.877157*	*8.667584*	*31.47605*	*2.343213*		*1.672397*
1970-2000								
mean	*-0.02449*	*0.001267*	*-0.01519*					*-0.02433*
sd	*0.291131*	*0.233028*	*0.459053*					*0.189174*
1970-1980								
mean	*-0.03281*	*0.036619*	*-0.05477*					*-0.01699*
sd	*0.305296*	*0.171906*	*0.654712*					*0.218123*
1980-1990								
mean	*0.019654*	*0.010679*	*0.179367*					*0.04059*
sd	*0.324001*	*0.311346*	*0.371452*					*0.165079*
1990-2000								
mean	*-0.0331*	*-0.04334*	*-0.00831*					*-0.05725*
sd	*0.262582*	*0.160829*	*0.148537*					*0.20252*

TABLE 11

Descriptive statistics for logs of real dividends in the US PC industry

Firm	*Market*	*Sample*	*selected by*	*reference test*	*Test stat.*	*95% crit. value*	*Process*
Apple	US	1989-1996	SBC	DF+drift+t	0.856	-4.196	I(1)
Hewlett-Pack	US	1979-2000	SBC	DF+drift+t	-2.016	-3.633	I(1)
IBM	US	1979-2000	SBC	ADF1+drift+t	-2.54	-3.633	I(1)
NCR	US	1979-1991	SBC	DF+drift+t	-4.571	-3.828	I(0)
Unisys	US	1979-1990	SBC	DF+drift+t	-1.304	-3.873	I(1)
Wang	US	1979-1989	SBC	DF+drift	-2.876	-3.18	I(1)
Wyse	US	1979-2000	-	-	-	-	-
DF-ADF tests for E/S by firm							
Apple	US	1980-2000	SBC	ADF(1)+drift	-3.498	-3.011	I(0)
Hewlett-Pack	US	1979-2000	SBC	DF+drift	1.905	-3.004	I(1)
IBM	US	1979-2000	SBC	ADF(1)+drift	-2.195	-3.004	I(1)
NCR	US	1979-2000	SBC	ADF(1)+drift+t	-2.505	-3.633	I(1)
Unisys	US	1979-2000	SBC	DF+drift	-3.618	-3.004	I(0)
Commodore	US	1979-1993	SBC	ADF(1)+drift	-2.46	-3.082	I(1)
Compaq	US	1983-2000	SBC	DF+drift	-4.611	-3.04	I(0)
Dell	US	1987-2000	SBC	DF+drift+t	0.815	-3.792	I(1)
Gateway	US	1992-2000	SBC	ADF(1)+drift+t	-4.993	-4.081	I(0)
Toshiba	US	1979-2000	SBC	DF+drift	-3.354	-3.004	I(0)
Wang	US	1979-1998	SBC	DF+drift+t	-2.613	-3.659	I(1)
Wyse	US	1983-1988	SBC	DF+drift	-1.696	-3.551	I(1)

TABLE 12

Descriptive statistics of dividends (logs of differences) in the US PC Industry

						dividends divided by the S&P 500 dividend			
		1970-00	**1970-80**	**1980-90**	**1990-00**	***1970-00***	***1970-80***	***1980-90***	***1990-00***
apple	st. dev	0.263737		0.20787	0.233295	*0.2505*		*0.2272*	*0.1972*
	mean	0		0.18809	-0.074697	*0.0279*		*0.2286*	*-0.0531*
compaq	st. dev	0.367919			0.367919	*0.3147*			*0.3147*
	mean	0.376664			0.376664	*0.3283*			*0.3283*
hpackard	st. dev	0.078744	0.05656	0.101334	0.040454	*0.1401*	*0.1227*	*0.1166*	*0.0387*
	mean	0.066423	0.08854	0.033962	0.085194	*0.1460*	*0.3103*	*0.0926*	*0.0886*
ibm	st. dev	0.116946	0.03359	0.017298	0.177071	*0.1255*	*0.0739*	*0.0193*	*0.1613*
	mean	0.008652	0.06962	0.013481	-0.040089	*0.0299*	*0.1375*	*0.0149*	*-0.0338*
nec	st. dev	0.159784	0.03196	0.232574	0.056952	*0.2020*	*0.0883*	*0.2796*	*0.0488*
	mean	-0.003193	0.05077	-0.017321	-0.00702	*0.0436*	*0.1812*	*0.0198*	*0.0107*
toshiba	st. dev	0.080092	0.08009			*0.1226*	*0.1226*		
	mean	0.047025	0.04702			*0.0756*	*0.0756*		
unisys	st. dev	0.125461	0.11623	0.09945		*0.1868*	*0.1933*	*0.0975*	
	mean	0.03501	0.11917	-0.013284		*0.0833*	*0.2308*	*-0.0065*	
industry	st. dev	0.1107	0.0663	0.0364	0.1689	*0.1161*	*0.1024*	*0.0425*	*0.1524*
	mean	0.0091	0.0567	0.0138	-0.0410	*0.0042*	*0.0663*	*-0.0096*	*-0.0443*

TABLE 13

Standard Deviation and Mean of Market Shares, Units, Stock Prices and Dividends

	MS Inst.	Units	Stock	Dividend	Stck/SP500	Div/SP500
AUTO						
1908-1918	**25.2**	**0.1620**				
		0.0401				
1918-1928	**22.6**	**0.1569**	**0.1458**	**0.3234**	**0.1257**	1.3520
		0.0304	*0.0939*	*0.0283*	*0.0617*	*-0.5536*
1918-1941	17.9	0.1500	0.1393	0.2608	0.1089	**2.2161**
		0.0378	*0.0620*	*0.0334*	*0.0352*	*-0.1484*
1948-2000	7.6	0.0638	0.0791	0.1668	0.0352	0.9974
		0.0070	*0.0298*	*-0.0881*	*-0.0020*	*-0.0863*
1948-1970	10.3	0.0759	0.0671	0.1663	0.0372	1.5054
		0.0171	*0.0335*	*0.0007*	*0.0002*	*-0.1759*
1970-2000	5.6	0.0523	0.0881	0.1694	0.0335	0.1772
		-0.0030	*0.0243*	*-0.0210*	*-0.0036*	*-0.0243*
PC						
1970-1980	1.4	**0.2062**	0.0708	0.0663	0.0294	0.1024
		0.2431	*-0.0047*	*0.0567*	*-0.0039*	*-0.0663*
1980-1990	11.5	0.1884	0.0662	0.0364	0.0324	0.0425
		0.1450	*0.0154*	*0.0137*	*-0.0136*	*-0.0096*
1990-2000	**17.9**	0.0357	**0.1196**	**0.1689**	**0.0445**	**0.1524**
		0.0646	*0.0585*	*-0.0410*	*-0.0003*	*-0.0043*
1970-2000	28.9	0.1758	0.0905	0.1107	0.0349	0.1166
		0.1504	*0.0258*	*0.0091*	*-0.0038*	*0.0041*

italics=mean value
bold number=highest decade
MS Inst.= instability index from Eq. (1)
Units=standard deviation and mean of units produced
Stock=standard deviation and mean of industry-level stock price
Dividend=standard deviation and mean of industry-level dividend
Stck/SP500= industry-level stock price divided by S&P500 stock price
Div/SP500=industry-level dividend divided by S&P500 dividend

TABLE 14

Auto industry 1927-1951

Restricted SURE estimates (ML estimates for the Fixed Effect Panel)

Homogeneity restrictions for all the coefficients (variables in logs of first differences)

	int	StPrSP500	Div	Div SP500	MktSh	Nfirms	Herf
Chrysler	0.097211	-	-	-	-	-	-
t-value	1.802						
Gen. Motors	0.029421	-	-	-	-	-	-
t-value	0.36932						
Studebaker	0.092913	-	-	-	-	-	-
t-value	0.34865						
Hudson	-0.012132	-	-	-	-	-	-
t-value	-0.13587						
Packard	-0.048739	-	-	-	-	-	-
t-value	-0.11418						
FE Panel	0.0317348	1.1901	0.22154	-0.75814	1.6945	0.10523	-2.5164
t-value	0.453984	*6.7143*	*7.8966*	*-3.5449*	*4.3548*	*0.29019*	*-8.4993*
Wald-test for Homog restr (1)		1.28E+11					
Wald-test for Homog restr (2)		31.7782	8.01E+10	105.6889	2.28E+09	165.1449	3.53E+01
ML	-23.3301						
SBC	-38.2243						

Note: Wald Homogeneity restriction test (1): Homogeneity restrictions (equality) for the firm-level coefficients of all the regressors

Note: Wald Homogeneity restriction test (2): Homogeneity restrictions (equality) for the firm-level coefficients of the single variables

TABLE 15

Auto industry 1957-1997

Restricted SURE estimates (ML estimate for the Fixed Effect Panel)

Homogeneity restrictions for all the coefficients (variables in logs of first differences)

	int	StPrSP500	Div	Div SP500	MktSh	Nfirms	Herf
Chrysler	-0.071372	-	-	-	-	-	-
t-value	-1.406						
Gen.Motors	-0.042365	-	-	-	-	-	-
t-value	-1.316						
Ford	-0.063612	-	-	-	-	-	-
t-value	-1.8497						
FE Panel	-0.05911633	0.94722	0.061502	0.0043001	0.50341	0.11348	*0.26794*
t-value	-1.5239	*5.0049*	*2.2092*	*0.18261*	*0.70544*	*0.2642*	*0.75981*
Wald-test for Homog restr (1)		11,5370**					
Wald-test for Homog restr (2)		0,70006**	4,9081*	2,6299**	1,4789**	0,21925**	2,3759**
ML	7.7857						
SBC	-8.9254						

Note: Wald Homogeneity restriction test (1): Homogeneity restrictions (equality) for the firm-level coefficients of all the regressors

Note: Wald Homogeneity restriction test (2): Homogeneity restrictions (equality) for the firm-level coefficients of the single variables

TABLE 16

PC industry 1975-2000)

Restricted SURE estimates (ML estimate for the Fixed Effect Panel)

Homogeneity restrictions for all the coefficients (variables in logs of first differences)

	int	StPrSP500	StPrIND	dldivIND	Pr/Earn	MktSh	Nfirms	Herf
Apple	0.050832	-	-	-	-	-	-	-
t-value	*0.48397*							
H-P	0.062499	-	-	-	-	-	-	-
t-value	*1.0608*							
IBM	0.032559	-	-	-	-	-	-	-
t-value	*0.58648*							
NCR	0.10719	-	-	-	-	-	-	-
t-value	*1.7181*							
Unysis	-0.018619	-	-	-	-	-	-	-
t-value	*-0.13622*							
Panel	0.0468922	-0.36311	0.66459	-0.25689	0.063212	-0.083297	1.0726	-0.143
t-value	*0.742626*	*-1.963*	*7.091*	*-4.0585*	*2.3336*	*-1.8048*	*1.1707*	*-2.0388*
Wald-test for Homog restr (1)		1.73E+10						
Wald-test for Homog restr (2)		8,3355*	362.8003	10.7475	142.7652	170.9432	1.73E+10	9.9136
ML	-9.1565							
SBC	-26.4987							

Note: Wald Homogeneity restriction test (1): Homogeneity restrictions (equality) for the firm-level coefficients of all the regressors

Note: Wald Homogeneity restriction test (2): Homogeneity restrictions (equality) for the firm-level coefficients of the single variables

Notes

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[i] The firms used to create the S&P index for automobiles are (dates in parentheses are the beginning and end dates): Chrysler (12-18-25), Ford Motor (8-29-56), General Motors (1-2-18), American Motors (5-5-54 to 8-5-87), Auburn Automobile (12-31-25 to 5-4-38), Chandler-Cleveland (1-2-18 to 12-28-25), Hudson Motor Car (12-31-25 to 4-28-54), Hupp Motor Car (1-2-18 to 1-17-40), Nash-Kelvinator Corp (12-31-25 to 4-28-54), Packard Motor Car (1-7-20 to 9-29-54), Pierce-Arrow (1-2-18 to 12-28-25), Reo Motor Car (12-31-25 to 1-17-40), Studebaker Corp. (10-6-54 to 4-22-64), White Motor (1-2-18 to 11-2-32), and Willy's Overland (1-2-18 to 3-29-33).

[ii] Since in the post-war period, the results were not sensitive to whether we used the aggregate industry data (provided by S&P) or the average of the firm-specific one, this suggests that the pre-war data is robust.

[iii] The computer industry was first labelled by S&P as *Computer Systems* and then in 1996 changed to *Computer Hardware*. Firms included in this index are:
Apple Computer (4-11-84), COMPAQ Computer (2-4-88), Dell Computer (9-5-96), Gateway, Inc. (4-24-98), Hewlett-Packard (6-4-95), IBM (1-12-19), Silicon Graphics (1-17-95), and Sun Microsystems (8-19-92).

[iv] Recent empirical studies have suggested that the best simple generalization is that, on average, smaller firms have a lower probability of survival, but those that survive grow proportionately faster than large firms. The real problem lies not in characterizing what happens on average but the fact that a wide range of different patterns occurs across different markets, so that it is difficult to generalize as to the normal size-growth relationship or the 'typical' shape of the distribution.

[v] Hymer and Pashigian (1962) define market share instability, I, as:

$$I = \sum_{i=1}^{n} [| s_{it} - s_{i,t-1} |], \text{ where } s_{it} = \text{the market share of firm } i \text{ at time } t.$$

[vi] In the 1980's IBM focussed on incremental technical change with backward compatibility: all other firms' hardware and software products had to work with IBM equipment. IBM's power first came under threat when the Intel 80386 chip was used by Compaq's new computer, so that the computer was marketed for the quality of the chip not the IBM compatibility. Once the "industry standard" label became more important than the "IBM compatible" label, IBM became much weaker. The next shakeup to the power structure came when IBM split with Microsoft over operating systems in 1990. The industry standard now changed to the "Wintel" standard, finishing off what remained of IBM's special status. Another reason why the 1990's presented such disruptive change was due to the development of the new "client/server" platform (networked platform with highly intelligent terminals). This new platform was based on a vertically disintegrated structure which devalued traditional management causing the strengths of the incumbents (mainly IBM and DEC) to become obsolete (Bresnahan and Greenstein, 1997). The tradition of backward compatibility made the incumbent platforms particularly hard to change in reaction to the users' new needs.

[vii] The capital asset pricing model (CAPM) measures *idiosyncratic risk* through the covariance between the firm-level (or industry-level) stock return and the market-level stock return: the lower is this covariance the higher is the unsystematic or idiosyncratic level of risk. Through cointegration analysis, Mazzucato (2002) finds that this idiosyncratic risk is higher in the early phase of the industry life-cycle.