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Mazzucato, M and Semmler, W (2002). The determinants of stock price volatility: an industry study. *Nonlinear Dynamics, Psychology, and Life Sciences*, 6 pp. 230–253.

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The Determinants of Stock Price Changes: An Industry Study.

M. MAZZUCATO* and W. SEMMLER**

Abstract

The currently ongoing IT-revolution is a great challenge for economists. The industry displays ever arising new technologies, unstable markets shares, long term swings and short term volatility of stock prices. Yet, to study those phenomena empirically one is constrained by a lack of data. The U.S. auto industry, for which long term time series are available, has shared a similar experience since its early development. This paper studies how long term swings and short term stock price volatility in the U.S. auto industry is related to innovative efforts and switching of market shares of firms. The early period of the life-cycle of the industry was characterized by high product innovation, high market share instability, volatile stock prices and the later period by fewer firms, process innovation, more stable market shares and less stock price volatility. In this paper we focus on the “transition” period leading from the first to the second period and study the relation of innovative effort, market share fluctuations and stock price dynamics. After presenting stylized facts on the life-cycle of the industry we introduce a dynamic model that is able to replicate some of the stylized facts. The dynamic model admits heterogeneous firms and encompasses both evolutionary as well as optimizing approaches.

Keywords: market share dynamics, industry life-cycle, stock price volatility

JEL Classification: L11 (Market Structure: Size Distributions of Firms), O30 (Technological Change), G12 (Asset Pricing)

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I Introduction

Models of behavioral finance tend to explain stock price volatility by heterogeneous trading strategies, for example, the interaction of fundamentalists and noise traders (Lux, 1998)¹ This study looks at the *real* cause for stock price long swings and short run volatility by focusing on the evolution of firm market shares and innovative behavior in a particular industry over time. An interesting example to study today would be the Information Technology (IT) industry. The study of the currently on-going IT-Revolution is indeed a great challenge for economic theorists. The IT industry displays ever arising new technologies, unstable market shares of firms, long term swings in stock prices and short-term volatility in stock prices. Yet, because there is still a lack of data to properly study the *evolution* of this industry, we focus on an industry, the US automobile industry, for which we have long time series data on firm market shares, innovative effort, and stock prices. Although this industry, as any other, has particular characteristics, we believe that interesting lessons can be learned regarding the general interaction between real and financial variables.

We explore how *switches* in firm market shares are related to switches in innovative effort and stock price movements. “Switching” refers to changes in the ranking of firms with respect to the variable in question. We focus on particular time periods in which there was a lot of instability and others in which there was less instability. The first period gives rise to a “transition” stage where a small number of firms become dominant due to their early success in innovation. In section III we review different theories which address the cause of this transition.

After presenting in section II some stylized facts regarding market shares, innovation and stock prices, section III uses insights from the industry life-cycle literature and *evolutionary* economics to argue why market share changes might be related to changes in other variables. Evolutionary economics is particularly useful for this analysis due to its emphasis on the origin and evolution of *variety* between firms with respect to strategic behavior, technology, and performance.

Section IV presents a dynamic model of the “switching” in market shares, innovative effort and stock prices, which incorporates both evolutionary and optimizing behavior. The model explores

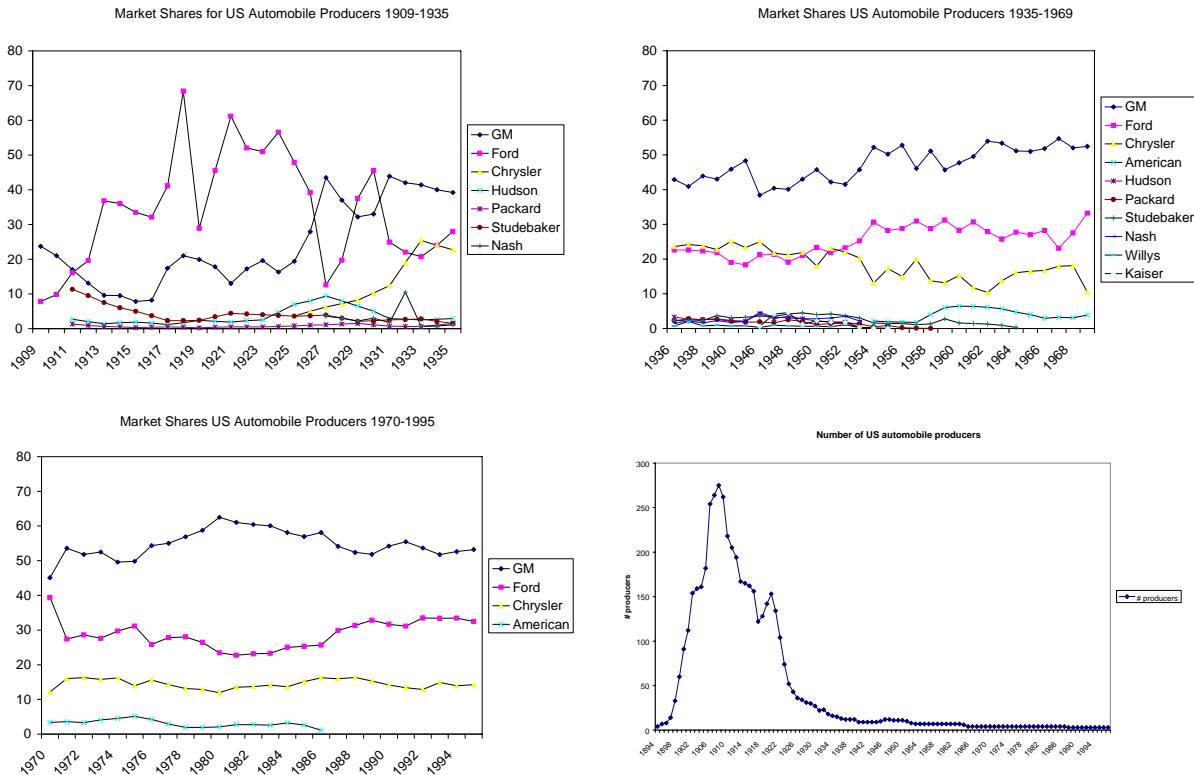
¹ For a stock market model with heterogenous agents , see also Aoki (1999).

three different types of interaction: *cooperative* behavior, *competitive* behavior and *predator-prey*. We relate the market share dynamics which emerge from the model to the empirical patterns observed in the data.

II Stylized Facts

Gort and Klepper (1982) found the following stylized facts to hold across 46 products. During the early stage of an industry’s evolution, when only primitive know-how exists, there is high entry with many small firms and the product price is relatively high. This phase is characterized by market share instability and relatively low concentration. As entry and total output increase, the product price falls. At some point, the number of producers reaches a peak, after which it falls steadily (a “shakeout”), although total industry output continues to rise. This later stage is characterized by more market share stability and greater market concentration. Studies on a wide set of industries have documented these patterns (see French, 1990 for the tire industry; Phillips, 1971 for the airframe industry; Gruber, 1994 for the semiconductor industry; and Datta, 1971 for the television set industry). Figures 1-4 illustrate the patterns for the US automobile industry:

Figs. 1-4 Market shares and firm numbers for US automobile producers (% of US production only)



We see that the early years of the US automobile industry were characterized by high market share instability and an increasing number of firms, while the later years were characterized by more stability, higher concentration and much fewer firms (from 275 in 1909 to only a dozen in 1950). We review some explanations of these patterns in section III.

As regards innovation rates, Klepper and Simons (1997) conduct a study which find innovation rates to also exhibit regularities over time in a wide set of industries (e.g. automobiles, tires, television sets, penicillin). Using innovation data for the automobile industry collected by Abernathy et al. (1983)², they review the patterns of innovation during the period 1895-1940. They find that the period of high market share instability was characterized by higher than average *product* innovation which was widely distributed among firm sizes, while the more stable period was characterized by higher *process* innovation which was instead carried out primarily by the largest firms:

“Product innovation [in the US automobile industry] was greatest from 1899-1905. After 1905, it peaks in 1912-1915, then again at a higher level in 1922-1925, and again in the early 1930’s...The two leading firms, Ford and GM, accounted for only 33.7% of the 52 product innovations [from 1895-1922], considerably less than their share of the market after the start of the shakeout. Relatively minor producers contributed a disproportionate share of innovation not only during the early years of the industry, but also after the start of the shakeout.” (Klepper and Simons, 1997: p. 396)

After the shakeout, there was a significant decline in product innovations. As regards process innovation:

“...In contrast to product innovation, the trend in process innovation is clearly upward from the start of the industry through 1915 or so. It then drops but reaches a new high around 1923 and an even greater high in the early 1930’s after which it drops sharply....The industry’s major process innovations were dominated by Ford and GM. From 1907 to 1920, all but two of the innovations [from 1896-1936] were developed by Ford. In the 1920’s, the majority of process innovations were introduced by GM, and then in the 1930’s all the innovations were from Ford. This pattern contrasts sharply with the major product innovations, for which Ford and GM’s share together was only 35% for 1910-1919, 39% for 1920-1929 and 29% for 1930-1939.” (Klepper and Simons, 1997: p. 399)

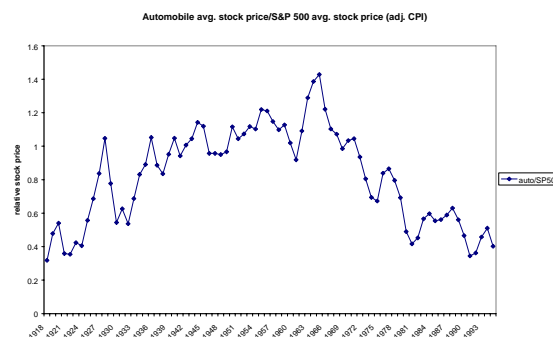
The turbulence that characterized the early period of the US automobile industry re-emerged in the 1970’s when consumers started to prefer small cars. Again, the opportunity for product innovation translated into market share turbulence (see more on this below).

² Abernathy et al. (1983) compiled a chronological list of automobile innovations by firm from 1893 to 1981. They devised a weighting scheme to evaluate each innovation in terms of its overall impact on the production process. They chose a seven-point transience scale, where 1’s represent those innovations that had little or no impact on the production process and 7’s those innovations that were very disruptive for the production process. The quotes by Klepper and Simons (1997) above refer to the *weighted* number of innovations.

What about regularities in stock prices? There are few studies which have looked at stock price changes over the history of an industry. Most of the time series literature focuses on the S&P500 data (i.e. across industries) and finds “excess volatility” to exist: stock prices are much more volatile than the underlying fundamentals. The explanation of the volatility has been on economy-wide factors such as the herd behavior and animal spirits of investors (Shiller, 1989; Shiller and Campbell, 1988). Some recent studies have made an attempt to connect stock price changes to the underlying changes in market shares and innovation patterns (Jovanovic and MacDonald, 1994; Mazzucato and Semmler, 1999). We review these in section III below.

Fig. 5 below shows the average stock price in the US automobile from 1918 (when the automobile stocks started being traded) to 1995 as a proportion of the average S&P 500 stock price. We see that the price rose until around the 1940’s, precisely the period in which market shares began to be much more stable, and fell later as the industry experienced less growth opportunities.

Fig. 5 Average automobile stock price divided by average S&P price

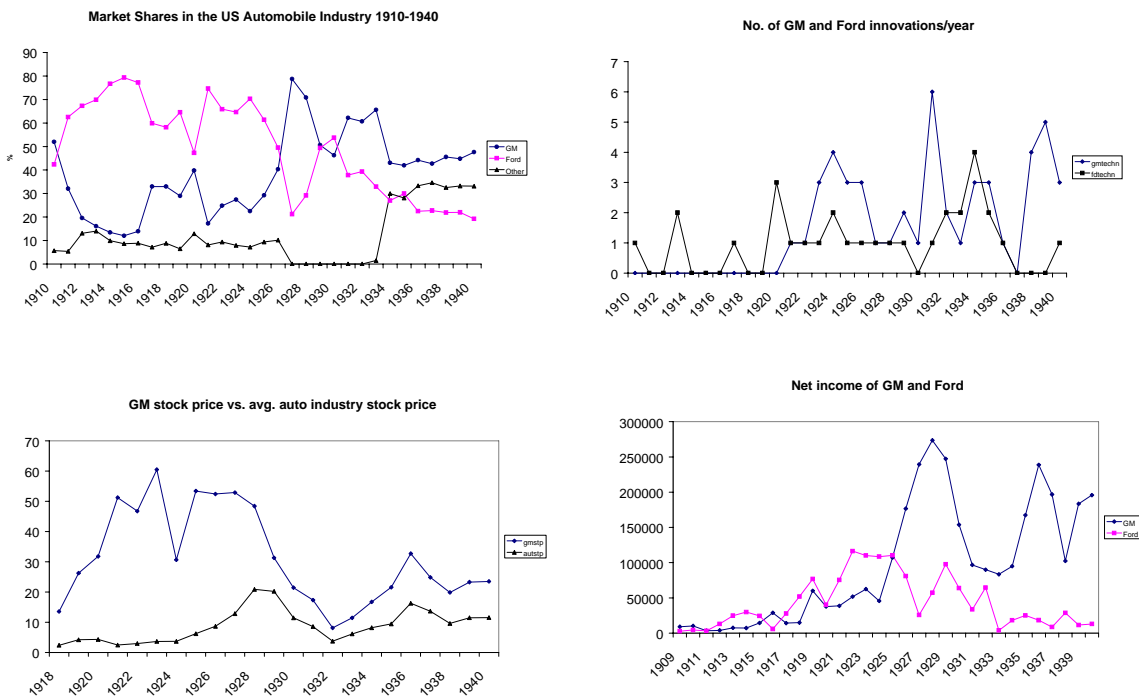


Mazzucato and Semmler (1999) find that the stock price patterns are distinct in different phases of the life-cycle, suggesting that stock price movements are related to industry-specific dynamics, not just to the stochastic elements of investor behavior. They find that: excess volatility is higher in the first phase of the life-cycle; average price-earnings ratios are higher in the first phase; and the variance across firms in market shares, stock prices and price-earnings is higher in the later stage.

The model we develop in section IV will attempt to explain these regularities, and specifically the transition period from unstable to stable market shares, in terms of the interaction between

innovating and non-innovating firms. Since market share turbulence amongst small firms is a characteristic that is not very surprising since it is often present during the entire life-cycle of an industry (when small firms exist), it is useful to focus here on the changes in ranking which occur between the relatively large firms, a characteristic that is only common in the really unstable period. Figures 6-9 below show the competition between Ford and GM during this period. Figure 6 shows that around 1927 Ford lost its market share lead to General Motors. Figure 7 shows that around 1922 the number of innovations/year carried out by GM superceded that of Ford. Figure 8 shows that, in contrast to the average industry stock price, the stock price of GM took off early on. And Figure 9 shows that net income (or profits) followed market shares closely. The time path of the patterns indicate that the switch in competitive position occurred first in the number of innovations/year, then in market shares and net income, and finally in stock prices.

Fig. 6-9 Ford and GM: market shares, innovative effort , stock prices, and net income



A possible explanation for these patterns runs as follows: to innovate, a firm must undertake significant initial costs, which will be repaid only once the innovation begins to affect future profits. This process takes time. Hence although GM began to supercede Ford in innovations in 1922, it took another 5 years for this success to begin affecting its market share and profits. In

turn, the increase in market share of GM did not begin to affect its *relative* stock price until 8 years after the increase in innovative effort.

III. Evolutionary Economics and the Industry Life-Cycle

Before outlining our dynamic model in Section IV, we review some explanations of the above patterns using the industry life-cycle literature and the Schumpeterian literature on “technological regimes,” both of which have drawn links between industry evolution and market share instability. At the end of the section we hypothesize the effect on stock prices.

Market shares and innovation

One group of life-cycle ideas claims that changes in market share patterns result from a change in competitive regime. Klein (1977), for example, claims that it was a change from “dynamic” to “static” efficiency which caused market share instability to decline in the US automobile industry. He defines static efficiency as decision making “along a given production possibilities frontier” and dynamic efficiency as the “extension of the frontier”. While in the former the lack of uncertainty allows decisions to be based on initial conditions, in the latter the existence of uncertainty prevents optimal tradeoffs to be known beforehand, rendering decisions based on “perfect knowledge” irrational. He claims that market share instability is more typical of periods in which firms compete based on dynamic efficiency, while market share stability is more typical of periods in which firms compete based on static efficiency. This view is similar to that found in Abernathy and Wayne (1974), where it is claimed that the changing nature of market patterns in the US auto industry resulted from the changing nature of demand and technology, which no longer made the learning curve (based on economies of scale) a good strategy to pursue. The advantages that Ford accrued from economies of scale worked to its disadvantage when consumers began to prefer a totally different style from the Model T: a closed body more comfortable car. In explaining the changes in market shares that resulted from Ford’s failure to adapt to changing demand conditions, they state:

“..the highly specialized production process lacked the balance to handle the new product ... management needs to recognize that conditions stimulating innovation are different from those favoring efficient, high-volume, established operations.” (Abernathy and Wayne 1974, p. 116, 118).

In this view, the strong economies of scale from 1909-1924 resulted in a stable large market share for Ford, while the changing nature of demand at the end of the 1920’s (which required

more flexible and explorative strategies to be used) led to its market share to undergo significant changes. When demand and technology became stable again, so did market shares (the above quote refers specifically to the changes that occurred at the end of the 1920's). Aoki (1986) too has claimed that when the environment surrounding a firm is stable, then economies of specialization are important and the hierarchical structure of (large) firms is better suited for the "exploitation" of such economies. If instead the environment is turbulent, and the adjustment to changing consumer tastes becomes crucial, decentralized information processing (more typical of small flexible firms) might be better for "exploration" and adaptation (Aoki, 1986).

Recent contributions in the Schumpeterian literature connecting market structure and technological regimes have made similar arguments (Malerba and Orsenigo, 1996). The technological regime called Schumpeter Mark I refers to those industries, or periods during the industry life-cycle, which are characterized by high rates of entry, less *persistence* in firms' abilities to innovate, and a more codifiable knowledge base. Under these conditions of "creative destruction," it is more common for innovators to be firms which are not currently leading the market. Mark II is instead characterized by increased process innovation and advertising spending, both of which are subject to strong economies of scale, allowing leaders to remain leaders. Under these conditions it is more common to find that typical innovators are the incumbent leading firms. The distinction between Mark I and Mark II can take place both between different periods in an industry's life-cycle (e.g. the early period is characterized more by Mark I while the mature period by Mark II), as well as between different industries or sectors. For example, Malerba and Orsenigo (1996) find that the chemical sector falls more into Mark II while the mechanical engineering sector falls more into Mark I. Likewise, the shampoo industry is currently more characterized by Mark I while automobiles by Mark II. During the industry life-cycle, industries may switch from a regime of Mark I, where competition is driven by product innovation, to one of Mark II when it is more driven by process innovation and advertising. Empirical studies by Malerba and Orsenigo (1996) have found market share instability to be higher in Mark I industries and concentration to be higher in Mark II industries. In an evolutionary simulation model which explores the types of market structures which emerge from these different types of technological regimes, Dosi et al. (1995) find that the former are characterized by more market share instability than the latter. Similarly, in a simulation model by

Mazzucato (1998), in which Mark I (II) is defined as the negative (positive) effect of size on the rate of cost reduction, market share instability is also found to be more characteristic of the Mark I period.

In the views described above, market share turbulence amongst small firms is considered to be part of normal affairs (across industries at different points in their histories) because of the greater vulnerability of small firms to economic events. However, turbulence amongst the large leading firms only occurs in periods characterized by “dynamic efficiency” or Schumpeter “Mark I”. It is for this reason that we focus our empirical example above (Figs. 6-9), as well as the dynamic model in section IV, on the transition between periods in which there is a lot of turbulence in the market shares of the leading firms and periods in which there is instead a lot of stability.

Another life-cycle approach is that found in Klepper (1996). In this view, it is not changes in regime that cause different types of market instability and concentration to emerge. Rather, there is always *positive* feedback between size and innovation but this does not lead to a monotonic increase in concentration due to the effect of randomly distributed innovation capabilities and timing of entry, which cause the early stage of the industry to be characterized by more market share instability. Market share instability later declines as a few firms get ahead and price-cost margins fall, reducing firm incentives to grow and to change their market shares given the related costs of adjustment. The role of chance events in the evolution of industry structure is also emphasized:

“...chance events and exogenous factors that influence the number of potential entrants to the industry, the growth rate of incumbent firms, and the ease of imitation of the industry leaders will influence the ultimate number and size distribution of firms in the industry.” (Klepper and Graddy, 1990, p.27)

This is similar to Brian Arthur’s emphasis on the effect of random events on positive feedbacks in the economy:

“...small fortuitous events – unexpected orders, chance meetings with buyers, managerial whims – to determine which ones achieve early sales and, over time, which firms dominate” (Arthur 1994, p. 5).

Stock prices

How might the market share patterns described above affect stock price changes?

Basing their work on the stylized facts found in Gort and Klepper (1982), Jovanovic and MacDonald (1994) make some predictions concerning the evolution of the average industry stock price around the “shakeout” period of the industry life-cycle. Focusing on the US tire industry, they build a model which assumes that an industry is born as a result of a basic invention and that the shakeout occurs as a result of one major refinement to that invention. They predict that just before the shakeout occurs the average stock price will fall because the new innovation precipitates a fall in product price which is bad news for incumbents. Later,

“...as some firms establish themselves as early winners in the innovation race, the index rises sharply, reflecting those firms’ enormous increase in both market share and value. Finally the index declines as the innovation diffuses, dissipating the rents earned by early innovators.”
(Jovanovic and MacDonald, (1994, p. 344-345)

Although Jovanovic and MacDonald (1994) is one of the few papers which directly connects the industry life-cycle to the evolution of stock prices, it does so at the industry level (and only during one specific period of the life-cycle), so that inter-firm variations are not accounted for.

As regards the effect of market share instability on investors’ anticipation of firm *growth*, various studies, including Ryals (1985) and Beaver and Morse (1978), have found that the P/E ratios are strongly affected by investors’ attitude, confidence and mood (Keynesian “animal spirits”). Beaver and Morse (1978) have attempted to measure such emotional anticipation of future events with detailed data reflecting how security companies make their predictions. They find growth anticipations to have less to do with the statistical patterns of *past* growth (the traditional way that economists have incorporated anticipated growth into models) than with more subtle ways in which expectations are formed. Thus in a period of high market share instability, since investors have less information regarding firm growth prospects (and hence future market shares as illustrated in Klein, 1977), they might be less “confident” to give a high price to a firm which experiences a sudden increase in market share than they would be in a more stable period. It is especially in such unstable periods that investors will be more likely to be influenced by the speculation of other investors, leading to herd effects and the type of over-reactions emphasized by Shiller (1989).

Kester (1984) offers an alternative view in his emphasis on the need for investors to balance considerations from net present value analysis and those from *expected future* growth analysis. While the former is better for simple growth options (from routing cost reduction, replacement projects, etc), the latter is better for “compound growth options” (from research and development, entry into a new market, etc.). Although his study is focused on the evaluation of investment projects, the analysis is useful for understanding the role of risk on stock prices. He states that it is often the smaller firms that have the highest growth opportunities (almost entirely based on future growth potential rather than on current cash flow). As an example, he cites an executive of a major consumer products company:

“If you know everything there is to know about a [new] product, it’s not going to be a good business. There have to be some major uncertainties to be resolved. This is the only way to get a product with a major profit opportunity.” (Kester 1984, p. 157).

Hence in this view, strong instability of market shares and earnings might represent the type of uncertainty signaling growth *opportunities*, causing the firm’s price-earnings ratio to be higher. Interestingly, Kester ends his article with a very similar question to that posed in the present study: “*What influence do industry structure and competitive interaction have on growth option value?*” He states that the answer will vary from one situation and industry to another.

Lastly, in terms of the variance of stock prices *across* firms, the above analysis might also prove useful. If periods of market share instability (signaling future growth opportunities for firms which are not currently leading) cause investors to have less confidence to bet too strongly with the firms who currently have attractive cash flows, the variance of stock prices (and price-earnings) between firms would be expected to be lower in the unstable period than in the more stable period.

Below we build a dynamic evolutionary model which attempts to reproduce the relationship between market shares, stock prices and innovative behavior reviewed in section II and III.

IV A Dynamic Model

The model we develop attempts to provide further insights on the above mentioned transition period where process innovation seems to have played a major role in stabilizing the market shares of the dominant firms. In particular, we are interested in explaining, for such a period, the

regularities in market shares, innovation and stock prices by looking at different types of interactions between firms which may be related to the changing nature of competition. We refer to two strands of literature. The first is grounded in the evolutionary approach. It revitalizes the Schumpeterian theory of technical change (Nelson and Winter, 1982; Silverberg et al., 1988) but also uses ideas from mathematical biology (Hofbauer and Sigmund, 1984) and the work by Arthur (1988, 1989) on the role of probability and positive feedback in the competition between old and new technologies. The second strand of literature assumes optimizing behavior. This was initiated by Arrow (1962) and has subsequently been extended by Dasgupta and Stiglitz (1980a,b).

As in the evolutionary tradition we present a model with *heterogeneous* firms. There are two types of firms, one group of firms, the challengers, who actively innovate and the other group, the incumbents, who operate existing technology, passively respond to changes in the technological environment. Innovating firms commit resources and undertake inventive investment expecting a return from it. They are postulated to optimize by computing the net present value of their revenue from the innovation. While the innovators aim at harvesting a technological rent, the second group, the incumbents or second movers, do not innovate, though, under competitive pressure, they may learn to improve their efficiency. Due to several kinds of interactions among the two groups of firms the model allows for switching in market shares and even multiple equilibria (Semmler and Greiner, 1996).

We posit that the new technology will be created at a certain cost – an innovation cost. The total cost for operating the new technology is assumed to be dependent on the effort spent to obtain the new technology (independent of the number of firms) and on a cost proportional to the number of firms operating it. We do not, however, presume that perfectly competitive conditions hold so that the innovation rent is instantly dissipating. The new technology is employed monopolistically. When the innovating firms expect gains from innovations - which in general will be equivalent to the present value of future profit flows - the firms will expand. Entry into the group of innovating firms from outside the industry may be encouraged when profits are positive and exit occurs with negative profits. The process of compressing the rent is assumed to be slow.

The above mentioned interaction effects are built into the model: a *predator-prey* relation between the new and the old firms; a *cooperative effect*; and a *competition* (or crowding) effect. The predator-prey relation occurs when new firms grow at the expense of the old firms. The competitive effect results when the new technology dissipates the rent of the old technology, reducing its price and compressing the mark-up. We use an inverse demand function to specify this effect (Dasgupta and Stiglitz, 1980a and 1980b). A cooperative effect (spillover or learning effect) bounds the number of old firms away from zero, so that, although firms exit, complete extinction of the old technology does not occur.

With a costly new technology, the innovating firms most likely will have an unprofitable period when the new technique is introduced. Yet, the forward looking stock market may anticipate stock gains. Firms then face a period when they can capture a technological rent, stock prices increase and finally firms lose their rent due to the subsequent competitive effect as a result of an increase in the capacity to produce.

Our intertemporal optimizing model reads as follows:

$$V_{\max} = \int_0^{\infty} e^{-rt} g(x_2, u) dt; u \in \Omega_+$$

with $g(x_2, u) = \mu(x_2, u)x_2u - cu - c_0x_2$, $\mu = 1/(\varnothing + x_2u)$, subject to

$$\dot{x}_1 = k - \alpha x_1 x_2^2 + \gamma x_2 - x_1 e / \mu \quad (1)$$

$$\dot{x}_2 = x_2(\alpha x_1 x_2 + v g(x_2, u) - \beta) \quad (2)$$

with $g(x_2, u) = \mu(x_2, u)x_2u - cu - c_0x_2$, $\mu = \alpha/(\varnothing + x_2u)$, where $k, \alpha, \beta, e, c, \varnothing$ and $v > 0$ are constants, x_1 is the number of firms operating the existing technique, x_2 the number of innovating firms, and u a control variable from the control space Ω_+ . Note that we require the control u to be non-negative. The control variable u indicates the level of effort spent to create the new technology. This can mean the hiring of engineers, running research laboratories or purchasing information on new technologies. The investment is risky since there is considerable uncertainty and risk involved (Arrow, 1962). For a stochastic version see Semmler (1994). The cost per unit of effort is denoted by c . The cost cu is independent of the number of firms and there is a cost proportional

to the number of firms, c_0x_2 . Thus, $cu+c_0x_2$ is the amount of resources that innovating firms have to devote to the innovation. The term $\mu(\cdot)$ is the (net) price, or markup, received for the product produced by the new technology, where $\mu(\cdot)x_2u$ is the net revenue.

When firms maximize a technological rent $g(\cdot)$, facing a revenue $\mu(\cdot)x_2u$ and the cost $cu+c_0x_2$, positive rent will increase their number. In (2) the term $\nu g(\cdot)$, with ν a constant, means that there is an expansion of the innovating firms which is proportional to their excess profit.

The term $ax_1x_2^2$ represents the predator-prey interaction where the adoption of the new technology is supposed to take place proportionally to the product of x_1 and x_2x_2 (a common assumption for the spread of information in sales-advertising models see Feichtinger et al. (1992) and Greiner/Semmler (1996)³). This implies that as the number of firms applying the new technology grows, so does the accessibility to that technology for the incumbents as well. This way the rate of decrease of the incumbents in (1) may be translated into an increase of the challengers in (2). It is reasonable to posit that information about the new technology leaks out faster the larger the number of firms that apply the new technology. Our assumption means that the diffusion speed accelerates by x_2 .

The term γx_2 in (1) reflects the cooperative effect of x_2 on x_1 . This represents learning by the incumbents to improve their production processes when information about the new technology spreads and the competitive pressure from the new technology increases. The last term x_1e/μ in (1) is the crowding effect for x_1 , with μ the mark up from an inverse demand function which also appears in (2).

Semmler and Greiner (1996) show that there are four equilibria of the optimally controlled system (1)-(2). These are: (E1): $x_1^*=1.2$, $x_2^*=17.1$; (E2): $x_1^*=20$, $x_2^*=0$; (E3): $x_1^*=31.1$, $x_2^*=0.2$; and (E4): $x_1^*=12.7$, $x_2^*=1.2$. However, only three equilibria are economically meaningful: (E1),

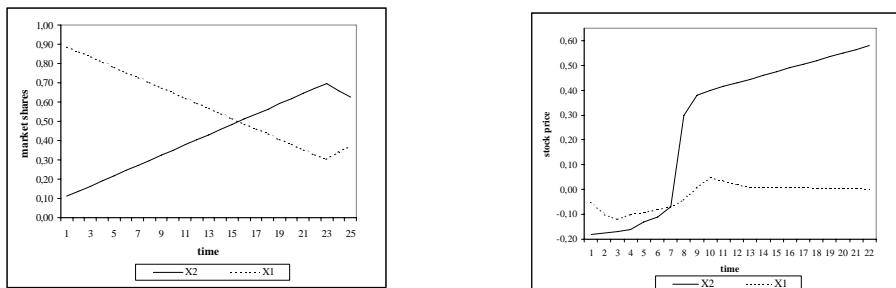
³ Our specific formulation of the predator-prey interaction can be justified in more general terms without reference to the sales-advertising model. A general form of a predator-prey interaction can be: $a(x_2)x_1$ with $a(x_2)=ax_2x_2$. The function $a(\cdot)$ is called a "trophic function". There are many forms of such a function discussed in the literature, cf. Svirzhev and Logofet (1983).

(E2) and (E4). This is because (E3) implies a negative control u^* for reasonable parameter constellations and is therefore not viable.

The dynamics of the model is solved analytically for $\delta \Rightarrow \infty$ and simulated for $\delta < \infty$ with the following parameters: $\varnothing=5$; $c=0.1$; $c_0=0.04$; $k=1$; $v=0.5$; $\gamma=0.8$; $e=0.01$; $\alpha=1$; $\beta=0.2$ (for details, see Semmler and Greiner, 1996).

Figure 10 depicts the relative market shares of the incumbents, x_1 and the innovators x_2 , for certain initial conditions. It shows that innovating firms that undertake an optimal inventive investment may succeed, but the incumbents may still coexist side by side with the challengers operating the new technology. In Fig. 11 the present value of the incumbents (dashed line) and the innovators (solid line) are depicted. The stock price of the incumbents is obtained by discounting their current profit flows and the innovators' stock price is obtained from the value function iteration using dynamic programming.⁴ Figures 10-11 replicate the aforementioned stylized facts on the innovators' expansion of market share, the delayed rise of its stock price, the long upswing of the innovators' stock price and the decline and low level of the incumbents' stock price due to the fact that they became the second mover (Arthur, 1989). They cease to be valued by the financial market.

Figs.10-11: Market Shares, Innovation and Stock Prices from the Model



⁴ Semmler and Greiner (1996) also show that, if the start-up cost for the innovator is too high compared to the expected returns, the innovator may end up with a negative present value and thus may go bankrupt.

V. Conclusions

As concerns the dynamics of such models it, generally, holds that instability emerges from cooperative interaction while stability emerges from competitive interaction. On the other hand the predator-prey interaction tends to generate cyclical market shares. Of course, which forces empirically prevail will depend on the strength of each of those interacting effects. Those interaction effects may provide us with useful guidelines on the evolution of the competitive dynamics of the industry. In fact our dynamic model allows us to connect industry life-cycle patterns which have been found to hold across a wide variety of industries (i.e. the early stage being characterized by higher product innovation, more market share instability, volatile stock prices, the later stage by fewer firms, process innovation and more stable stock market dynamics), to the underlying microeconomic interactions and innovation strategies of firms.

The results can be interpreted as follows:

- In the early stage of industry evolution, competition tends to have a *cooperative* nature because the high opportunities for technological innovation and the associated increases in demand provide potential benefits to all firms. This stage leads to much volatility in market shares and stock prices due to the trial and error aspect of innovation.

-The *predator-prey* interaction can be expected to occur when a set of successful innovative firms start growing at the expense of the non-innovative firms. Those firms that fail to innovate successfully may fall prey to the more successful innovators -- being the object of mergers and acquisitions -- or are forced to exit, leading to a large exit (shakeout) of firms⁵.

-The result that *competition* (crowding out) leads to stability can be interpreted as follows. Fierce competition between firms occurs when the high cost of competition only allows the large profitable firms to survive and grow. This is characteristic of the later stage of the industry life-cycle, when competition is mainly conducted via process innovation and advertising, both

⁵ This process may lead to multiple equilibria because who the winners are depend on the outcome of the early probabilistic trial and error aspect of innovation (Arthur, 1989).

subject to strong economies of scale and sunk costs which prevent the entry of small new firms (Sutton, 1990). Large firms grow through a “success breeds success” dynamic from the positive feedback embodied in the economies of scale. This path-dependent cumulative dynamic leads to a more stable and concentrated market structure.

In our model we have mostly focused on the transition stage between an early and a mature period in the industry life-cycle, but in most industries the mature phase of the industry life-cycle, once it has been established, is again shaken up when demand is saturated and only product innovation can re-stimulate consumer demand (Malerba and Orsenigo, 1996). This occurred in the U.S. automobile industry in the early 1970’s with the advent of small cars. The large size and inertia (caused by factors like internal bureaucracy) of the incumbents caused them to fail to note the opportunity that small cars presented. This allowed a wave of new entrants from abroad (mainly Japan) to fill the niche. The new innovations, centered around small car technology, caused the industry to re-experience some of the characteristics of the early stage of the life-cycle: high entry, product innovation, unstable market share and some stock price volatility.

Overall, the study of the life cycle of an established industry, such as the US automobile industry, from an evolutionary perspective, may reveal to us the dynamics of market shares and stock markets that we could also expect in the IT industry to come. The IT industry appears to be in its early period, with turbulence of market shares, long swings in stock prices and short term volatility of stock returns. Since, however, the transition stage to the second period is already visible, we might, with insight from the above results, be able to foresee some of the likely changes that are to come.

References

- ABERNATHY, W.; K. CLARK, K. and A. KANTROW (1983), Industrial Renaissance: Producing a Competitive Future for America, New York: Basic Books.
- ABERNATHY, W.J., WAYNE, K. (1974) “Limits to the Learning Curve”, *Harvard Business Review*, 52: 109-120
- AOKI, M. (1986), “Horizontal vs. Vertical Information Structure of the Firm,” *American Economic Review*, 76; 971-83
- AOKI, M (1999), “Open Models of Share Markets with Several Types of Participants,” mimeo, Dept. of Economics, UCLA.

ARROW, K. (1962), Economic Welfare and the Allocation of Resources for Innovation, in R. Nelson (ed.), The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton, Princeton University Press.

ARTHUR, B. (1989), "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Economic Journal*, vol. 99 (394): 116-131.

ARTHUR, B. (1994), Increasing Returns and Path Dependence in the Economy, Ann Arbor: University of Michigan Press.

BEAVER, W., and D. MORSE (1978), "What Determines Price-Earnings Ratios," *Financial Analysts Journal*, July: 65-76

CAMPBELL, J., and R. SHILLER (1988), "The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors," *Review of Financial Studies*, 14: 195-228

DASGUPTA, P. and J. STIGLITZ (1980a), "Industrial Structure and the Nature of Innovative Activities," *Economic Journal*, vol. 90: 266-293.

DASGUPTA, P. and J. STIGLITZ (1980b), "Uncertainty, Industrial Structure and the Speed of Innovation," *The Bell Journal of Economics*, vol. 11(1): 143-166.

DATTA, Y. (1971), "Competitive Strategies and Performance of Firms in the US Television Set Industry, 1950-60," Ph.D. Dissertation, SUNY Buffalo, Business Administration Department.

DOSI, G., MARSILI, and O., ORSENIGO, and L., SALAVATORE, R. (1995), "Learning, Market Selection and the Evolution of Industrial Structures," *Small Business Economics*, 7

EPSTEIN, R. (1928), The Automobile Industry; Its Economic and Commercial Development, New York: Arno Press

FEICHTINGER, G. (1992), "Hopf Bifurcation in an Advertising Diffusion Model," *Journal of Economic Behavior and Organization*," vol. 17: 401-411.

FRENCH, M.J. (1991), The US Tire Industry, Boston: Twayne Publishers.

GORT, M., KLEPPER, S. (1982), "Time Paths in the Diffusion of Product Innovations," *Economic Journal*, 92.

GRUBER, H. (1994), Learning and Strategic Product Innovation: theory and evidence for the semiconductor industry, Amsterdam: North-Holland.

HOFBAUER J., and K. SIGMUND (1988), Evolutionary Theory and Dynamic Systems, Cambridge, MA: Cambridge University Press.

JOVANOVIC, B., MACDONALD, G. (1994), "The Life-cycle of a Competitive Industry," *Journal of Political Economy*, 102 (2).

JOVANOVIC, B., GREENWOOD (1999), "The Information Technology Revolution and the Stock Market," *American Economic Review*, 89.

KESTER, C. W. (1984), "Today's Options for Tomorrow's Growth," *Harvard Business Review*, 62(2): 153-160.

KLEIN, B. H. (1977), Dynamic Economics, Cambridge, MA: Harvard University Press.

KLEPPER, S. (1996), "Entry, Exit, Growth, and Innovation over the Product Life Cycle," *American Economic Review*, 86 (3): 562-583

KLEPPER, S., and E. GRADDY (1990), "The Evolution of New Industries and the Determinants of Market Structure," *Rand Journal of Economics*, 21: 24-44

- KLEPPER, S. and K. SIMONS (1997), "Technological Extinctions of Industrial Firms: An Inquiry into their Nature and Causes," *Industrial and Corporate Change*, Vol. 6.
- LUX, T. (1998), "The Socio-economic Dynamics of Speculative Markets: Interacting Agents, Chaos, and the Fat Tails of Return Distributions," *Journal of Economic Behavior and Organization*; 33(2): 143-65.
- MALERBA, F., and L. ORSENIGO (1996), "The Dynamics and Evolution of Industries," *Industrial and Corporate Change*, 5(1): 51-88.
- MALKIEL, B.G., and J.G. CRAGG (1970) "Expectations and the Structure of Share Prices," *American Economic Review*, 60(4): 601-617
- MAZZUCATO, M. (1998), "A Computational Model of Economies of Scale and Market Share Instability," *Structural Change and Economic Dynamics*, 9: 55-83
- MAZZUCATO, M., SEMMLER, W. (1999), "Stock Market Volatility and Market Share Instability during the US Automobile Industry Life-Cycle," *Journal of Evolutionary Economics*, 9(1).
- NELSON, R., and S.G. WINTER (1982), An Evolutionary Theory of Economic Change, Cambridge, MA: Harvard University Press.
- PHILLIPS, A. (1971), Technology and Market Structure: a study of the aircraft industry, Lexington: Heath Lexington Books.
- RYALS, S. D. (1985), "Secular and Cyclical Trends in Price-Earnings Ratios," *Business Economics*, 20(2): 19-23
- SEMMLER, W. (1994), "Information, Innovation and Diffusion of Technologies," *Journal of Evolutionary Economics*, Vol. 4: 45-58.
- SEMMLER, W., GREINER, A. (1996), "Inventive Investment and the Diffusion of Technology," *Revue Internationale de Systemique*, Vol. 100 (3).
- SHILLER, R.J. (1989), Market Volatility, Cambridge: MIT Press
- SILVERBERG, G., and G. DOSI, and L. ORSENIGO (1988), "Innovation, Diversity and Diffusion: A Self-Organizing Model," *Economic Journal*, 98(393): 1032-54.
- SVIREZHEV, Y. and D.LOGOFET (1983), Stability of Biological Communities, Moscow, Mir Publishers.