The Information Technology Revolution and the Stock Market: Preliminary Evidence

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Abstract

Since 1968, the ratio of stock market capitalization to GDP has varied by a factor of 5. In 1972, the ratio stood at above unity, but by 1974, it had fallen to 0.45 where it stayed for the next decade. It then began a steady climb, and today it stands above 2.

We argue that the IT revolution was behind this and, moreover, that the capitalization/GDP ratio is likely to decline and then rise after any major technological shift. The three assumptions that deliver the result are:

1. The IT revolution was *anticipated* by early 1973,
2. IT was *resisted* by incumbents, which led their value to fall, and
3. Takeovers are an imperfect policing device that allowed many firms to remain inefficient until the mid 1980's.

We lay out some facts that the IT hypothesis explains, but that some alternative hypotheses – oil-price shocks, increased market volatility, and bubbles – do not.

*New York University. This paper is part of a project that includes J. Greenwood, and it implements many of his suggestions. We thank H. Chun and V. Ramey for providing us with data, and T. Cooley, P. Gourinchas, L. Li, and A. Viard for comments.

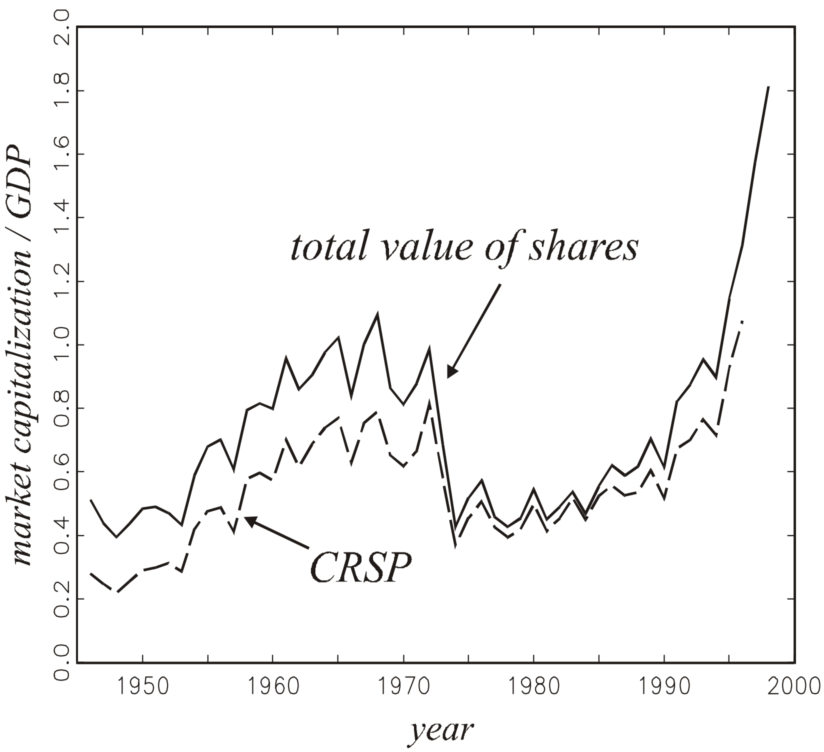

Figure 1: Stock market value relative to GDP

1 Introduction

In this paper, we shall study the post-war behavior of the U.S. stock market. We shall argue that a major technological innovation causes the stock market to be temporarily undervalued until the claims to future dividends enter the stock market via initial public offerings. In other words, aggregate capitalization can fall below the present value of dividends because a chunk of the capital stock may be missing from the stock market. Capital is likely to "disappear" during epochs of major technological change – especially at the beginning of such epochs, because this is when new capital forms in small, private companies. Only when a private company promises to be successful is it IPO'd, and only then does its capital stock become a part of stock-market capitalization. Greenwood and Jovanovic (1999) have used this logic to argue that the information technology (IT) revolution caused the post-1972 fall and the post-1985 rise in the ratio of market capitalization to GDP. Here, we shall present new evidence on this view, and on other proposed explanations of the '70's episode, explanations like oil-price shocks, increased market volatility, and nonfundamentals.

Figure 1 depicts a puzzling phenomenon. The solid line is the market value of U.S. equity relative to GDP since World War II, measured as the ratio of market capitalization to GDP as published by the Federal Reserve Board of Governors. After

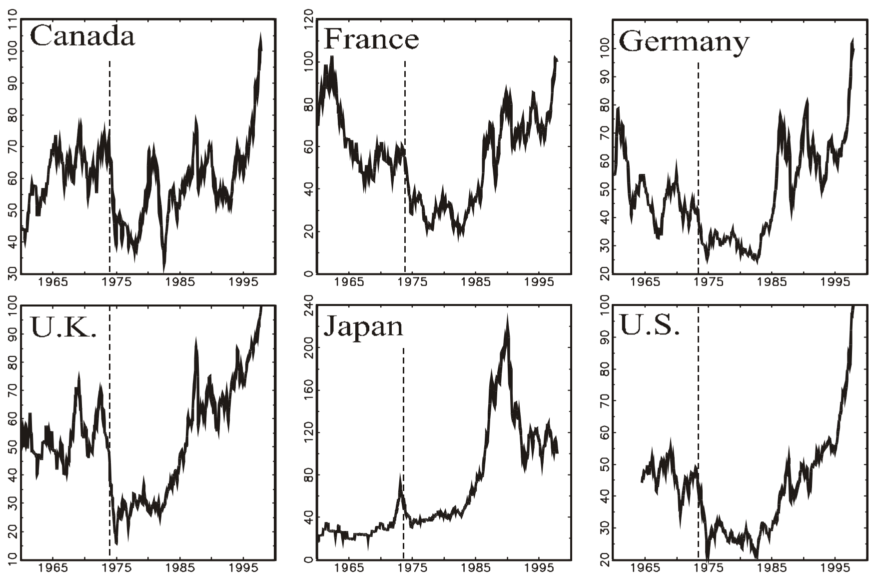

Figure 2: Real stock market indices in 6 OECD countries

reaching 1.1 in 1968, and, again, unity in 1972, market-cap/GDP plummeted to 0.4 in 1973, and did not recover until the mid-1980's, and then it rose quite sharply.

Figure 2 shows that except Japan, the leading OECD countries experienced similar movements in their stock markets. The figure plots the real stock market indices for 5 European countries and the U.S. – not quite the variable plotted as the solid line in Figure 1; instead of market cap, Figure 2 plots a stock market index, and the index is not divided by output. The data are from the macroeconomic indicators published by the OECD and cover 1960 -1998, except for the U.S. for which the share index was unavailable prior to 1964.

Clearly, if one were to add up the market capitalizations of these 6 countries and divide them by their combined output, one would obtain a "world" series that would look much like the solid line in Figure 1. Japan is an outlier, but too small to overturn the broad pattern in the rest of the advanced world.

Mehra (1998) argues that the kind of volatility that Figures 1 and 2 portray is not consistent with the standard stochastic growth model, and Hall (1999) notes that the standard model implies a puzzling "meltdown" of capital in 1973-4. The puzzle then, in terms of Figure 1, is the nearly threefold decline in market-cap/GDP in 1973-4, followed by its fivefold rise since 1985. The literature offers three solutions to the puzzle. First, Bernanke, Gertler and Watson (1998) suggest that the first oil crisis, combined with monetary policy, reduced expected future profits of firms and, as a result, led to a drop in stock prices. Second, Pindyck (1984) asks if the decline of the 1970's reflected a response of risk-averse investors to a secular rise in the volatility of stock returns. And, third, the popular press and the bubbles literature suggest that

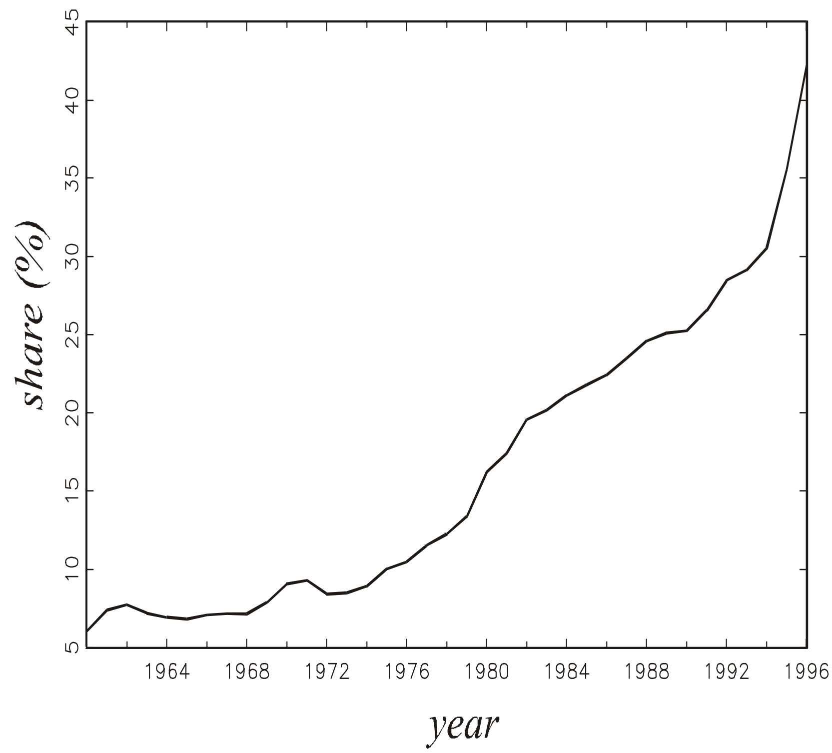

Figure 3: Share of computers in real equipment investment

a positive bubble burst, or a negative one formed in 1973 and that today a positive bubble exists, especially in the internet stocks.

This paper takes on a different view. The view is that *good* news arrived in 1973, news that information technology was on the horizon. Figures 1, 2 show that stock prices fell just after Intel had developed the microprocessor in late 1971, and just as IT investment, plotted in Figure 3, was about to take off. In 1968, IT comprised only 7 percent of equipment investment, but it then started to rise, reaching 52 percent in 1998, and is rising still. Moreover, this pertains only to the hardware component of that investment and ignores software expenses. It seems natural, therefore, to label early 1973 as the date in which "the news about IT arrived". Arrived, in the sense that this is when it started to matter, and when American business started incorporating it in a major way.

The paper proceeds as follows. Section 2 describes the main assumptions and, then, the model. Section 3 describes several tests of the IT hypothesis, Section 4 considers some other explanations, and, finally, Section 5 concludes the paper.

2 The IT hypothesis

Our argument rests on three assumptions. First, that the success of the IT revolution suddenly became evident in early 1973. Second, that the IT revolution favored new firms, that incumbents resisted it, and that this caused their values to fall. And, third, that as a policing device, mergers and takeovers worked with less than perfect efficiency, and therefore allowed incumbents to remain inefficient until the mid-1980's. We now explain why we think that these assumptions are reasonable.

Assumption 1: The IT revolution was heralded in 1973

Before 1971, the computer was no friend of small business. Computers were expensive and users shared computer-time. Mainframe computers and minicomputers had been used at some large companies, at NASA, at the Defense Department, at the Bureau of the Census, and at other federal and local government bureaus. But it would take a technological leap before the computer could transform the way business was done, and before any firm, large or small, could afford to provide one to each of its administrative workers.

That technological leap was the invention of the microprocessor – the "4004 computer chip." This invention made the powerful "PC" of today possible. By late 1971 Intel was advertising the chip,[1] and commercial implementation followed almost at once: A French company produced the "MICRAL," a general purpose computer that embodied the new chip. "A base model cost under $2,000, and it found a market replacing minicomputers for simple control operations. Around two thousand were sold in the next two years...." (Ceruzzi, 1998, p. 222).[2] In the U.S., the early adopters of the new microprocessor – Intel's "4004" miniature computer – were outside the corporate sector, which surprised even Intel's sales staff.[3]. Intel had IPO'd in October

[1] "Robert Noyce [The 1968 co-founder of INTEL] negotiated a deal with Busicom [a Japanese calculator manufacturer] to manufacture for Intel chips [that Intel had designed] at a lower cost giving Intel, in return, the right to market the chips. From these unsophisticated negotiations with Busicom, in Noyce's words, came a pivotal moment in the history of computing.

"The result was a set of four chips, first advertised in a trade journal in late 1971, which included a'a microprogrammable computer on a chip!" That was the 4004, on which one found all the basic registers and control functions of a tiny, general-purpose stored-program computer. The other chips contained a read-only memory (ROM), random access memory (RAM), and a chip to handle output functions. The 4004 became the historical milestone, but the other chips were important as well, especially the ROM chip that supplied the code that turned a general-purpose processor into something that could meet a customer's needs." (Ceruzzi 1998, p. 220).

[2] Similarly, Campbell-Kelly and Aspray (1996, p. 237) write that it was "possible to produce an affordable personal computer (costing less than $2000, say) any time after...November 1971." Indeed, by March of 1974, Intel was offering the kit for the Scelbi-8H minicomputer for as low as $440 (Ceruzzi, 1998, p. 225).

[3] "Since it was a miniature general-purpose computer, [the 4004] could be used by industrial designers to do any number of different jobs. The customization would be in the software.... The target customers for this use of the 4004 chip were engineers in America's biggest industrial companies. But most of these engineers knew nothing about computer programming. Instead, it was smaller,

of 1971 and, by August 1972, it had released its second microprocessor – the "8008".[4]

To be sure, the early microprocessor was a highly primitive ancestor of today's PC – it had no keyboard, no screen, and a minute fraction of the power. But, by early 1973, it should have been clear that now one could expect rapid development of both hardware and software. By "Moore's Law," the power of computers would quickly become phenomenal, and, as soon as the software needed to turn the computer into a multi-purpose problem-solver became available – and this was just a matter of time – the computer would transform the face of American business.

Assumption 2: The IT revolution favored new firms

An old firm has old physical capital on hand, and so it faces an additional economic cost to investing in frontier methods. It also has old human capital on hand; its manager may lack the awareness and its workers may lack the skill to implement the new technology (e.g., in 1972, large companies didn't have the programming expertise needed to use the microprocessor productively). In short, incumbents have a comparative disadvantage in adopting new technology. This is the "sunk cost" argument that we have seen in vintage capital growth models, in incumbent *vs.* potential-entrant models of R&D, and elsewhere. Other arguments that relate incumbency to technological change have recently surfaced: Holmes and Schmitz (1990) argue that some people are good at starting new firms, while others are good at running existing ones, and this distinction matters especially in times of major technological change; similarly, Ueda (1997) and Takii (1999) argue that the onset of technological uncertainty reallocates resources to those that are best able to cope with it – an argument that rests on Nelson-Phelps notions.

An even more telling reason why an incumbent firm will resist change is the entrenchment of its personnel. A large company is likely to be more top-heavy, and many of its employees are more likely to be drawing salaries that bear no relation to performance. Neither a tenured worker on a fixed salary, nor his CEO with a handsome golden parachute, has any reason to do *anything* for his firm, much less learn something new.

Based on this logic, our model will assume that when the news of the new technology arrives, the market correctly expects an incumbent to go on doing business as usual – indefinitely.

Assumption 3: Mergers and takeovers are an imperfect policing device

In theory, a stock market should raise efficiency by ensuring that productive resources reach the hands that can generate most value from them. The mechanism that

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hungrier companies without a strong, entrenched market position that saw the potential of the tiny chip first....The early adopters of the 4004 were much more obscure. Someone inside Intel's marketing department described the 4004 customer list as "not so much *Who's Who* as *Who's That*?" " (Jackson 1997, p. 75)

[4] Two buyers of the 8008 were none other than Bill Gates and Paul Allen who used it for a project that failed (Jackson 1997, p. 76).

accomplishes this is the takeover. If the takeover market were frictionless, entrenchment and comparative disadvantage could not survive: An inefficient firm would quickly be acquired, its management replaced, and its inefficient work practices eliminated. Gort (1969) emphasizes that, by rearranging the pattern of comparative advantage, a new technology would usher in a merger-wave and that, instead of losing value, incumbents would simply face reorganization.

In practice, however, the takeover process has frictions. Insiders – management and unionized workers especially – can protect themselves from hostile takeovers. They may succeed in securing a share of a firm's profits property rights far in excess of their contribution to it. To succeed, a raider would need to compensate these insiders, and such compensation could exceed the efficiency gains that the transfer of control would secure, and may, therefore, prevent the takeover from taking place. Moreover, as Grossman and Hart (1981) argue, incumbent shareholders too can hold out and extract the efficiency gain from the acquiring firm.[5] These barriers have meant that a takeover has to raise value by about 40% before it goes through, and that, as a result, a firm can lose value and not be taken over.

Frictions in the takeover process also imply that the removal of inefficiency must, in part at least, take place through process of entry of efficient firms, and exit of inefficient ones. This process is slower than the takeover, and this may be why the market took more than 10 years to recover. But, recover it did, and the painful adjustments are taking place.[6] Not surprisingly, the "excess fat" is mostly among managerial and nonproduction workers (Lichtenberg and Siegel 1991).[7] And since the adoption of IT is, in many firms probably long overdue, some firms are seeing extremely high rates of return on their IT investments.[8]

[5] Brearly and Myers's (1996, ch. 33) account of the RJR-Nabisco buyout indicates that the shareholder appropriated the entire gain from the deal.

[6] Farber and Hallock (1999) find that over the past thirty years, announcements about labor-force reductions are increasingly likely to lead to stock-price increases. The authors find this to be consistent with the view that such reductions are increasingly designed to improve efficiency, and are less likely than before to reflect reductions in product demand.

[7] This will seem odd to anyone who thinks of the unionized blue collar worker as the prime machine-resister. But the computer displaces mainly white-collar labor ("Behind each ATM flutter the ghosts of three bank-tellers," says a recent N.Y.Times article), and so this is where one would expect to be able to cut costs the most. In their study of the Indian iron and steel industry, Das and Sengupta (1999) find that in the typical (presumably sheltered) public sector firm, managerial workers are much more overemployed than the production workers.

[8] "Using eight years of data for over 1000 firms in the United States, we find that an increase of one dollar in the quantity of computer capital installed by a firm is associated with an increase of five to 20 dollars in the financial markets' valuation of the firm. Other forms of capital do not exhibit these high valuations." (Brynjolfsson and Yang 1998, p. 1). If these numbers are even close to being correct, IT must have met with some pretty stiff resistance.

2.1 The model

The model is a version of the Lucas (1978) exchange economy. There are some old trees today, and new trees will appear in the future. If the fruit from the new trees is a substitute in consumption for the fruit from the old trees, the old trees will lose value when people learn that new trees are growing.

The two types of fruit are apples and oranges, and their quantities are x and y. A representative agent's lifetime utility is

$$\sum_{t=0}^{\infty} \beta^t U(x_t, y_t).$$

Apples, i.e. x, are the numeraire good, while the relative price of oranges, i.e. y, is

$$p_{y,t} = p^y(x_t, y_t) = \frac{U_y(x_t, y_t)}{U_x(x_t, y_t)}.$$

Claims to the current and future output of the apple and orange trees in this economy trade freely at prices $P_{x,t}$ and $P_{y,t}$ respectively. GDP at date t, denoted by Q_t, equals

$$Q_t = x_t + p_{y,t} y_t,$$

where x_t and y_t denote the apple and orange crop in period t. The date τ price of a tree that promised a stream of x-denominated dividends $\{d_{i,t}\}_{t=0}^{\infty}$, where $i = x, y$, would be

$$P_{i,\tau} = \sum_{t=\tau}^{\infty} \beta^{t-\tau} \left(\frac{U_x(x_t, y_t)}{U_x(x_\tau, y_\tau)} \right) d_{i,t}$$

2.1.1 Before the shock

Assume that, at date zero, there are no orange trees, just a unit measure of apple trees that yield a constant crop of x apples per period. No change is expected to occur, ever. The aggregate stock market value is then equal to the value of the apple trees, i.e. for all τ,

$$P_{x,\tau} = \sum_{t=\tau}^{\infty} \beta^{t-\tau} \left(\frac{U_x(x, 0)}{U_x(x, 0)} \right) x = \frac{x}{1-\beta}.$$

Since GDP in this case equals $Q_\tau = x$ for all τ, we obtain that market-cap/GDP equals

$$\pi_t^* = \frac{P_{x,t}}{Q_t} = \frac{1}{1-\beta} \equiv \pi$$

for all t.

2.1.2 A shock is announced at date zero

Unexpectedly, news arrives at $t = 0$ that a unit-measure of orange trees will spring forth at the beginning of date T, and that each will yield y oranges per period forever. At date T (not at date zero) agents will also expect to receive an equal share of claims to the output of these new orange trees. All this is expected at date zero, and no further shocks are expected.

At date T, the output of oranges rises permanently from 0 to y, such that

$$y_t = \begin{cases} 0 & \text{for } t \leq T-1 \\ y & \text{for } t \geq T \end{cases}.$$

The value of the apple trees now becomes

$$P_{x,t} = \begin{cases} \frac{1-\beta^{T-t}}{1-\beta} x + \frac{\beta^{T-t}}{1-\beta} \left(\frac{U_x(x,y)}{U_x(x,0)} \right) x & \text{for } t \leq T-1 \\ \frac{x}{1-\beta} & \text{for } t \geq T \end{cases},$$

and the value of the orange trees now equals

$$P_{y,t} = \begin{cases} 0 & \text{for } t \leq T-1 \\ \frac{p^y(x,y)y}{1-\beta} & \text{for } t \geq T \end{cases}.$$

Note that we have *defined* $P_{y,t}$ to equal zero for $t \leq T-1$, even though, even before date T, the value of the orange trees would be positive if they were traded on the stock market. We are assuming, however, that claims to the output of these trees come into being only at date T. This delay is supposed to reflect the reality that a new company takes years before reaching its initial public offering.

After the shock, the path of GDP is expected to be

$$Q_t = \begin{cases} x & \text{for } t \leq T-1 \\ x + p^y(x,y)\, y & \text{for } t \geq T \end{cases},$$

and so market-cap/GDP will be

$$\pi_t^* = \begin{cases} \pi - \frac{\beta^{T-t}}{1-\beta} \left[1 - \left(\frac{U_x(x,y)}{U_x(x,0)} \right) \right] & \text{for } t \leq T-1 \\ \pi & \text{for } t \geq T \end{cases} \tag{1}$$

2.1.3 The initial impact of the news

The impact of the shock to the stock-market-value to GDP ratio is determined by whether x and y are gross substitutes or gross complements:

Proposition 1 If x and y are gross substitutes, news of the shock lowers the ratio of market value to GDP for $t \leq T-1$. That is:

$$\pi_t^* < \pi \text{ for all } t \leq T-1 \quad \text{if} \quad U_x(x,y) < U_x(x,0)$$

Proof. From (1), $\pi_t^* < \pi$ if $1 > U_x(x,y)/U_x(x,0)$. ■

Similar reasoning easily reveals that if, conversely, x and y were gross complements, the news of the shock would actually raise the stock market to GDP ratio.

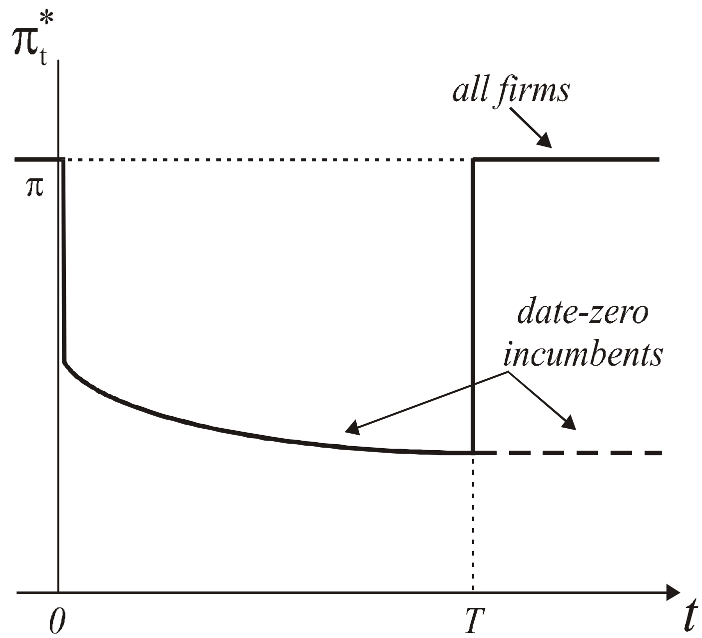

Figure 4: The predicted market-cap/GDP ratio, π_t^*.

2.1.4 The stock market share of the date-zero incumbents

Considering the share of apple trees in the stock market, which equals

$$S_{x,t} = \frac{P_{x,t}}{P_{x,t} + P_{y,t}}$$

it can be seen that this follows

$$S_{x,t} = \begin{cases} 1 & \text{for } t \leq T-1 \\ \frac{x}{x+p^y(x,y)y} & \text{for } t \geq T \end{cases}$$

This all assumes that apple farmers do not plant orange trees, and that, indeed, no one owns the land on which these trees will grow. This is where our second assumption about resistance kicks in. If the new orange trees were to grow on the land that the apple farmers already owned, the value of apple farms would rise immediately, and market-cap/GDP would not fall. But because this is ruled out by assumption, the incumbents' share suffers the most in times of rapid product innovation, i.e. a large y. That is, in times of rapid technological change.

The counterpart of Figure 1 is π_t^* plotted in Figure 4. The two figures look similar if the date $t = 0$ is set to correspond to the year 1973, and if $T = 13$ years. This seems like a long time, but the time-to-IPO should be longer when a technology is young and, hence, risky. Microsoft, for example, formed in 1976, but went public only in 1986.

3 Tests of the IT hypothesis

The model suggests that the drop and subsequent rise in market-cap/GDP should have been accompanied by the following five observations:

1. Most of the post-1985 rise in market capitalization should be due to the post-1972 entry of new firms and not to an increase in the value of the 1972 stock market incumbents.

2. The model should work best for the IT-intensive sectors of the economy. The largest 1973-4 price declines should have occurred in sectors that had the largest post-1973 investments in IT – sectors like Finance, Insurance and Real Estate (FIRE), and the service sector generally.

3. If IT revolution really did change the pattern of comparative managing advantage in 1973, then we should see a rise in mergers, takeovers, and exits before or around the same time the new firms arrive in the market.

4. If the IT revolution favored new firms, then new (and, perhaps young and, hence, small) firms should have grown faster than big ones in the period after 1973.

5. The model implies a one-time rise in the growth rate of output and the rate of interest at date T, i.e., in 1986 or so.

We shall now report the tests and their results.

3.1 The dismal fate of the 1972 incumbents

Figure 4 states that incumbents do not take part in the date-T recovery of the stock market. To test this proposition, we need to identify incumbents. Most are covered by the Center for Research in Security Prices (CRSP) data. In 1972 this dataset included most big firms. The dashed line in Figure 1 is the ratio of market capitalization to GDP for the dataset published by the CRSP that contains the stocks traded on the NYSE, AMEX, and NASDAQ. The difference between the two are stocks traded over the counter.

Figure 5 shows the 1972 CRSP incumbents' value relative to GDP fell more than threefold over a few years, and never recovered. Yet, since 1985 the value of the market relative to GDP has tripled! *The source of this new value must, therefore, be firms that entered after* 1972, roughly as Figure 4 asserts.

The 1972 incumbents thus fared badly, and entrants did spectacularly well, some 15-20 years later. But, is this at all unusual? After all, we know that even after one controls for survivorship bias, small firms grow faster than large ones, and we believe that all firms must eventually die and make way for new firms. The question,

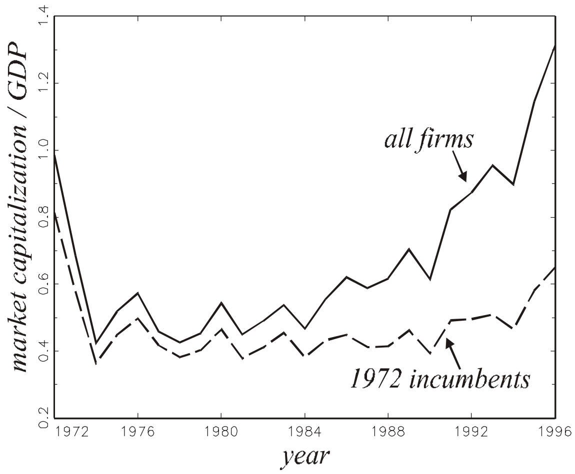

Figure 5: The fate of the 1972 incumbents

then, shouldn't be whether the 1972 incumbents did badly relative to subsequent entrants, but rather, whether the 1972 incumbents did badly when compared with incumbents of *other* vintages. Specifically, then, what became of incumbents that, at a corresponding stage in their existence, did *not* have to cope with technological change as major as IT?

Figure 6 tackles this question by plotting the time path of market shares of three incumbent-vintages against their "age" (defined as calendar time minus their vintage). Two things stand out from the figure. First, if no security traded over the counter, all three curves would begin at 100 percent. Instead, the intercepts of the curves rise with vintage, implying that over-the-counter trading has declined in importance relative to market trading The capitalization of stocks that traded over the counter declined from 45 percent of total capitalization in 1948, to 28 percent in 1960, and finally to 17.5 percent in 1972.

Figure 6 also shows that the 1972 incumbents lost market share much faster than the other two generations of incumbents. At age 24, the share of all three generations is around 50 percent, even though the 1972 incumbents start off with a much higher market share.

3.2 IT-intensive sectors lost more value in 1973

The service sector has invested much more heavily in IT than has the manufacturing sector, and, within the service sector, the FIRE segment of services being the first to do so. Figure 7 reports the fate of the 1972 incumbents by major sector: Manufacturing, FIRE, services (excluding FIRE) and, and Transportation, Communication and Public Utilities.

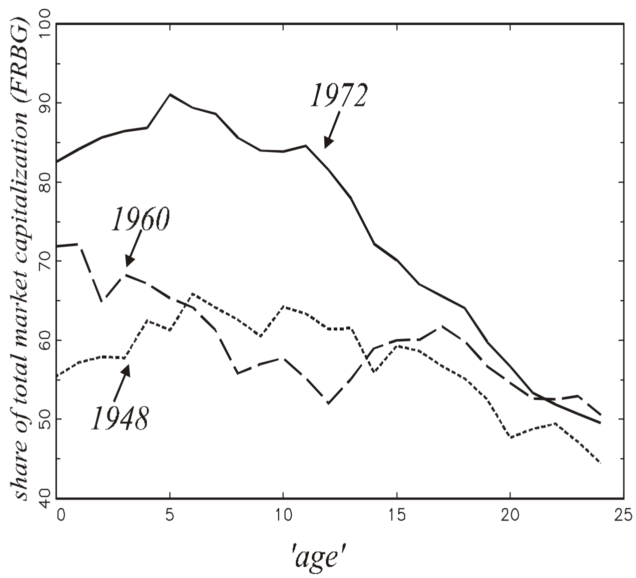

Figure 6: Shares of three vintages of incumbents

Table 1: Summary statistics

sector	exposure to IT		'72	'96 Incumbent	drop per unit of exposure	
	inv. share	cap. share	Drop	share	inv. share	cap. share
Manuf.	33.9	17.9	45.5	76.6	2.9	5.4
TCPU	33.8	38.5	44.9	54.2	5.6	5.0
FIRE	30.0	41.5	46.7	52.2	6.6	4.8
Services	31.2	42.4	73.4	19.0	10.8	8.0

Two things emerge from Figure 7. First, the biggest 1973 value drops occurred where subsequent IT investment was the highest. The smallest 1973 decline is in manufacturing, where values fell by a factor of 45 percent. A larger decline (52 percent) occurred in FIRE , and a larger one still (73 percent) in other services. And, second, where incumbents' values fell the most in 1973, the subsequent recovery was the weakest. The point is, not being as much "at risk" from IT, manufacturing firms were not hit as hard by it as other sectors were.

This is all summarized in Table 1. The table reports two different measures of exposure to IT. The first, a flow concept, is the average real investment share of IT equipment in equipment investment for 1974-1996. The second, stock concept, is the share of real IT equipment in the real total stock of equipment. All data are from the BEA's tangible wealth table. The first measures more closely the costs of *adopting* IT, the second measures the *use* of IT in production. The two measures differ when industries' rates of investment are not constant. The stock measure conforms much

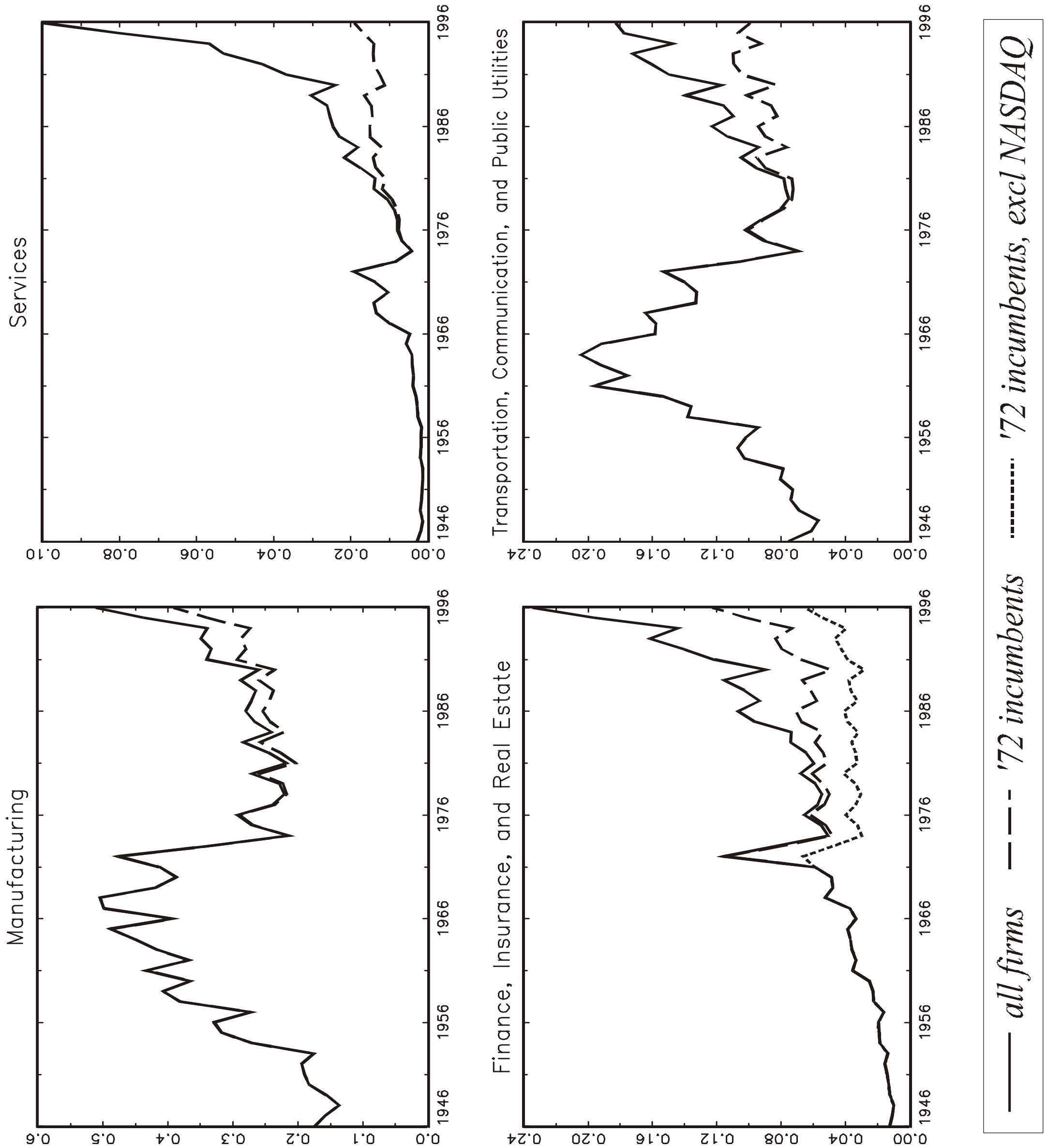

Figure 7: The fate of the 1972 incumbents by major sector

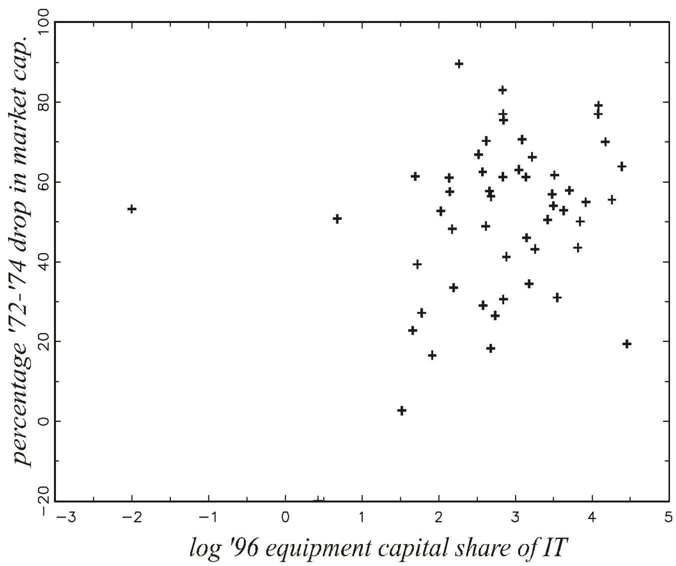

Figure 8: 1973-4 drop in value vs. the share of IT capital.

better to the theory – a clear positive relation exists between the second and third columns.

At lower levels of aggregation, a weak but still positive relation still exists between value lost and the stock measure of IT-exposure. This relation is plotted in Figure 8.[9] Figure 9 portrays a stronger relation: It shows that the sectors in which the 1972-incumbents lost the most value in 1973-4 ended up having the most subsequent value created by entrants so that, by 1996, the share in 1996-value of the 1972-incumbents was the lowest.

We also decided to combine the data in Figures 8 and 9, and regress the 1973-4 percentage drop of sector i, denoted by D_i, on the log of the capital share of IT in the '96 equipment capital stock (measured in 1992 prices, taken from the BEA tangible wealth table), denoted by $CapS_i$, and on the log of the share of the '72 incumbents in the sector's '96 market value, denoted by $IncS_i$. The regression results for the 53 sectors for which we have data are

$$D_i = \underset{(5.15)}{61.56} + \underset{(2.20)}{5.24}\ CapS_i - \underset{(-2.82)}{7.00}\ IncS_i \quad n = 53 \quad R^2 = .216.$$

Hence, the more IT intensive a sector turned out to be the higher its drop in 1973, the more threatened incumbents were by entry in the 1974-1996 period the higher the drop again. This evidence is consistent with our hypothesis.

[9]We thank Hyunbae Chun of NYU for providing us with the the sectoral-IT investment data.

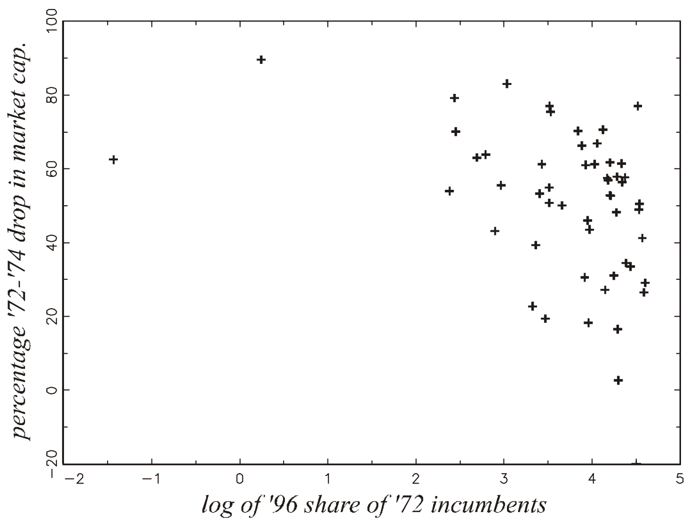

Figure 9: 1972-4 drop in value vs. the share of 1972-incumbents in 1996 value.

3.3 The rise of entry, exit, takeovers, and mergers

The introduction of information technology coincided with a period in which entry, exit, takeover, and merger activity in stock market, all increased. We argued in section 2 that these events were to be expected given that the advent of IT, a major new technology, rearranged the pattern of comparative advantage among managers. Ueda (1997) finds, for instance, merger waves focus on sectors that subsequently show high productivity growth. It seems, then, that when technology shifts, it prompts a re-shuffle.

The plot in the top panel of Figure 10 shows a pronounced rise in both entry and exit in the CRSP[10], denoted in terms of their share of the total market capitalization. As suggested by the model entry and exit activity both increased significantly after 1973. This remains true when one looks outside the CRSP. As Figure 12 shows, the rate of incorporations and real exits has risen substantially in the 1980's and remains high[11] Together with the entry rate, we also plot the number of IPO's at least \$1.5 million in size.[12] Since the 1980's IPO's are much higher than they were in the 1970's, although not much higher than they were during the 1960's. But new incorporations, a better measure of the "start-up" peaked in the 1980's, as were exits, plotted in the bottom panel of Figure 12.

[10] For the entry series, two observations are left out on purpose – 1961 and 1972 – the years that AMEX and NASDAQ enter the CRSP.

[11] The entry and exit data plotted in Figure 12 are rates per 10,000 registered enterprises. The data were provided us by Valerie Ramey; she had presented them in a discussion at the NBER Fluctuations meeting, July 17, 1999.

[12] More details on these data are in Ibbotson *et al* (1994).

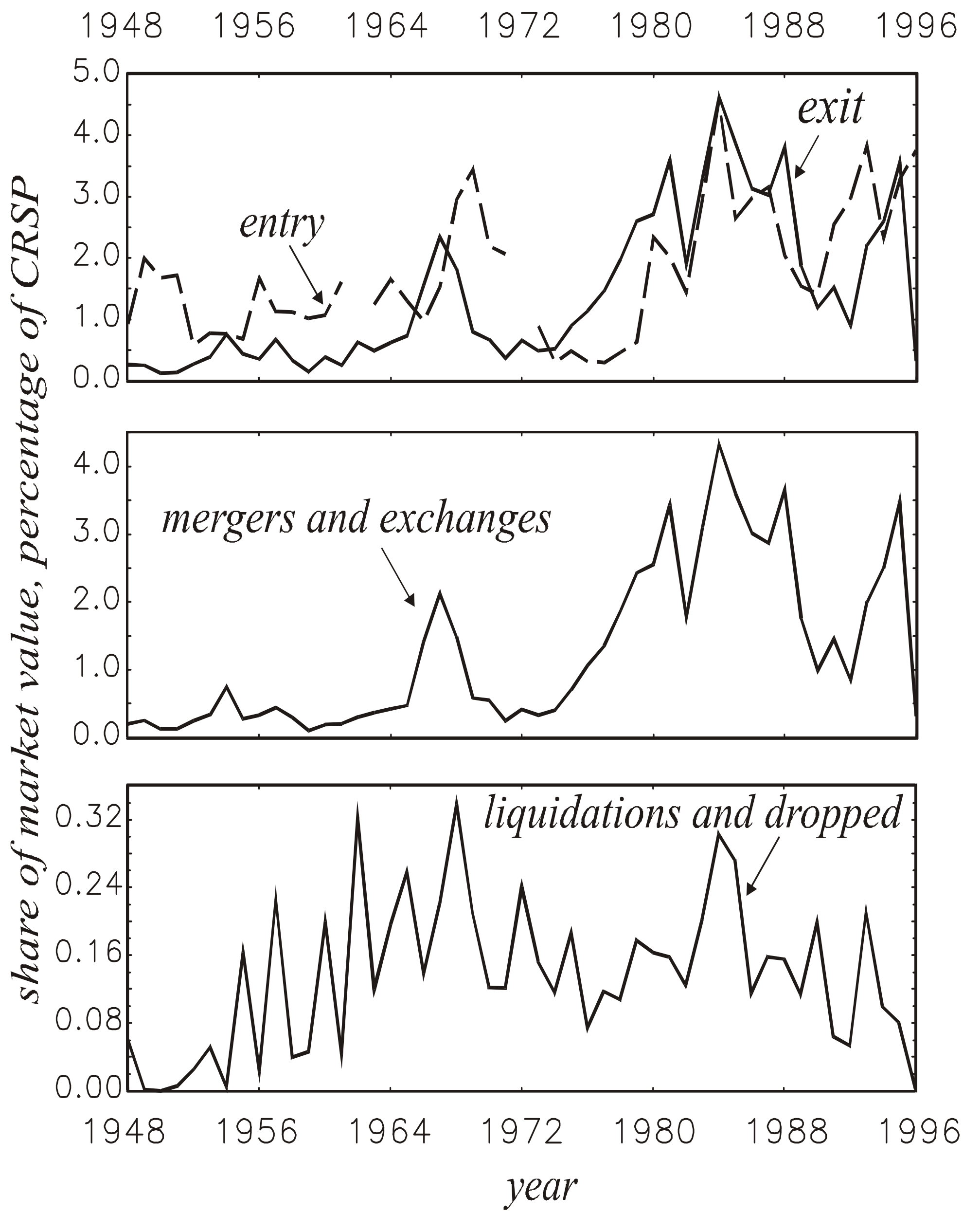

Figure 10: Entry, exit, and reasons for exit from stock market

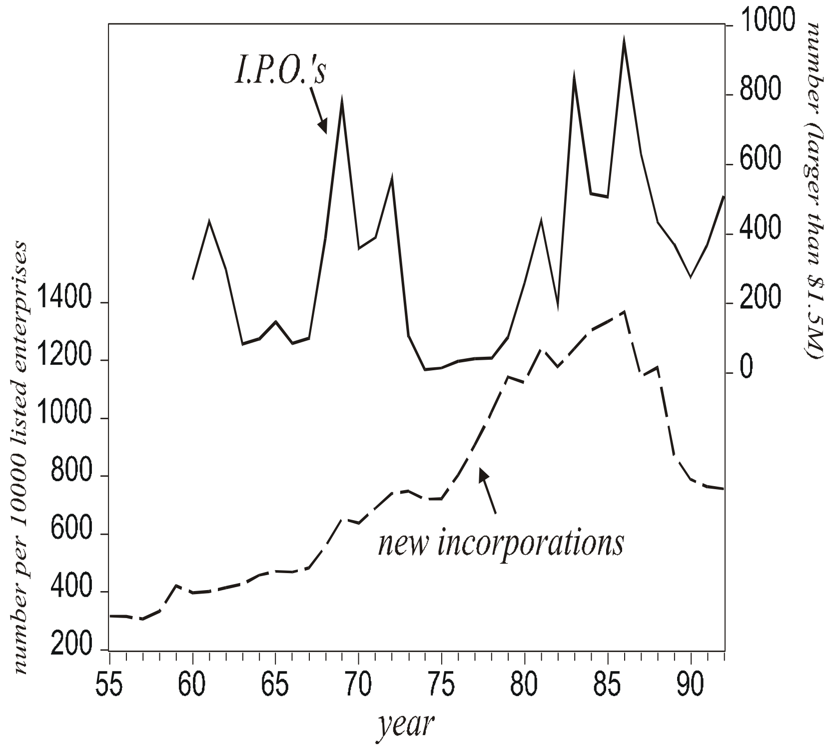

Figure 11: The rate of business incorporations and the number of IPO's

Figure 12: The rate of failure of businesses

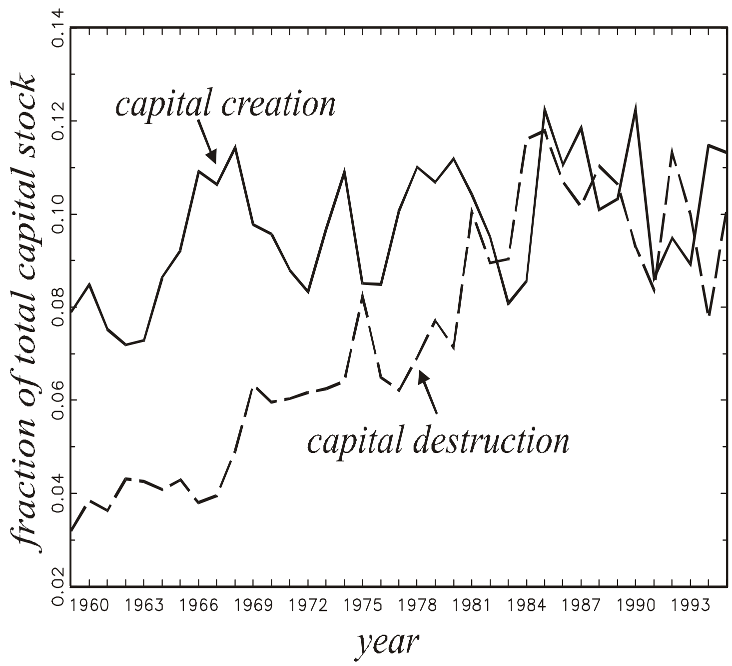

Figure 13: Entry and exit of physical capital

In the manufacturing sector, the rate of gross job flows shows a slight, but relatively unbroken downward trend. This does not support our argument, but, as we shall shortly document, the manufacturing sector has invested the least IT investment, and is the least likely to offer empirical support for our argument. Moreover, Haltiwanger and Schuh (1999, Figure 6) finds that there has been a rise in the permanent (i.e., exceeding two years) component of job-destruction. That is, a job is now less likely to be destroyed, but when it is gone, it is gone for good. This also explains why unemployment duration has risen in the 1990's, a time when the unemployment rate is generally falling.[13]

Gross job-flows may have slightly declined, but, on the other hand, gross flows of capital have risen. Ramey and Shapiro (1998) compiled a gross-capital-flow series, reproduced in Figure 13, that shows a definite rise since the 1980's, especially in capital destruction.

The gross flows of firms and of capital seems, therefore, to have picked up since the 1980's. Next, we return to the CRSP which decomposes the exits (but not entries) into several categories. Our next task is to quantify the individual exit flows.

The bottom two panels of figure 10 depict the reasons for exit of the different firms. The bulk of the peak in exit in the 1980's is due to mergers, this peak in mergers is consistent with the evidence in Golbe and White (1993). However, also the share

[13] We thank Scott Schuh for this fact, documented in the Dallas Fed. Review (1994-5).

of value of stocks that exited because they could be exchanged for other issues, as is often the case in takeovers, and that of stocks of firms that were liquidated peaked in the early 80's. The fraction of value dropped from the market, mainly because the firm decides to stop to be traded on the market, is fairly constant for the post war period and does not peak in the eighties.

The CRSP data contain no information on the reasons for entry of a firm in the stock market. However, it is likely that part of the peak in entry in the early 80's is due to the issuance of new stocks by firms after their merger.

One important *caveat* here. We have interpreted the rise in stock-market entry as a symptom of greater frequency of "policing activity" the origin of which is the established firms' resistance of IT. to has risen. But the increased entry may have a different explanation: Computerized trading and the NASDAQ made it relatively cheaper for firms to be traded on the stock market. Such a decrease in transaction costs would induce more firms to go public, but it should have *raised* market-cap/GDP.

3.4 The post-1973 boom of entrants and small firms

Did entrants and small firms do better than large firms? This section asks whether entrants and small incumbents did especially well after IT-revolution. We look first at entrants, and then at the small incumbents – i.e., the small-cap stocks.

3.4.1 Entrants

The results in Table 2 report on the fate of entrants ten years after their CRSP entry. Each row reports the fraction of entrants exiting by a decade's end. The first row gives the fraction of entrants that merged at some point during the decade. The second row, "exchanges", also pertains to mergers, because this is when stock of a company is exchanged for shares of the company that took it over. But this category probably also includes firms that went private. Combining these two categories leads to a series that has risen sharply over time: In '85-95, exits for these two reasons were 2.5 times higher than they had been in '45-'55. Some old firms are entering the IT era by acquiring the small innovators.

The last two rows of Table 2 present figures on genuine exits from the CRSP. A "drop" arises when a firm stops being traded, usually because its value has fallen below a critical level. Combined with "liquidations", such exit has risen dramatically – by a factor of 13.

3.4.2 Small incumbents – the performance of small-cap stocks

Aside from entrants, the arrival of a new technology should have favored younger, and generally smaller, firms that tend to have a nonhierarchical structure, fewer unionized or tenured workers, and fewer outdated management practices.

Table 2: Achievements of entrants per decade

decade	**45-55**	**55-65**	**65-75**	**75-85**	**85-95**
Fraction merged	.042	.051	.049	.080	.111
Fraction "exchange"	.004	.013	.004	.006	.002
Fraction liquidated	.007	.006	.006	.006	.008
Fraction "dropped"	.007	.061	.150	.175	.173
Total	.060	.131	.209	.266	.293

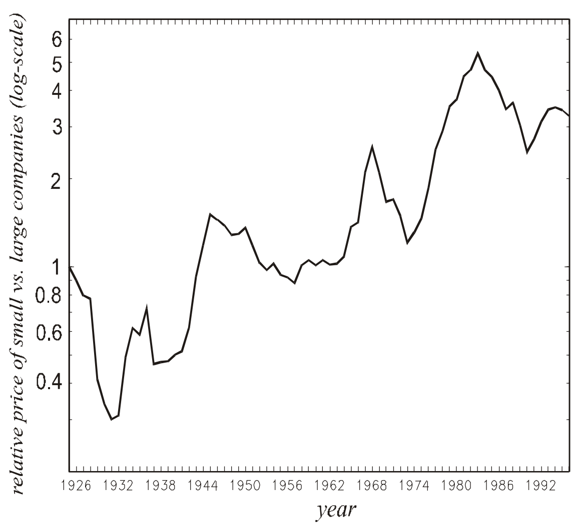

Figure 14: Performance of small companies vs. large companies

Figure 14 plots the ratio of the Ibbotson small cap index to the S&P 500 index. During the period 1974 - 1982, small cap stocks outperformed the S&P 500 by a factor of nearly 4. Since then, the S&P 500 has done better than the small caps, probably because, by the early 1980's and the advent of the junk-bond, inefficient large firms began to feel stronger hostile-takeover pressures, and responded by becoming more efficient. The strong performance of the small caps in the 1974-82 period mirrors the small product-market performance of small relative to large firms that was summarized in Figure 8 of Greenwood and Jovanovic (1999). A summary of some information in Figure 14 is in Table 3 with the changes in the small/large-cap ratio for various time periods.

Table 3: Small cap performance for various historical periods

period	**years**	**change**
IT revolution	74-82	increased by factor of 3.7
Sixties boom	56-65	increased by factor of 1.5
WWII	41-45	increased by factor of 2.9
Depression	28-31	decreased by factor of 2.6

3.5 Output and interest rates

In the model, the rate of interest and output growth both experience a one-time rise at T, and then return to their original levels.

Did the yield curve steepen in the 1970's?

The yield curve is a predictor of short term fluctuations in output and consumption. Before booms, the yield curve steepens, and before slumps, it flattens. In our case, we have a lower frequency movement at hand. We posit that in 1973 the economy got the news that output would rise after the mid-1980's. That is, with perfect foresight, the onset of IT and the resulting rise in consumption after date T should have produced a steepening of the yield curve before date T – long term rates (e.g. on 10 year government bonds) should have risen relative to short-term rates. Formally, the period t yield of a bond that matures in period $t+h$, denoted by $R_t^{(h)}$, must satisfy

$$U_x\left(x_t, y_t\right) = \beta^h U_x\left(x_{t+h}, y_{t+h}\right)\left(1 + R_t^{(h)}\right)^h.$$

Evaluating and solving for $h=1$ and $h=T$ yields

$$R_t^{(1)} = \begin{cases} \frac{1}{\beta} - 1 & \text{for } t \leq T-2 \\ \frac{1}{\beta}\frac{U_x(x,0)}{U_x(x,y)} - 1 & \text{for } t = T-1 \\ \frac{1}{\beta} - 1 & \text{for } t \geq T \end{cases}, \text{ and } R_t^{(T)} = \begin{cases} \frac{1}{\beta}\left(\frac{U_x(x,0)}{U_x(x,y)}\right)^{1/T} - 1 & \text{for } t \leq T-1 \\ \frac{1}{\beta} - 1 & \text{for } t \geq T \end{cases}.$$

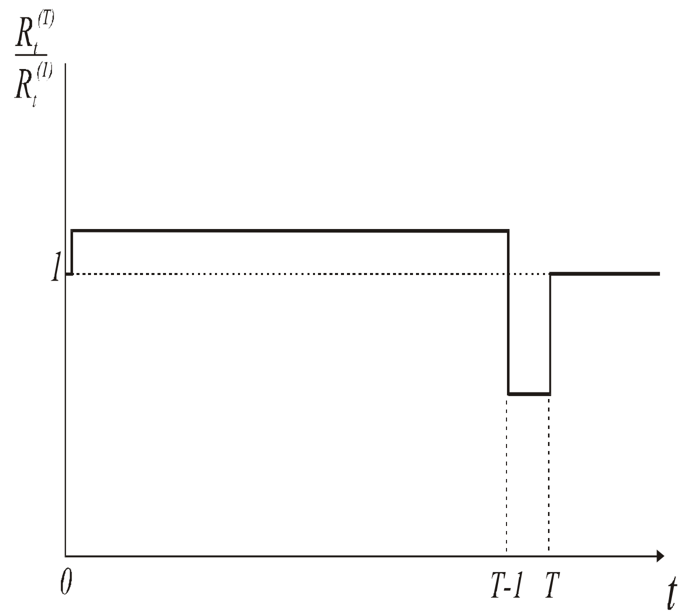

Figure 15: Predicted ratio of the long-term and short term yields

Figure 15 plots the implied ratio of $T-$ period and $1-$ period bonds' interest rates. Figure 16 shows what actually happened to the ratio of the nominal yield on long-term (10-year) government bonds and short run (1-year) government bonds for monthly data for 1960.01 to 1996.12. The dashed line is the sample mean. Though the yield curve indeed steepened temporarily in 1972, the data do not suggest that this shift was persistent, as the model would suggest. These are nominal interest rates, however, and it is likely that the ratio fell below unity for a large portion of the 1970's because people didn't expect the high inflation of the 1970's to persist.

Did output growth eventually rise?

Only in the last few years has output growth risen. Output growth fell in the 1970's – a manifestation of the productivity slowdown. The model does not include an adoption cost, but it is pretty clear that adding such a cost would only reinforce the conclusion that the stock market should initially fall and then recover later on. Greenwood and Yorukoglu (1997) and Atkeson and Kehoe (1997) assume that it takes time to learn the new technology, and Helpman and Trajtenberg (1998) assume that complementary inputs must be developed before the new technology can operate efficiently.

4 Other explanations

The IT hypothesis manages to explain and link the following three facts:

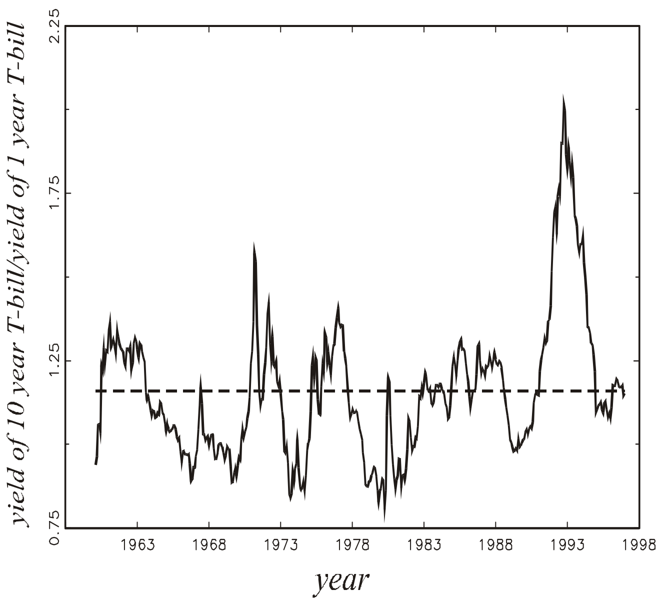

Figure 16: Ratio of yields on 10-year/1-year bonds

1. The decline and subsequent rise of market-cap/GDP,
2. The dominant role of entrants in the post '85 market boom, and
3. The merger wave of the eighties.

What about the other possible explanations?

4.1 Oil shocks?

The oil-price increases of October-December of 1973 – the "first oil shock" – usually get blamed for some part of the productivity slowdown of the 1970's. According to Bernanke, Gertler and Watson (1998), this shock, reinforced by monetary policy, lowered expected profits for U.S. firms and, as such, depressed the stock market. The attractive thing about this explanation is that oil prices behaved the same way everywhere, and therefore their behavior may, perhaps, explain the universally dismal worldwide performance of stock markets in the 1970's and early 1980's. But, monetary policies differed by country, and so this "reinforcement", which may have harmed stock prices in the U.S., did not exist elsewhere. Therefore, if we are to explain the collapse in the world's stock markets, we are left with the oil-shock by itself.

Three problems plague the oil-shock explanation. First, the larger 1979 shock had no impact at all on the variables plotted in the first two figures. Second, oil was too small a fraction of costs to have much effect on dividends. And, third, a rise in oil prices should have lowered current profits more than future profits, because of the greater ease of finding substitutes for oil on the long run, perhaps current output more than future output and, therefore, should have produced a *rise* in the ratio of market capitalization to GDP, not a fall. We shall now formalize this argument by adding an "oil price shock" to the model that we introduced in Section 2.

Suppose that, instead of a new type of fruit arriving at T, the economy at date zero is hit by an unexpected storm which is expected to last for T periods, i.e. from $t = 0$ till $t = T - 1$. For the duration of this storm, the output of the apple trees is reduced from x to $(1 - \alpha) x$, where $0 < \alpha < 1$. Expected GDP now is

$$Q_t = \begin{cases} (1-\alpha)\, x & \text{for } t \leq T-1 \\ x & \text{for } t \geq T \end{cases},$$

and the stock market value is

$$P_{x,t} = \begin{cases} \frac{x}{1-\beta}\left[1 - \alpha\left(1 - \beta^{T-t}\right)\right] & \text{for } t \leq T-1 \\ \frac{x}{1-\beta} & \text{for } t \geq T \end{cases}.$$

Thus, not surprisingly, this shock reduces the stock market value. However, for the first T periods, market-cap/GDP *rises*:

$$\pi_t^* = \begin{cases} \left(1 + \frac{\alpha\beta^{T-t}}{1-\alpha}\right)\pi & \text{for } t \leq T-1 \\ \pi & \text{for } t \geq T \end{cases}$$

If this is how the oil price shock affected output, this story cannot explain the drop in market-cap/GDP. Moreover, this scenario does not suggest any entry in the stock market, and so, it implies that the share of the incumbent firms is constant at 1. Hence it also cannot explain the entry-driven increase in market value relative to GDP that we have observed in the late 80's and 90's.

Does this conclusion hinge on our assumption that dividends are a constant fraction of output? This is a potential concern because, as figure 17 shows, the first oil shock was followed by a drop in dividends relative to output.

But this drop was around 20 percent only, not large enough to produce the required rise in market-cap/dividends. In Figure 18 we plot this ratio, and it, too falls in 1973 instead of rising as one would have expected. Finally, the oil shock story also cannot explain why entrants were so important in the subsequent market rise. We conclude that, whatever role the oil shock may have played in generating the productivity slowdown of the '70's, it does not help explain the behavior of the stock market.

4.2 Exhaustion of Old Technologies?

A similar line of argument is that, in 1973, news arrived that was *bad* for existing technologies, i.e., that the old technologies had played themselves out. Zeira (1999)

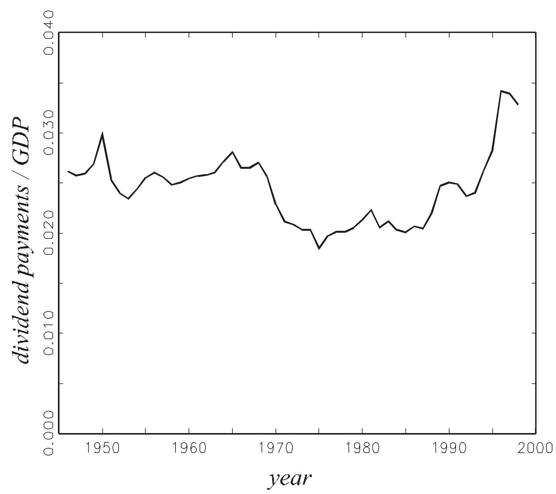

Figure 17: Dividends as a fraction of GDP

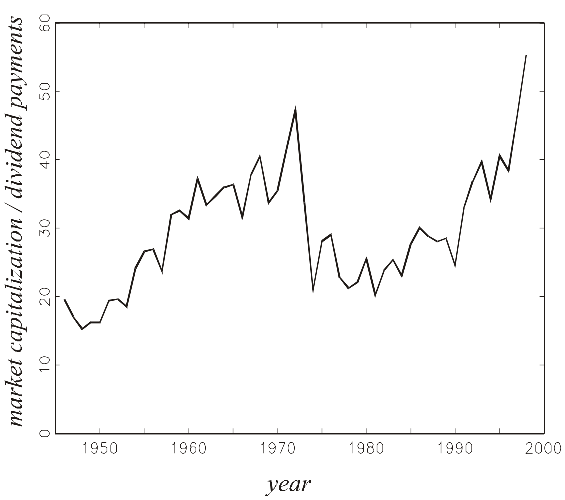

Figure 18: Market capitalization over dividend payments

offers a model in which such news arrives suddenly: Old technologies have a maximum potential, but we don't know what the maximum is; once we hit this ceiling, however, we suddenly realize that no further growth is possible, and this causes the technology's present value to crash. In other words, in Zeira's model, a crash occurs when output and dividends stop increasing. In particular, stock prices fall relative to output, just as Figure 1 says they did. Similarly, Jovanovic and Rob (1990) argue that the economy does well when the technologies in current use are working out well and that we direct our efforts towards developing new technologies only when we get bad news about the incumbent ones.

This line of argument faces two problems, both quantitative in nature. First, the sheer number and variety of technologies that are in use make it quite unlikely that they would all expire at the same time. Some adverse shock, common to them all, would have to have hit them simultaneously. The only candidate is the oil shock, but, as we have argued above, it should have produced a *rise* in market-cap/GDP, not a fall, because its short-term effect on output and dividends should have exceeded its expected long-run impact.

The second, and more important problem with the argument is that, as technologies get older, we get to know them better. The more we use a technology and the more we refine it, the fewer surprises it holds in store, certainly fewer negative surprises.[14] A new technology like the computer technology was in 1971, an unexplored avenue – the transformation of the transistor into the microprocessor – produced a big payoff.

4.3 Increased volatility?

Pindyck (1984) considers Malkiel's suggestion that the decline of the 1970's reflected the response of risk-averse investors to a secular rise in the volatility of stock returns and in the uncertainty in the business environment. But after rising in the 1970's, the volatility of stock returns has not reverted to its pre-1970 level, yet stock prices bounced back after 1985. And judging, at least, by the higher turnover of values in the CRSP, the business environment is riskier than ever. Moreover, the very stocks that are now so highly valued are also extremely risky. This hypothesis does not, therefore, seem to be a serious contender for explaining the broader picture, unless one takes seriously the "Peso Problem" idea that investors considered an economic catastrophe (the likes of which are not included in the time series) more likely during the 1970's.[15]

[14] In Zeira's model, the growth-epoch is exponentially distributed, and the probability distribution of the residual lifetime of growth stays constant as the technology ages. Because of this, news of the demise of growth is always a nasty surprise, no matter how old the technology that generates the growth. In Jovanovic and Rob's model, residual uncertainty shrinks as the technology ages, but , then, so does the potential surprise.

[15] Pindyck also discusses the Feldstein-Summers suggestion that the high inflation of the '70's reduced the value of firms because it reduced the real value of their depreciation write-offs, and

4.4 Nonfundamentals?

Is the stock market bubble-prone? Did a positive bubble burst, or a negative one form sometime between 1968 and 1974? And today, do we see a positive bubble, especially in the internet stocks? One can, perhaps, dismiss explanations like "crazes", "manias", etc. that invoke investor irrationality, but this still leaves a class of models in which rational bubbles can form.

Theory says that to have sunspot equilibria in which the prices of assets fluctuate independently of fundamentals, we need finite horizons, or heterogeneous beliefs. These conditions seem reasonable enough, and one certainly could not, offhand, rule out the possibility that the story of the large post-war swings in the stock market is largely one of bubbles. To be at all convinced, however, we would also need to be told why the bubbles simultaneously burst and then, later, simultaneously formed in various stock markets around the world, but let's suppose that a respectable argument for this, too, can be found. What would this tell us about why the swings in the stock market took place? Exactly nothing, of course, since switches among equilibrium points *have* no economic explanation.[16]

5 Conclusion

We have argued that aggregate valuation can fall below the present value of dividends because capital may "disappear" right after a major technological shift because this is when new capital forms in small, private companies. Later, these companies are IPO'd, and their value then become a part of stock-market capitalization.

To put it another way, the vintage capital model teaches us that technological change destroys old capital. We go a step further and argue that major technological change – like the IT revolution – destroys old *firms*. It does so by making workers and managers obsolete. Product-market entry of new firms and new capital takes time, and their stock market entry takes even longer. In the meantime, the stock market declines. That is the story we have told.

Arbitrage opportunities arise in the model only for an agent who has advance information. For instance, if an agent were to get the news about the IT shock before anyone else, he could make money by selling the incumbent firms short. Or, if he could identify the successful entrants at date T before anyone else did, he could acquire a stake in them, and make money at the IPO stage. In fact, many people must have made money in precisely this way. Moreover, through apparent good fortune, stockholders have done very well since the mid '80's – the growth of IPO values is

Modigliani's suggestion that, in the '70's, inflationary expectations found their way into nominal interest rates but, somehow, not into future dividends.

[16]Some sunspot equilibria are not jumps among equilibrium points, but the jumps that they display still lie beyond the grasp of economic science.

only a part of the reason why the stock market has done so well in the last 15 years; after their IPO's these firms have done better than expected.

What of the excess volatility puzzle? The paper has used a compositional argument to explain some excess volatility in the aggregate – more specifically, occasional undervaluation of the aggregate dividend stream because of shifts in the composition of traded firms. On the other hand, *individual* stocks exhibit no aggregate volatility. A further test of our model, then, would be to see if excess volatility in the aggregate exceeds any excess volatility that may exist in a representative security.

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