The Information-Technology Revolution and the Stock Market: Evidence

By BART HOBIJN AND BOYAN JOVANOVIC*

Why did the stock market decline so much in the early 1970's and remain low until the early 1980's? We argue that it was because information technology arrived on the scene and the stock-market incumbents of the day were not ready to implement it. Instead, new firms would bring in the new technology after the mid-1980's. Investors foresaw this in the early 1970's and stock prices fell right away. In our model, new capital destroys old capital, but with a lag. The prospect of this causes the value of the old capital to fall right away. (*JEL* G12, O16, O33)

In this paper, we shall study the postwar 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 (IPOs). In other words, that aggregate capitalization fell below the present value of dividends because a chunk of the dividend-yielding capital stock was temporarily 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. Jeremy 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 improve on the model that captures this logic, we shall present new evidence on that model, and comment on another proposed explanation for the 1970's episode, the first OPEC shock.

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 (FRBG). After hovering around one all through the 1960's, market-cap/GDP plummeted to 0.4 in 1973, did not recover until the mid-1980's, and it then rose sharply.

Figure 2 shows that except for Japan, the leading OECD countries experienced similar movements in their stock markets. The figure plots market capitalization as a fraction of GDP for Japan, Canada, and three European countries. If one were to combine the panels of Figure 2, 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 world.

Rajnish Mehra (1998) argues that the kind of volatility that Figures 1 and 2 portray is not consistent with the standard stochastic growth model, and Robert Hall (1999) notes that the standard model implies a puzzling "meltdown" of capital in 1973–1974. The puzzle, in terms of Figure 1, is the nearly threefold decline in market-cap/GDP in 1973–1974, followed by its fivefold rise since 1985. The literature offers three solutions to the puzzle. First, that the first oil crisis, combined, perhaps, with a reaction in monetary policy, reduced expected future profits of firms and, as a result, led to a drop in stock prices. Second, that the decline of the 1970's

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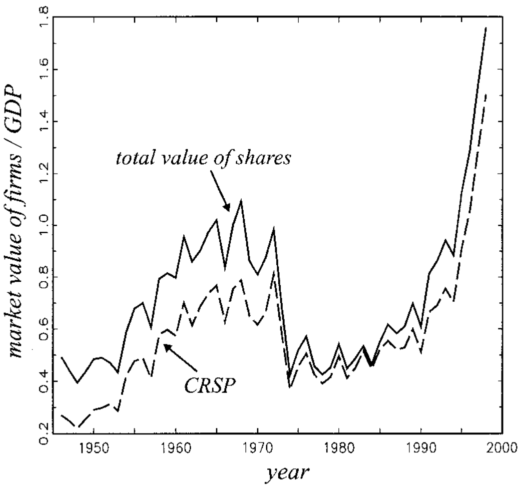

FIGURE 1. STOCK-MARKET VALUE RELATIVE TO GDP

Sources: Total value of shares: taken from the Flow of Funds Accounts, published by the Federal Reserve Board of Governors, "Issues at Market Value," Table L.213. *CRSP:* Total market capitalization of all securities contained in the CRSP data set. All market capitalization data are end of year, December 31, market capitalizations.

reflected a response of risk-averse investors to a secular rise in the volatility of stock returns. And, third, that a positive bubble burst, or a negative one formed in 1973 and that today a positive bubble still exists.

This paper takes on a different view. The view is that *good* news arrived in the early 1970's, news that information technology was on the horizon. Figures 1 and 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 56 percent in 1998, and is rising still. It seems natural, therefore, to label the early 1970's 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 I describes the main assumptions and, then, the model. Section II describes several tests of the IT hypothesis. Section III considers some other explanations, and Section IV concludes the paper.

I. The IT Hypothesis

Our argument rests on three assumptions. First, that the success of the IT revolution became evident in the early 1970's. 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 imperfectly, thereby allowing incumbents' values to fall and remain low until the mid-1980's. We now explain why we find these assumptions reasonable.

ASSUMPTION 1: *The IT revolution was heralded in 1973, or perhaps in stages during 1968–1974.*

Before 1971, the computer was no friend of small business. A computer was 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 fol-

[1] Paul Ceruzzi (1998 p. 220) writes:

> 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 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

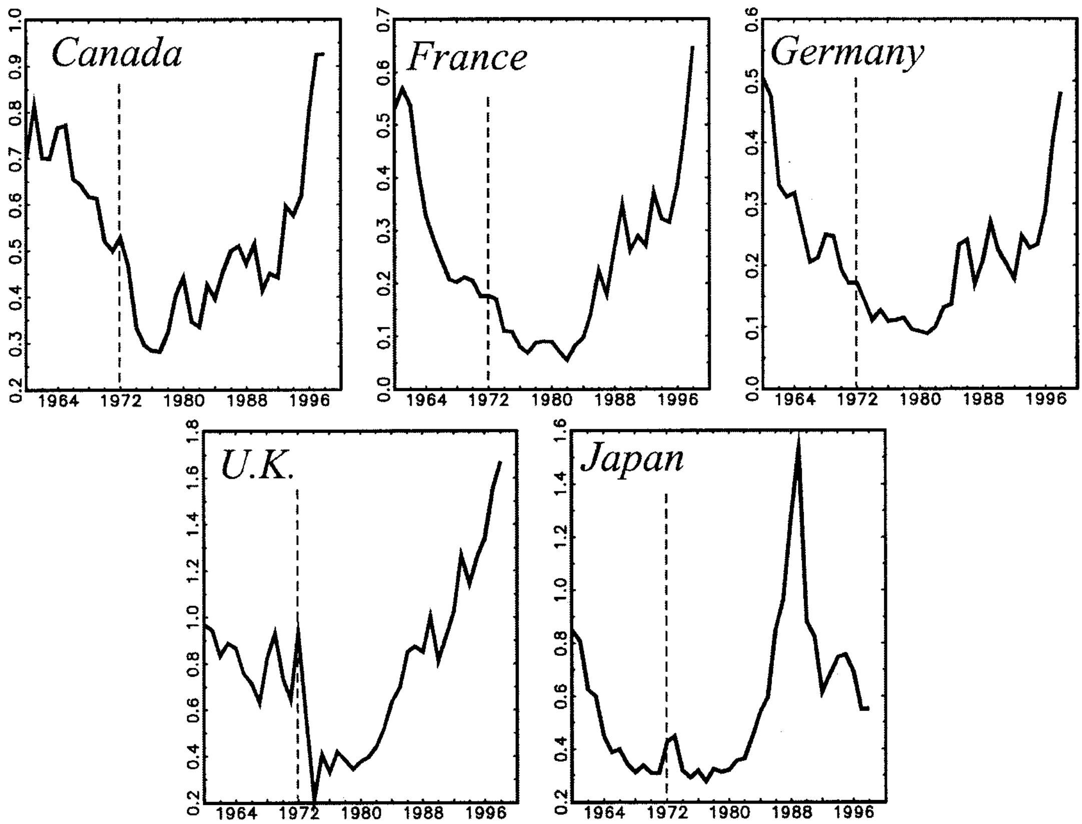

FIGURE 2. MARKET CAPITALIZATION AS A FRACTION OF GDP IN FIVE OECD COUNTRIES

Sources: Market capitalization data for 1975–1998 are obtained from the International Federation of Stock Exchanges and include value of domestically listed firms on the Paris, Frankfurt, London, Toronto, and Tokyo stock exchanges. For before 1975, we "backcast" total market capitalization on the basis of the share price indices published for these countries in the IMF's International Financial Statistics.

lowed 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 United States, 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

well, especially the ROM chip that supplied the code that turned a general-purpose processor into something that could meet a customer's needs.

[2] Similarly, Martin Campbell-Kelly and William Aspray (1996 p. 237) write that it was "possible to produce an affordable personal computer (costing less than $2,000, 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] Tim Jackson (1997 p. 75) writes:

> 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, 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

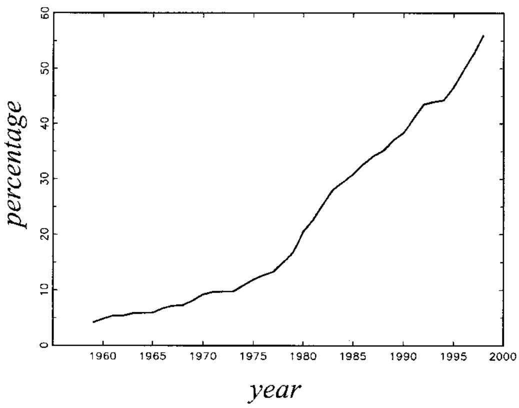

FIGURE 3. SHARE OF COMPUTERS AND SOFTWARE IN REAL EQUIPMENT INVESTMENT

Notes: Real investment in "Information Processing Equipment and Software" as a percentage of real investment in "Nonresidential Equipment and Software." Both are converted to 1992 dollars.
Source: NIPA 1999 revision.

IPO'd in October of 1971 and, by August 1972, it had released its second microprocessor—the "8008."[4]

To be sure, the early microprocessor was a primitive ancestor of today's PC—it had no keyboard, no screen, and a small 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 observation that the power of microprocessors doubles every 18 months) the power of computers would quickly become phenomenal, and, as soon as the software needed to turn the computer into a multipurpose problem solver became available—and this was just a matter of time—the computer would transform the face of American business.

It may well be that the world realized more gradually that computers would transform things in a big way. Our story works—and we do not resist this interpretation—if, instead of one big news flash in late 1973, the news came in several stages, starting in 1968 or so, and ending in 1974. This was the period during which the P/Y ratio declined by a factor of three, with some bumps along the way. For simplicity, though, we shall model the episode by assuming that all the information arrived at once.

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 did not 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 such as Jennifer Reinganum (1983), and elsewhere.

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 top-heavy, and its employees more likely to be drawing salaries that do not reflect their performance—a CEO with a handsome "golden parachute" has little reason to do *anything* for his firm, much less learn something new. Golden parachutes are severance payments that, along with a host of other defensive measures, became popular in the early 1980's, stimulated into being by the rash of hostile tender bids (Andrei Shleifer and Robert W. Vishny, 1988).

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.*

Whether management is separate from ownership or not, we believe that we need to assume a friction in the takeover market. We reason as follows: Suppose that a friction between owners and managers puts half of the rents in the manager's pocket. Then, shareholders would still want a manager who can generate the highest total rent. If the firm has a manager at the helm

described the 4004 customer list as "not so much Who's Who as Who's That?"

[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).

who cannot handle IT, a frictionless takeover market would transfer the firm to someone who can. A frictionless takeover market cannot lead the firm to their first-best efficiency levels, but it should be able to maintain manager-firm matches at their second-best optimum. If so, the arrival of a new technology that some managers cannot implement would usher in a merger wave and, instead of losing value, incumbents would simply face reorganization. One would expect this outcome even if ownership is separate from control and even if managers skim some percentage from the firm's rents. Knowing they can get, say, just 50 percent of the rents, the firm's shareholders would still want the most efficient manager running things and would welcome any bidder that could effect this change. An argument of this sort is implicit in Michael Gort (1969). It says that the shock should prompt takeovers, but no reductions in value.

But that is not what happened in the early 1970's. Instead, values fell and stayed low, and the merger wave took place not in the 1970's but in the 1980's. But when the wave finally did form, it was the first obvious "cleansing" merger wave: In their study of mergers in this period, Randall Morck et al. (1988) find not just that targets of hostile takeovers show signs of managerial malfunction, but that they show it all too clearly. In a sample of about 371 large firms of which 40 were acquired between 1981 and 1985, the average 1980 Tobin's q of a target of a future hostile bid was 0.52, as compared to the average q of 0.85 for the sample as a whole. In other words, the targets had q values about 40 percent below average. Morck et al. found that most of the differential arose because the targets were in declining industries. But in a larger sample of manufacturing plants, Frank R. Lichtenberg and Donald Siegel (1987) found that takeover targets had TFP levels 5 percent smaller than that of an average plant in their industry. In short, targets are in the wrong industries, and on top of that, they are less productive than the average competitor. Since the current productivity differential was small relative to the differential in q, it would seem that the firms in question were targeted for takeover less for their currently low productivity than for their poor long-run prospects, and the model we present will have a drop in incumbents' values for precisely this reason.

Given that a firm's q could fall by nearly 50 percent before it was taken over, and given that it took the best part of a decade for hostile takeovers to get off the ground, one may well ask if takeovers serve a policing function at all. Shleifer and Vishny (1988) outline some major frictions in the disciplining role of takeovers. Insiders—management and unionized workers especially—can protect themselves from hostile takeovers. Their firm may guarantee them a lot more than they are worth. To succeed, a raider would need to buy such people out, and the cost of doing so could exceed the efficiency gains that he could bring to the firm, in which case the takeover will not take place. Moreover, as Sanford J. Grossman and Olivier D. 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 percent before it goes through, and that, as a result, a firm can lose value and not be taken over.

Where the takeover hurdle is too high, the inefficient firm stays in business until it is driven out by more efficient entrants. This process is slower than the takeover, and this may be why the market took more than ten years to recover. But, recover it did, and the painful adjustments are now taking place.[6] Not surprisingly, the "excess fat" is mostly among managerial and nonproduction workers (Lichtenberg and Siegel, 1990).[7] And since the adoption of IT

[5] Richard Brealy and Stewart Myers's (1996 Ch. 33) account of the RJR-Nabisco buyout by the private firm Kohlberg, Kravis, and Roberts indicates that the shareholder appropriated the entire gain from that deal.

[6] Henry Farber and Kevin Hallock (1999) find that over the past 30 years, announcements about labor-force reductions are increasingly likely to lead to stock-price increases. The authors argue that such an announcement is now more likely to signal a rise in efficiency, and is less likely than before to reflect a reduction 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 newspaper 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, Sangamitra Das and Ramprasad Sengupta (1999) find that in the typical (presumably sheltered) public sector firm, managerial workers are much more overemployed than the production workers.

is in many firms probably long overdue, some firms are seeing extremely high rates of return on their IT investments.[8]

A. *The Model*

The model is a version of the Robert E. Lucas, Jr. (1978) economy. A similar model in Greenwood and Jovanovic (1999) had counterfactual implications for interest rates, and we shall depart from it in two ways. First, in order to allow obsolescence into the model, our economy will have two types of fruit and, second, fruit is an intermediate good that firms use to make a single final good—fruit juice. So, this is a production economy with a single final good, two intermediate goods, no storage, and a fixed capital stock—trees—that does not depreciate physically.

Let y_t denote gallons of juice produced and consumed at date t. Preferences are

$$\sum_{t=0}^{\infty} \beta^t U(y_t). \tag{1}$$

Competitive firms make juice using apples, x, oranges, z, and a third factor, n, as its inputs in the constant-returns-to-scale production function for final goods

$$y = \bar{F}(x, z, n), \tag{2}$$

taking the prices of fruit, p_x and p_z as given. The factor n is fixed; we shall normalize its supply to equal 1, and define

$$F(x, z) \equiv \bar{F}(x, z, 1). \tag{3}$$

The numeraire is y_t. Optimal input choice means that prices of x and z must equal their marginal products:

$$p_{x,t} = \frac{\partial F}{\partial x}(x_t, z_t) \text{ and } p_{z,t} = \frac{\partial F}{\partial z}(x_t, z_t). \tag{4}$$

Since returns are constant, factor payments equal output, and firms make zero profits.

The proceeds from the sales of apples and oranges are paid out as dividends. Claims to the apple-tree and orange-tree dividends trade freely at prices $P_{x,t}$ and $P_{z,t}$ respectively. If the stream of dividends that these trees will pay is $\{x_t\}$ and $\{z_t\}$, the date-τ "cum-dividend" prices of the trees would be

$$P_{x,\tau} = \sum_{t=\tau}^{\infty} \beta^{t-\tau} \frac{U'(y_t)}{U'(y_\tau)} \frac{\partial F}{\partial x}(x_t, z_t)x_t \tag{5}$$

and

$$P_{z,\tau} = \sum_{t=\tau}^{\infty} \beta^{t-\tau} \frac{U'(y_t)}{U'(y_\tau)} \frac{\partial F}{\partial z}(x_t, z_t)z_t. \tag{6}$$

Before the Shock.—Initially, there are no orange trees. The economy comprises a unit measure of apple trees, each yielding x apples. Output and consumption are

$$y = F(x, 0), \tag{7}$$

and expected to remain there indefinitely. Any change in this state of affairs is thought to be impossible, or at least, highly improbable. The aggregate stock-market value or "market capitalization," is then,

$$M_\tau = \sum_{t=\tau}^{\infty} \beta^{t-\tau} \frac{U'(y)}{U'(y)} \frac{\partial F}{\partial x}(x, 0)x = \frac{(1-s)y}{1-\beta}, \tag{8}$$

for all τ, because by Euler's Theorem $(\partial F(x, 0)/\partial x)x = (1 - s)y$, where s is the cost share of the factor n. The ratio of market capitalization to GDP is just $(1 - s)/(1 - \beta)$.

News Arrives at Date Zero.—News arrives at $t = 0$ that a unit measure of orange trees will spring forth at the beginning of date T, and that each tree will yield z oranges per period. At date

[8] "Using eight years of data for over 1,000 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." (See Erik Brynjolfsson and Shinkyu Yang, 1998 p. 1.) If these numbers are even close to being correct, IT must have met with some pretty stiff resistance.

T—and *not* at date zero—agents will also expect to receive an equal share of claims to the output of these orange trees. This assumed delay is supposed to reflect the reality that a new company takes years before reaching its initial public offering. The arrival of the orange trees permanently raises the output of juice to

$$y' = F(x, z). \tag{9}$$

Until date T, stockholders will only receive the dividends from the apple trees. All this becomes known at date zero, and no further shocks are expected.

The Effect of the News on Stock Prices.—In what follows, we shall assume that s, the share of the third input, is constant. Since $(1 - s)y = F(x, 0) = (\partial F(x, 0)/\partial x)x$, the apple trees will command a price of

$$P_{x,t} = \begin{cases} \dfrac{1-\beta^{T-t}}{1-\beta}(1-s)y + \dfrac{\beta^{T-t}}{1-\beta}\left(\dfrac{U'(y')}{U'(y)}\right)\dfrac{\partial F(x, z)}{\partial x}x & \text{for } t \le T-1 \\ \dfrac{1}{1-\beta}\dfrac{\partial F(x, z)}{\partial x}x & \text{for } t \ge T \end{cases}, \tag{10}$$

and market capitalization now becomes

$$M_t = \begin{cases} P_{x,t} & \text{for } t \le T-1 \\ \dfrac{(1-s)y'}{1-\beta} & \text{for } t \ge T \end{cases}. \tag{11}$$

Note that we have *defined* $P_{z,t}$ to equal zero for $t \le T - 1$, even though, even before date T, the value of the sprouting orange trees would be positive if they were to trade on the stock market.

When the news arrives, $P_{x,t}$, and therefore M_t as well, falls for two reasons. First, the rate of interest between date $T - 1$ and date T rises because that is when output rises permanently from y to y'. Before date T arrives, dividends beyond date $T - 1$ are now discounted at a higher rate, i.e., they are multiplied by the factor $(U'(y')/U'(y)) < 1$. This effect cannot really explain the stock-market drop, however, because the real rate of interest simply did not rise by that much during the 1970's and 1980's. Moreover, in an open economy, if the price of juice at all dates was fixed and constant, the interest rate impact does not exist, even in theory.

The second effect is a possible obsolescence of apples—oranges may displace apples as an input and, assuming that apples and oranges are substitutes in the production of juice, this would show up as a lower price of x, in that $(\partial F(x, z)/\partial x) < (\partial F(x, 0)/\partial x)$. The largest impact would occur if the arrival of oranges were to make apples *fully* obsolete so that $F_x(x, z) = 0$. This would happen, e.g., if people wanted at most one glass of juice, and if they preferred that juice to be pure orange. The value of the apple trees relative to GDP would then be

$$\frac{P_{x,t}}{y_t} = \begin{cases} (1-s)\dfrac{1-\beta^{T-t}}{1-\beta} & \text{for } t \le T-1 \\ 0 & \text{for } t \ge T. \end{cases} \tag{12}$$

The impact of the news at date zero would be $1 - \beta^T$, which, at $T = 12$ and $\beta = 0.96$ would represent a 61-percent drop—the largest that this model can deliver. To get a drop of this size, however, requires that we assume the value of incumbents to be zero after date T, and this, as we shall see, does not fit the facts.

After the orange trees start to trade, the ratio M_t/y_t reverts to its pre-news level of $(1 - s)/(1 - \beta)$. Figure 4 shows the predicted time path of M_t/y_t before and after the news arrives—it is the theoretical counterpart of Figure 1. The two figures look similar if the date $t = 0$ is set to correspond to the year 1973, and if $T = 12$ years. This might seem like a long time, but the time to IPO should be longer when a technology is young and, hence, risky.

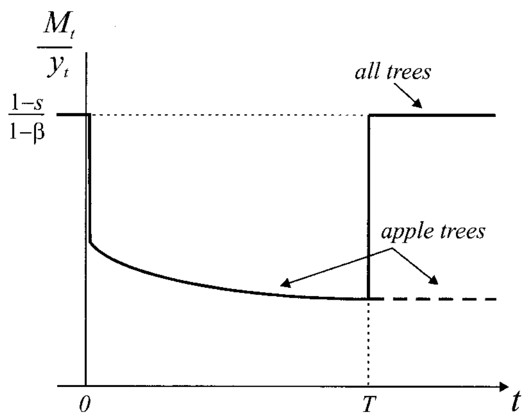

FIGURE 4. THE PREDICTED PATH OF THE MARKET-CAP/GDP RATIO

Microsoft, for example, was formed in 1976 but only went public in 1986.

II. 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. Most of the value brought in by the post-1972 entrants should have surfaced at the time of their IPO, not afterwards.
3. The model should work best for the IT-intensive sectors of the economy. The largest 1973–1974 price declines should have occurred in sectors that had the largest post-1973 investments in IT.
4. If the 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.
5. In a closed economy, the model predicts a rise, at date zero, in the T-period interest rate. In an open economy, the model predicts a permanent increase in consumption at date zero—or when the news about the IT revolution arrives.

This section takes up each implication in turn.

A. *The Extraordinary Decline 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 know who the 1972 incumbents were. Most are covered by the Center for Research in Security Prices (CRSP) data. The lower, dashed line in Figure 1 is the ratio of market capitalization to GDP for the data set published by the CRSP that contains the stocks traded on the NYSE, AMEX, and NASDAQ. The top, solid line is the capitalization of all firms from aggregate data provided by the Federal Reserve Board. The difference between the intercepts of the top and bottom lines is the 1972 capitalization of stocks that traded over the counter and that, therefore, were not then covered by the CRSP data.

Because of mergers that took place after 1972, the "fate" of the 1972 incumbents is a little ambiguous. Some incumbents merged with firms that entered after 1972. If so, does the new value belong to the old vintage or to the new? We call this ambiguous class of firms *hybrids*. We shall distinguish these hybrid incumbents from *pure* 1972 incumbents that did not merge with any post-1972-vintage firms. An incumbent is either hybrid or pure.[9]

Figure 5 shows that relative to GDP, the 1972 CRSP incumbents' value fell by more than 50 percent over a few years, and never fully 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 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 die sooner or later and make way for new firms. The question, then, should not be whether the 1972 incumbents did badly relative to subsequent entrants, but rather, whether the 1972

[9] A complete description of the data construction is given under the specific figures.

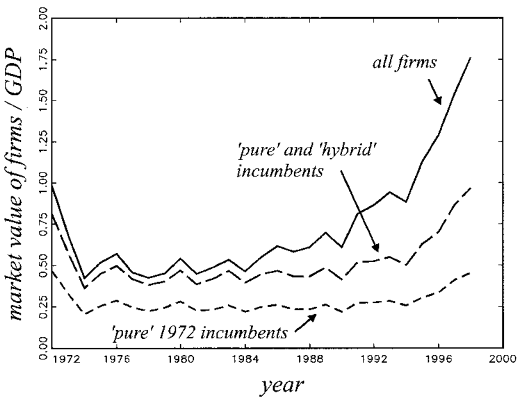

FIGURE 5. THE FATE OF THE 1972 INCUMBENTS

Notes: Year of entry of firms in CRSP is based on the first entry date of a security with the firms' permanent company number (permco). The CRSP does not contain data on the merger partners of all firms that exit due to mergers from the data set. To be specific, CRSP contains 3,168 firms that exit due to exchanges or mergers, for which their merger partners are unaccounted for. For 1,075 of these firms we have found their merger partner, which is part of the CRSP, in various editions of the Semi-Annual Stock Reports. The other 2,093 firms either merged with partners that were not in the CRSP or were not tractable.

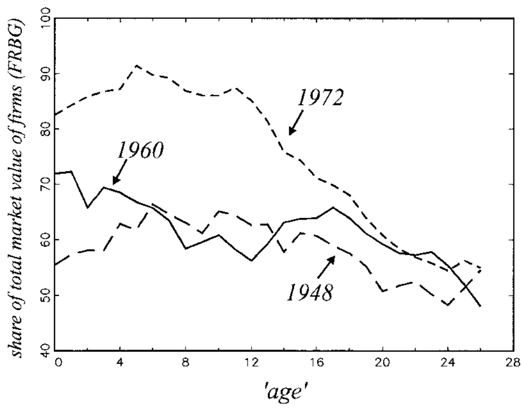

FIGURE 6. SHARES OF THREE VINTAGES OF INCUMBENTS

incumbents did badly when compared with incumbents of *other* vintages. 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 plots the market shares of three vintages of incumbents against their "age" (defined as calendar time minus their vintage). 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 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. This decline probably took place because stock-market trading has become much easier over time, a trend that is itself due in part to the computer. Figure 6 also shows that the 1972 incumbents lost market share much faster than the other two generations. At age 26, the share of all three generations is around 50 percent, even though the 1972 incumbents start off with an 11-percent higher market share. Thus, the 1972 incumbents did worse than the other generations.

B. *Entrants Gained Value Mainly at the IPO Stage*

In the model, all the loss in incumbents' share happens at the time of IPO, at date T. Thereafter, the rate of return on the shares of the new firms equals the rate of return on the shares of the old firms. This is precisely what happened, although there is no single date, "T," at which all the new firms enter. Figure 7 plots, by entrant vintage, the annualized real return between time of entry and 1998 on value-weighted portfolios continually reinvested in these entrants. This is the solid line in the graph. The dashed line is the annualized average real return on a portfolio consisting of all the firms in the market at time t. This figure shows that most generations of entrants did slightly worse than incumbents after they entered. This is consistent with the evidence in Jay R. Ritter (1991). Two recent exceptions are the 1986 and 1990 vintages, which include Microsoft and Cisco Systems, respectively.

This means that *all* of the market share that entrants gained, they gained at the *outset*, at their IPOs. Thereafter, they did not gain market share. In other words, the 1972 incumbents were displaced largely by capital created *outside* the stock market and brought into the stock market at the time of the entrants' IPOs, exactly as the model asserts. After they did grab a share of stock-market value at their IPOs, the

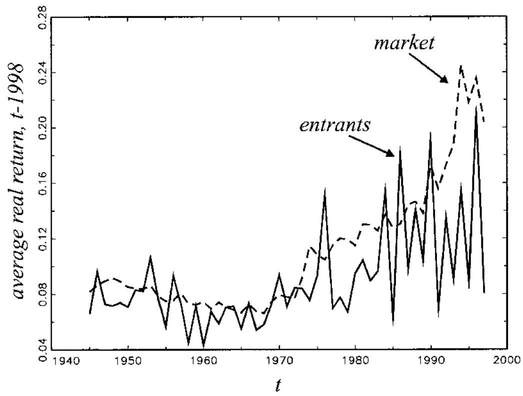

FIGURE 7. AVERAGE RETURN ON ENTRANT VERSUS MARKET PORTFOLIOS

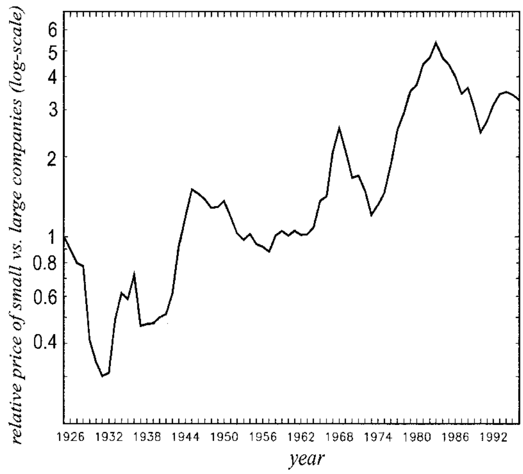

FIGURE 8. PERFORMANCE OF SMALL COMPANIES VERSUS LARGE COMPANIES

post-1972 entrants did not perform better than incumbents, and, therefore, did not gain further market share.

This all fits with the recognized fact that since the mid-1980's the U.S. stock market has been carried by its large-cap firms. The performance of entrants in their early postentry period is probably similar to that of small firms in which ownership is closer to management, in which it is likely that fewer workers are unionized, and fewer management practices are outdated. Figure 8 plots the ratio of the Ibbotson small-cap index to the S&P 500 index.[10] 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 1974–1982 period mirrors the small product-market performance of small relative to large firms evident in Figure 8 of Greenwood and Jovanovic (1999).

If so much value was, indeed, financed at the pre-IPO stage, then who financed it? Initially, the hidden entrepreneurs may have financed themselves, or formulated their ideas while working for established companies, but as their projects matured they would have needed outside funds. At that point, in the late 1970's and early 1980's, perhaps, we would expect to see banks raise their lending to small business. The data do not show a general rise in bank lending during the mid-to-late 1970's, except for a pronounced rise in 1973, and a subsequent reversion of the loan-GDP ratio to about 33 percent of GDP, as Figure 9, based on data analyzed by Ben Craig and Joseph Haubrich (1999), shows. We do not have micro evidence on whether banks directed more loans towards small businesses in the mid-to-late 1970's and early 1980's, and this is something worth pursuing further.

This points to a data limitation that our study has faced from the outset, namely the lack of firm-level debt data for any of the CRSP firms before 1970, and their sporadic availability since 1970. To test the IT hypothesis, it would have been better to compute the value of a firm by adding its debt to the value of its shares, because this is the total value of the claims on a firm's profit. This can be done in the aggregate, and Hall (1999) has done so. Using data from the Federal Reserve Board's Flow of Funds Accounts on equity and debt, he has shown that these data also show a drop in 1973. For individual firms, however, debt data as detailed as the CRSP equity data are hard to find. We

[10] The Ibbotson Small Company Stocks Index is based on fifth capitalization quintile of stocks on the NYSE for the period 1926–1981, and on the performance of the Dimensional Fund Advisors (DFA) Small Company Fund for 1982–present. It is published in Ibbotson Associates (1997).

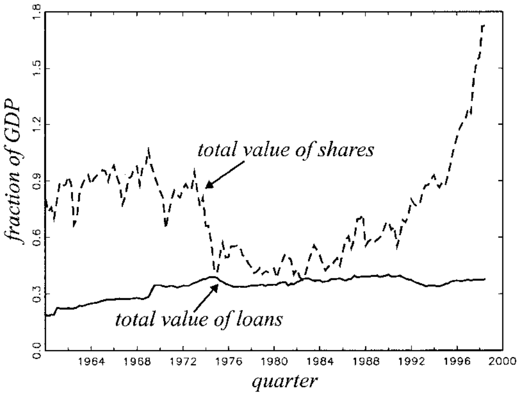

FIGURE 9. TOTAL VALUE OF LOANS AND OF SHARES AS A FRACTION OF GDP, 1960–1998

Sources: Total value of loans is taken from Craig and Haubrich (1999). Total value of firms is based on Flow of Funds Accounts.

merged the CRSP data with the Compustat debt data, which we have only for the past three decades, with less and less representation the farther back one goes so that in the early 1970's, we are left with debt data on mainly large firms. We have, nevertheless, analyzed this restricted sample, and the results were qualitatively the same as the ones that we present here.[11]

C. *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 (Finance, Insurance, and Real Estate) segment of services being the first to do so. Figure 10 reports the fate of the 1972 incumbents by major sector: Manufacturing, FIRE, Services, and Transportation, Communication, and Public Utilities. Two things emerge from Figure 10. First, the biggest 1973 value drops occurred where subsequent IT investment was the highest. The smallest 1972–1974 decline is in manufacturing, where values fell by a factor of 45 percent. A larger decline (50 percent) occurred in FIRE, and a larger one still (72 percent) in other services. Second, where incumbents' values fell the most in 1973, the subsequent recovery was the strongest. 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 better to the theory—a clear positive relation exists between the second and third columns.[12]

We also regressed the 1973–1974 percentage drop of sector i, denoted by D_i, on the log of the capital share of IT in the 1996 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 1972 incumbents in the sector's 1998 market value, denoted by $IncS_i$. The regression results for the 52 sectors for which we have data are

$$(13)\quad D_i = \underset{(3.38)}{64.06} + \underset{(2.66)}{7.82}CapS_i - \underset{(-2.22)}{9.52}IncS_i$$

$$n = 52 \quad R^2 = 0.205.$$

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

D. *Entry, Exit, and M&A's Rose in the Late 1970's and Early 1980's*

The model assumes a T-period gestation for the new technology following its announcement. At date T all the new entrants come in.

[11] The April 25, 2000 version of our paper contains these results and the reader can obtain it from us on request.

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

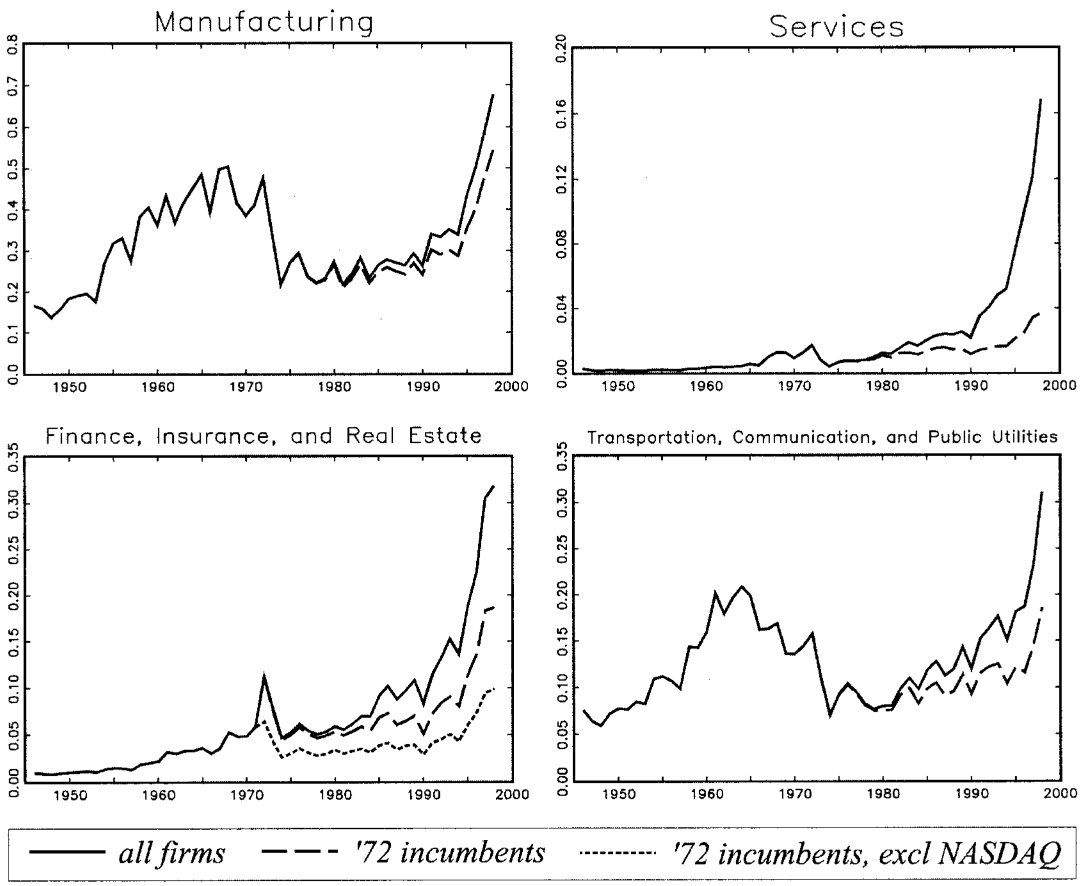

FIGURE 10. THE FATE OF THE 1972 INCUMBENTS BY MAJOR SECTOR

TABLE 1—SUMMARY STATISTICS

	Exposure to IT			
Sector	Investment share	Capital share	1972–1974 drop	1998 incumbent share
Manufacturing	33.9	17.9	44.7	80.2
TCPU	33.8	38.5	45.8	59.9
FIRE	30.0	41.5	49.5	58.7
Services	31.2	42.4	71.8	22.0

Notes. Cross-sectoral regressions: Based on 2- and some 3-digit SIC industries. Data on value drop and incumbent share constructed from the CRSP. Real output growth is obtained by combining nominal output data from the Gross Product Originating tables published by the BEA with producer price indices published by the BLS.

Market shares are then reshuffled, and, stretching things a bit, we may expect to see some exit. The news arrives at date zero, which corresponds to 1973 on the calendar, and therefore the reshuffle should occur at date $1973 + T$. We now look at some indicators of creative destruction—entry, exit, incorporations, IPO's, takeover, and mergers—which suggest that T is somewhere between five and ten years, depending which indicator one looks at.

The plot in the top panel of Figure 11 shows a pronounced rise in both entry and exit in the

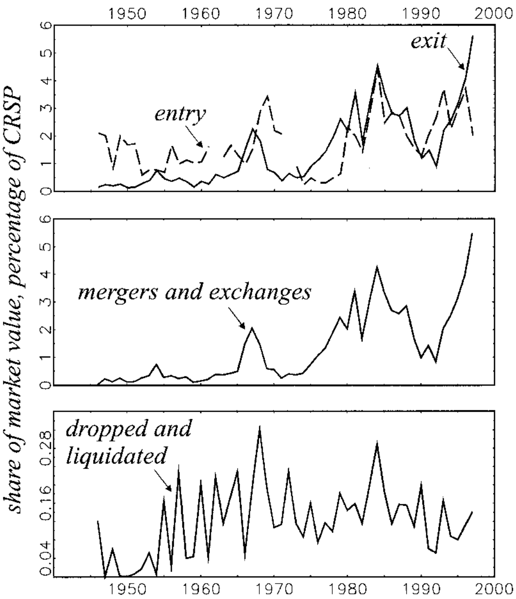

FIGURE 11. ENTRY, EXIT, AND REASONS FOR EXIT FROM STOCK MARKET

Note: Firms that enter as the result of a merger between two other firms are not counted as entrants.

CRSP,[13] denoted in terms of their share of the total market capitalization. Exits begin to rise in 1975, but entry does not rise markedly until 1980. The bottom two panels of Figure 11 depict the reasons for exit. The peak in exit in the 1980's is due mainly to mergers and exchanges, consistent with the evidence in Devra L. Golbe and Lawrence J. White (1993). The share of firms liquidated also peaked in the early 1980's. The fraction of value dropped from the market, mainly because the firm decides to stop being traded on the market, is fairly constant for the postwar period.

Figure 12 shows that incorporations rise markedly after 1975, and Figure 13 shows that real exits have risen substantially, but only since the early 1980's, and that they remain high.[14] Together with the entry rate, we also plot the number of IPO's at least $1.5 million in size.[15] 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.

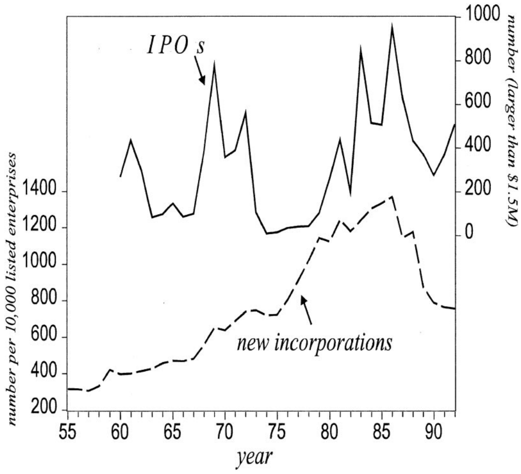

FIGURE 12. THE RATE OF BUSINESS INCORPORATIONS AND THE NUMBER OF IPOS

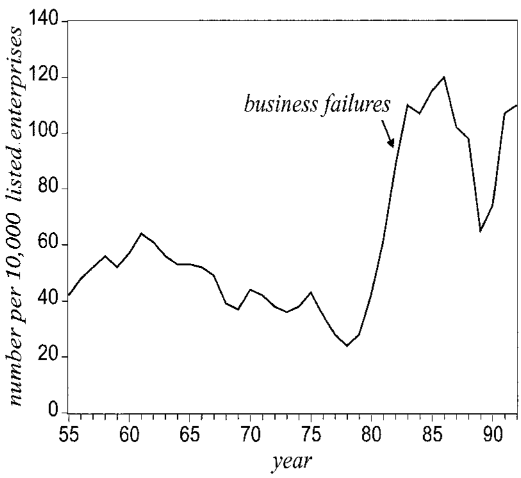

FIGURE 13. THE RATE OF FAILURE OF BUSINESSES

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 in IT, and is the least likely to offer empirical

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

[14] The entry and exit data plotted in Figures 12 and 13 are rates per 10,000 registered enterprises. The data were provided to us by Valerie Ramey; she had presented them in a discussion at the NBER Fluctuations meeting, July 17, 1999.

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

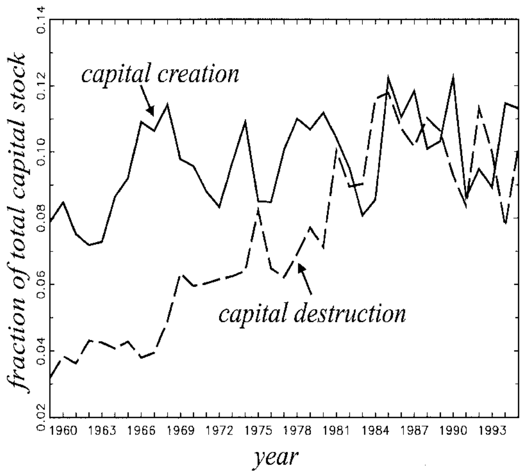

FIGURE 14. ENTRY AND EXIT OF PHYSICAL CAPITAL

support for our argument. Moreover, John C. Haltiwanger and Scott Schuh (1999 Figure 6) find 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.

Gross job flows may have slightly declined, but, on the other hand, gross flows of capital have risen. Valerie Ramey and Matthew Shapiro (1998) compiled a gross-capital-flow series, reproduced in Figure 14, that shows a definite rise since the 1980's, especially in capital destruction.

The CRSP data also show a rise in destruction—exits, whether because of failure or because of merger—have risen. The results in Table 2 report on the fate of entrants ten years after their CRSP entry. Each row reports the percentage of entrants exiting by a decade's end. The first row gives the percentage of entrants that merged or "exchanged" at some point during the decade. Mergers and exchanges have risen sharply over time: In 1985–1995, exits for these two reasons were 2.5 times higher than they had been in 1945–1955 and even 2 times higher than during the 1960's merger wave. 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 exits have risen dramatically—by a factor of 13.

E. *Consumption Rose Sharply in the 1970's*

Since the real interest rate did not change much during the 1970's, the IT hypothesis implies that consumption should have risen when the good news arrived. In the model, consumption cannot rise until date T because the model includes neither capital nor imports, but in fact consumption could and, indeed, did rise in the 1970's. The U.S. personal savings rate was at a 30-year high in 1973, and has declined dramatically since then. Figure 15 shows that U.S. personal consumption was at 61.5 percent of GDP in 1973, it rose to 63 percent in 1974, and it has been rising more or less steadily ever since. Moreover, Jonathan Parker (1999) shows that consumption has been rising the most among the youngest cohorts, and this is what should have happened if the good news included a forecast of higher wages for them in the 1990's.

Overall, the five informal tests seem to confirm the model's implications. Before turning to the alternative hypothesis of a sharp rise in oil prices in 1973, we mention in passing yet another hypothesis, namely cheaper stock-market participation. We have interpreted the rise in stock-market entry as the creative destruction of inept incumbents, and the observed rise in exits, etc., supports this interpretation. But the rise in entry may have taken place for a different reason: It is now much cheaper to raise money on the stock market because of computerized trading and the NASDAQ, and this would induce more firms to list. The prospect of a future entry of small firms could have reduced the rents to those who had already paid the entry cost and may even explain a part of the stock-market drop of the early 1970's. Not an instance of cleansing but simply a more democratization of stock-market financing. This hypothesis may be worth developing further, but we cannot pursue that here.

III. The Role of the First Oil Shock

The first OPEC shock may also explain a part of the drop in the stock market in the early

TABLE 2—ACHIEVEMENTS OF ENTRANTS PER DECADE

Decade	1945–1955	1955–1965	1965–1975	1975–1985	1985–1995
Percentage merged or exchanged	5.61	8.84	7.27	10.78	15.37
Percentage liquidated	1.40	1.70	0.63	0.77	0.24
Percentage "dropped"	0.35	5.17	10.12	21.74	18.51
Total	7.36	15.71	18.02	33.29	34.12

1970's, as well as a part of the productivity slowdown of the 1970's (which our model does not explain). One argument says that the 80-percent rise in the price of energy, reinforced perhaps by a reaction by the Fed in setting its 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 globally, and therefore their behavior may, perhaps, explain the universally bad performance of stock markets in the 1970's and early 1980's. But, monetary policies differed by country, and so the reinforcement, which may have harmed stock prices in the United States, 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 large 1979 shock had no impact at all on the variables plotted in the first two figures. Second, 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. 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 1980's and 1990's. Similarly, a rise in oil prices should have lowered current dividends more than future dividends, and yet Figure 16 plots market capitalization relative to dividends, and this ratio also fell in 1973 instead of rising, as one would have expected if the oil shock was to blame for the drop in capitalization in 1973–1974.

The third difficulty with the oil-price-shock explanation for the stock-market drop is that the energy-intensive sectors did not experience the largest drop in value in 1973–1974. Our own model says that the IT-intensive sectors should be where the drop is the largest in 1973–1974,

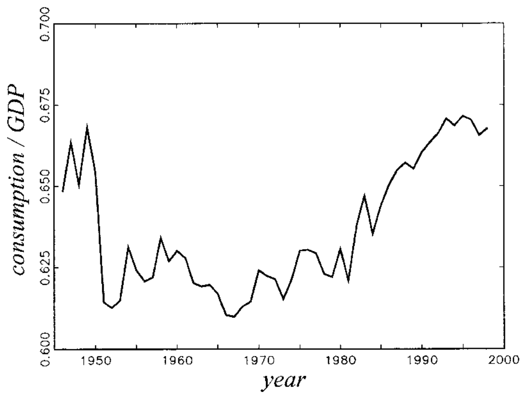

FIGURE 15. CONSUMPTION INCREASE

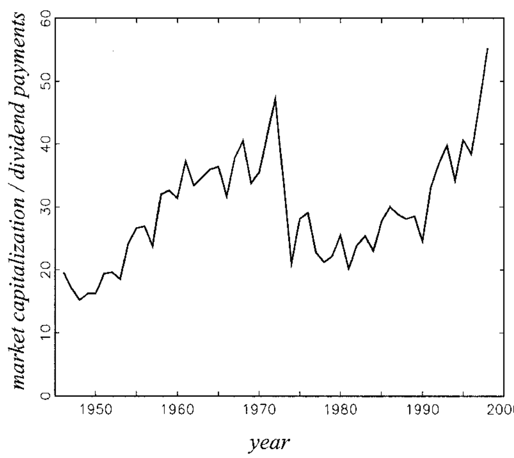

FIGURE 16. MARKET CAPITALIZATION OVER DIVIDEND PAYMENTS

Source: Total dividend payments are taken from the Flow of Funds Accounts.

TABLE 3—REGRESSION RESULTS

Dependent variable: 1972–1974 percentage drop in market capitalization ($n = 52$)	I	II	III	IV	V
Intercept	26.63	64.06	71.48	77.64	78.67
	(2.94)	(3.37)	(3.79)	(4.13)	(4.15)
Logarithm of 1996 IT equipment capital share	8.12	7.82	9.00	7.68	7.80
	(2.67)	(2.66)	(3.08)	(2.59)	(2.61)
Logarithm of 1998 share of 1972 incumbents		−9.52	−13.42	−13.96	−14.58
		(2.22)	(−2.89)	(−3.06)	(−3.12)
1973–1974 growth rate of output			−0.83	−1.19	−1.10
			(−1.92)	(−2.53)	(−2.24)
Logarithm of 1972 oil share				−6.66	−5.86
				(−1.75)	(−1.47)
Durables dummy					5.73
					(0.68)
R^2	0.124	0.205	0.262	0.307	0.314

whereas the oil-price hypothesis says that they should be the oil-intensive sectors. We run a statistical horse race and find that IT wins hands down.

The dependent variable in the regressions in Table 3 is the percentage drop in the market capitalization of sector *i* in the 1972–1974 period, and it comes from the CRSP. Thus a positive value is a drop, a negative value a rise. The regressors should measure the relevance of IT and the relevance of oil prices. The first regressor is the logarithm of the share of computer and related equipment in the 1996 real equipment capital stock of sector *i*, in 1992 dollars, and it comes from the BEA's tangible wealth table. It measures how important IT was in the subsequent investment in sector *i*, and our model says that its coefficient should be positive, because sectors with a lot of investment exposure to IT should have been the hardest hit by the new technology. The second regressor is essentially the 25-year survival rate of the 1972 incumbents' capital and arguably proxies for resistance to change in that sector; this variable is the logarithm of the 1996 share of the 1972 incumbents in the market capitalization of sector *i*, and it, too, comes from the CRSP. Our model says that its coefficient should be negative: Sectors in which value falls most should be ones in which entrants add the most value later on. The fourth regressor is the log of the 1972 share of oil in the production costs of sector *i*—dollars spent (directly and indirectly, i.e., through inputs from other sectors) on crude petroleum and natural gas per $100 of the output produced. These data come from the 1972 input-output tables. Our sectors do not completely correspond to the ones in the input-output table, so we have matched them as well as we could. Finally, if by some chance the IT-intensive sectors were hit harder than others by the recession of 1973–1974, the outcome could be due to the recession and not to IT. To handle this possibility we include as a regressor the 1973–1974 growth rate of real output of the sector. Moreover, durable goods are more cyclical than others, and so to control for this concern, we include a dummy variable which is one for durable-goods-producing sectors (Construction, Furniture, Industrial machinery, Electronic and electric equipment, Motor vehicles, Transportation equipment, Instruments).

The regressions in Table 3 show that oil did not cause the stock-market drop in 1973–1974, and they favor the IT interpretation—both of the IT variables are of the correct sign and they differ significantly from zero. The coefficient associated with oil is not significant and, in fact, has the opposite sign from what one would have expected. That is, the sectors that were the *least* energy intensive dropped the most in value. The inclusion of the durable goods dummy doesn't change the conclusion.

Table 4 lists the cross correlations between the regressand and regressors that we considered. Our model would predict a higher correlation between the *ex post* IT intensity of the industries and their incumbent shares. The data, however, suggest that this correlation is close to zero, −0.046 to be precise. This is probably

TABLE 4—CORRELATION MATRIX

	1	2	3	4	5
1. 1972–1974 percentage drop in market cap	1.000	0.353	−0.299	−0.015	−0.234
2. Logarithm of 1996 IT equipment capital share	0.353	1.000	−0.046	0.209	−0.322
3. Logarithm of 1998 share of 1972 incumbents	−0.299	−0.046	1.000	−0.437	0.150
4. 1973–1974 growth rate of output	−0.015	0.209	−0.437	1.000	−0.483
5. Logarithm of 1972 oil share	−0.234	−0.322	0.150	−0.483	1.000

because the incumbent variable does not only proxy for the degree of resistance but also for the degree of deregulation in the various sectors. That is, sectors that are deregulated generally see a lot of entry of new firms. The most notable example of this is Sprint and MCI's threat to AT&T's telecommunications monopoly.

The coefficient of the 1998 share of the 1972 incumbents may be biased in the negative direction. Suppose, for instance, that some markets were hit by adverse and permanent demand shocks in 1974. Along the lines of Tobin's q theory of investment, incumbents that suffered the largest decline in market cap in 1973–1974 would, presumably, invest less than other firms. If our sectors do not quite match the markets that are hit by these shocks, the firms in the declining sectors would appear as losers of market share in sectors as we measure them, and one should see a negative coefficient of the 1998-share variable in Table 3. But this logic does not imply that the 1996 share of IT coefficient is biased, because this variable measures the *composition* of investment rather than its scale.

We should mention one similarity between the oil shock and the arrival of IT as we have interpreted it: Each made life harder for the stock-market incumbent. But the adjustment costs that they imposed on the incumbent were fundamentally different. A rise in the price of an input is something that a firm deals with all the time, and it should not present it with the kind of reorganization problem that the arrival of IT posed. Because of that fact, the oil-shock story cannot explain why entrants were so important in the subsequent market rise.

Chao Wei (2000) has studied the effects of the first OPEC shock in greater detail and she, too, finds that the energy-intensive sectors were not the ones that suffered the greatest price declines in 1973–1974. Therefore, while the oil shock may have played a role in generating the productivity slowdown of the 1970's, and perhaps in delaying entry of IT implementors until the early 1980's, it does not seem to explain the behavior of the stock market.

IV. Conclusion

The vintage capital model teaches us that technological change destroys old capital. We have gone further and argued that major technological change—like the IT revolution—destroys old *firms.* It does so by making machines, 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. We have argued that aggregate valuation can fall below the present value of dividends because capital may "disappear" right after a major technological shift, as new capital forms in small, private companies. Later, these companies are IPO'd, and only then does their value become a part of stock-market capitalization.

This was a report on our case study of a technological revolution. The study used a wealth of information on thousands of firms over dozens of years, but it remains, nevertheless, a case study. We have, in a sense, studied just one data point: The IT revolution in the United States. A logical next step is to study how IT is spreading to other countries, and to see if incumbents are suffering the sorts of declines in value that they did in the United States. A harder task is to see how incumbents dealt with the technological revolutions of the past. Firm-level data for these epochs will be harder to find, but we think we know what the other major revolutions were—100 years ago the revolutionary technologies were electricity and internal combustion, and 200 years ago, it was steam.

REFERENCES

Brealey, Richard and Myers, Stewart. *Principles of corporate finance.* New York: McGraw-Hill, 1996.

Brynjolfsson, Erik and Yang, Shinkyu. "The Intangible Costs and Benefits of Computer Investments: Evidence from the Financial Markets." Mimeo, Massachusetts Institute of Technology, 1998.

Campbell-Kelly, Martin and Aspray, William. *Computer: A history of the information machine.* New York: Basic Books, 1996.

Ceruzzi, Paul. *A history of modern computing.* Cambridge, MA: MIT Press, 1998.

Craig, Ben and Haubrich, Joseph. "Gross Loan Flows." Mimeo, Federal Reserve Bank of Cleveland, 1999.

Das, Sangamitra and Sengupta, Ramprasad. "A Semi-Nonparametric Analysis of the Indian Iron and Steel Industry." Mimeo, Indian Statistical Institute, 1999.

Farber, Henry and Hallock, Kevin. "Have Employment Reductions Become Good News for Shareholders? The Effect of Job Loss Announcements on Stock Prices, 1970–97." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 7295, August 1999.

Golbe, Devra L. and White, Lawrence. "Catch a Wave: The Time Series Behavior of Mergers." *Review of Economics and Statistics*, August 1993, *75*(3), pp. 493–99.

Gort, Michael. "An Economic Disturbance Theory of Mergers." *Quarterly Journal of Economics*, November 1969, *83*(4), pp. 624–42.

Greenwood, Jeremy and Jovanovic, Boyan. "The Information-Technology Revolution and the Stock Market." *American Economic Review*, May 1999 (*Papers and Proceedings*), *89*(2), pp. 116–22.

Grossman, Sanford J. and Hart, Oliver D. "The Allocational Role of Takeover Bids in Situations of Asymmetric Information." *Journal of Finance*, May 1981, *36*(2), pp. 253–70.

Hall, Robert. "The Stock Market and Capital Accumulation." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 7180, June 1999.

Haltiwanger, John C. and Schuh, Scott. "Gross Job Flows between Plants and Industries." *New England Economic Review*, March/April 1999, pp. 41–64.

Ibbotson, Roger; Sindelar, Jody and Ritter, Jay. "The Market's Problems with the Pricing of Initial Public Offerings." *Journal of Applied Corporate Finance*, Spring 1994, *7*(1), pp. 66–74.

Ibbotson Associates. *Stocks, bonds, bills, and inflation, 1997 yearbook*. New York: John Wiley and Sons, 1997.

Jackson, Tim. *Inside Intel.* New York: Dutton, 1997.

Lichtenberg, Frank R. and Siegel, Donald. "Productivity and Changes in Ownership of Manufacturing Plants." *Brookings Papers on Economic Activity*, 1987, *3*, pp. 643–73.

______ . "The Effect of Leveraged Buyouts on Productivity and Related Aspects of Firm Behavior." *Journal of Financial Economics*, September 1990, *27*(1), pp. 165–94.

Lucas, Robert E., Jr. "Asset Prices in an Exchange Economy." *Econometrica*, November 1978, *46*(6), pp. 1429–45.

Mehra, Rajnish. "On the Volatility of Stock Prices: An Exercise in Quantitative Theory." *International Journal of Systems Science*, November 1998, *29*(11), pp. 1203–11.

Morck, Randall; Shleifer, Andrei and Vishny, Robert. "Characteristics of Targets of Hostile and Friendly Takeovers," in Alan Auerbach, ed., *Corporate takeovers: Causes and consequences*. Chicago: University of Chicago Press, 1988.

Parker, Jonathan. "Spendthrift in America? On Two Decades of Decline in the U.S. Saving Rate." National Bureau of Economic Research (Cambridge, MA) Working Paper No. 7238, July 1999.

Ramey, Valerie and Shapiro, Matthew. "Capital Churning." Mimeo, University of California, San Diego, 1998.

Reinganum, Jennifer. "Uncertain Innovation and the Persistence of Monopoly." *American Economic Review*, September 1983, *73*(4), pp. 741–48.

Ritter, Jay R. "The Long-run Performance of Initial Public Offerings." *Journal of Finance*, March 1991, *46*(1), pp. 3–27.

Shleifer, Andrei and Vishny, Robert W. "Value Maximization and the Acquisition Process." *Journal of Economic Perspectives,* Winter 1988, *2*(1), pp. 7–20.

Wei, Chao. "Energy, the Stock Market and the Putty-Clay Investment Model." Mimeo, Stanford University, November 2000.