The Stock Market and Capital Accumulation

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Abstract:

The value of a firm's securities measures the value of the firm's productive assets. If the assets include only capital goods and not a permanent monopoly franchise, the value of the securities measures the value of the capital. Finally, if the price of the capital can be measured or inferred, the *quantity* of the firm's capital is the value divided by the price. A standard model of adjustment costs enables the inference of the price of installed capital. I explore the implications of the proposition using data from U.S. non-farm, non-financial corporations over the past 50 years. The data imply that corporations have formed large amounts of intangible capital, especially in the past decade. The resources for expanding capital have come from the output of the existing capital. An endogenous growth model can explain the basic facts about corporate performance, with a substantial but not implausible increase in the productivity of capital in the 1990s.

I.   Introduction

Securities markets—primarily the stock market—measure the value of a firm's capital stock. The value is the product of the price of installed capital and the quantity of capital. This paper is about inferring the quantity of capital and therefore the amount of capital accumulation from the observed values of securities. In the simplest case, without adjustment costs, the price of capital is observed in capital goods markets and is also the price of installed capital. The quantity of capital is the value observed in the stock market divided by the price. More generally, in the presence of convex adjustment costs, the observed value of capital is the product of the shadow value of installed capital and the quantity of capital. The shadow value can be inferred from the marginal adjustment cost schedule. Then the quantity of capital is the value of capital divided by the shadow value of capital.

The method developed in this paper provides a way to measure intangible capital accumulated by corporations, where both the flow of investment and the stock of capital are not directly observed. There are good reasons to believe that otherwise unmeasurable intangible capital is an important part of the capital of a modern economy.

Three key assumptions underlie the method developed here. First, product markets are competitive, in the sense that firms do not earn any pure profits in the long run. Otherwise, the value of a monopoly franchise would be confused with the quantity of capital. Second, production takes place with constant returns to scale. Firms do not earn Ricardian rents. Third, all factors owned by the firm can be adjusted fully in the long run. Firms purchase factors at known prices, which, in the longer run, are equal to the internal shadow prices of those factors. In the longer run, capital earns no rent because it is in perfectly elastic supply to the

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firm. I call this the *zero-rent economy*. The idea that securities values reveal the quantity of capital in the absence of rents was stated clearly by Baily [1981] in the context of the events of the 1970s.

The zero-rent economy is the polar opposite of the endowment economy where the quantity of capital and its returns are exogenous. Claims on endowments are valued in the stock market according to principles set forth in Lucas [1978]. There is no investment in the endowment economy. The quantity of capital is exogenous and its price is endogenous. The price of capital is determined entirely by the rent that capital earns. By contrast, in the zero-rent economy, firms purchase newly produced physical capital whenever such a purchase generates an expected gain, with suitable discounting for risk.

This paper interprets data from the U.S. non-farm, non-financial corporate sector within the zero-rent framework. I calculate the quantity of capital from the observed value of corporate securities. I also calculate the product of capital, the amount of output produced each year by a unit of capital. The output includes the capital produced as well as the observed output. Over a broad range of adjustment costs, the movements of the implied quantity of the capital stock in the U.S. non-farm, non-financial corporate sector are similar. Two features stand out in all of my calculations: First, capital accumulation was rapid and the productivity of capital was high in the 1950s and 1960s, and again in the 1980s and 1990s. Second, either the capital stock or its price fell dramatically in 1973 and 1974.

This paper is not a contribution to financial valuation analysis—it adopts standard modern finance theory as given. Nonetheless, I will examine the data used in this paper within finance theory. If there were anomalies in the valuation of corporate securities, they would cause anomalies in the measurement of produced capital, within the measurement framework developed here.

The data suggest that U.S. corporations own substantial amounts of intangible capital not recorded in the sector's books or anywhere in government

statistics. There is a large discrepancy between the market value of corporate assets and the purchase or reproduction cost of recorded produced capital. This point is well known from research in the framework of Tobin's *q*. When securities markets record an increase in the firm's quantity of capital greater than its observed investment, the inference in the zero-rent framework is that the firm has produced and accumulated the additional capital. The extra production is not included in accounting records of returns.

Cochrane [1991 and 1996] measures the return to physical capital as its marginal product within a parametric production function, rather than as a residual. If intangible capital is an important factor of production, the marginal product of physical capital will depend on the quantity of intangible capital. Hence, within the framework of this paper, Cochrane's test for physical capital is contaminated because it ignores intangible capital. And the data are completely absent for extending Cochrane's strategy to intangible capital or total capital.

A number of recent papers have studied the theory of the stock market in an economy with production (for example, Naik [1994], Kogan [1999], and Singal and Smith [1999]). The theory paper closest to my empirical work is Abel [1999]. That paper demonstrates that random influences—such as an unexpected increase in the birth rate—will raise the price of installed capital temporarily in an economy with convex adjustment costs for investment. Abel's intergenerational model assumes, implicitly, that adjustment costs impede adjustment from one generation to the next. I believe that this characterization of the effect of adjustment costs is implausible. I believe that a reasonable rate of adjustment is around 50 percent per year, though I also present results for a much lower rate of 10 percent per year. Neither rate would permit much fluctuation in the price of capital from one generation to the next.

The primary goal of this paper is to pursue the hypothesis that securities markets record the quantity of produced capital accumulated by corporations.

Although this view is particularly interesting with respect to huge increases in stock-market values that have occurred over the past five years, this paper has ambitions beyond an attempt to explain recent events. Rather, I look at data over the entire postwar period. I concentrate not on the stock market, but on the combined value of equity and debt. The view that emerges from my review of the data is the following, based on averages from 1945 to 1998. Firms produce productive capital by combining plant, equipment, new ideas, and organization. The average annual net marginal product of capital is 8.4 percent. That is, a unit of capital produces 0.084 units of output beyond what is needed to exchange for labor and other inputs, including adjustment costs, and to replace worn capital. Corporations divide this bonus between accumulating more capital at a rate of 6.4 percent per year and paying their owners 2.0 percent of the current value of the capital.

At the beginning of 1946, non-farm, non-financial corporations had capital worth $645 billion 1996 dollars. Shareholders and debt holders have been drawing out of this capital at an average rate of 2.0 percent per year. The power of compounding is awesome—the $645 billion nest egg became $13.9 trillion by the middle of 1999, despite invasion by shareholders and debt holders in most years. An endogenous growth model, applied to corporations rather than the entire economy, describes the evolution of the capital stock.

Spectacular increases in stock-market/capital values in 1994-1999 are associated with high values of the product of capital. The average for the 1990s of 17 percent compares to 9 percent in another period of growth and prosperity, the 1950s. In the 1970s, the figure fell to 0.5 percent. I discuss some evidence linking the higher product of capital in the 1990s to information technology.

II. Inferring the Quantity of Capital from Securities Values

A. Theory

Define the following notation:

v_t	=	value of securities deflated by the acquisition price of capital goods, at the beginning of the period, after payouts to owners (*ex dividend*)
$\bar{v}_t$	=	value of securities at the beginning of the period, before payouts to owners (*cum dividend*)
k_t	=	quantity of capital held for productive use during period t
$\pi_t(k_t)$	=	the restricted profit function showing the firm's maximized profit as a function of its capital stock, with all other inputs variable, earned at the end of the period
$s_{t,t+\tau}$	=	the economy's universal stochastic discounter, in the sense of Hansen and Jagannathan [1991], from the end of period $t+\tau$ back to the beginning of period t
x_t	=	investment in new capital at beginning of period t
δ	=	depreciation rate of capital
$c\left(\dfrac{x_t}{k_{t-1}}\right)k_{t-1}$	=	capital adjustment costs, incurred at beginning of period t, convex with continuous derivative, with constant returns to scale

I assume constant returns, competition, and immediate adjustment of all factors of production other than capital. Consequently, the restricted profit

function has the form $\pi_t(k_t) = z_t k_t$ where the product of capital, z_t, depends on the prices of non-capital inputs. At the beginning of period t, the firm pays out profit less investment and adjustment costs to its shareholders, in the amount:

$$z_{t-1}k_{t-1} - x_t - c\left(\frac{x_t}{k_{t-1}}\right)k_{t-1}. \tag{2.1}$$

The value of the firm is the present value of the future payouts:

$$\begin{aligned}\overline{v}_t &= z_{t-1}k_{t-1} - x_t - c\left(\frac{x_t}{k_{t-1}}\right)k_{t-1} \\ &+ E_t\left[s_{t,t}\left(z_t k_t - x_{t+1} - c\left(\frac{x_{t+1}}{k_t}\right)k_t\right) + \cdots\right]\end{aligned} \tag{2.2}$$

The capital stock evolves according to:

$$k_t = x_t + (1-\delta)k_{t-1} \tag{2.3}$$

Let q_t be the Lagrangian multiplier associated with the constraint (2.3); it is the shadow price of installed capital. Necessary conditions for the maximization of the value of the firm with respect to the investment decision made at the beginning of period t are (see, for example, Abel [1990]):

$$E_t\left[s_{t,t}z_t - q_t + s_{t,t}(1-\delta)q_{t+1}\right] = 0 \tag{2.4}$$

and

$$c'\left(\frac{x_t}{k_{t-1}}\right) = q_t - 1 \tag{2.5}$$

Equation (2.4) calls for the marginal product of installed capital to be equated, in expectation, to the rental price of installed capital, with the price of capital taken to be its shadow value. Equation (2.5) calls for the current marginal adjustment

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cost to be equated to the excess of the shadow value of capital to its acquisition cost.

Note that the first condition, equation (2.4), is a restriction on the factor prices embedded in z_t, on the shadow values of capital, q_t and q_{t+1}, and on the stochastic discounter—it does not involve the capital stock itself. The basic story of this condition is that the wage and the shadow value of capital rise to the point of extinguishing profit as firms expand to exploit a positive value of expected profit.

Hayahsi [1982] derived the following important result:

> *Theorem (Equality of Marginal and Average q)* The value of the firm, v_t, is the product of the shadow value of capital, q_t, and the quantity of capital, k_t.

Thanks to this result, which makes the quantity $q_t k_t$ observable, it is straightforward to find the quantity of capital. The basic idea is that the value relationship,

$$k_t = \frac{v_t}{q_t} \tag{2.6}$$

and the cost of adjustment condition,

$$c'\left(\frac{k_t - (1-\delta)k_{t-1}}{k_{t-1}}\right) = q_t - 1 \tag{2.7}$$

imply values for k_t and q_t given k_{t-1} and v_t:

> *Theorem (Quantity Revelation)* The quantity of capital can be inferred from the value of capital, v_t, and the cost of adjustment function by finding the unique root, (k_t, q_t), of equations (2.6) and (2.7).

Figure 1 displays the solution. The value of capital restricts the quantity, k_t, and the price, q_t, to lie on a hyperbola. The marginal adjustment cost schedule slopes upward in the same space. Appendix 1 demonstrates that the two curves always intersect exactly once.
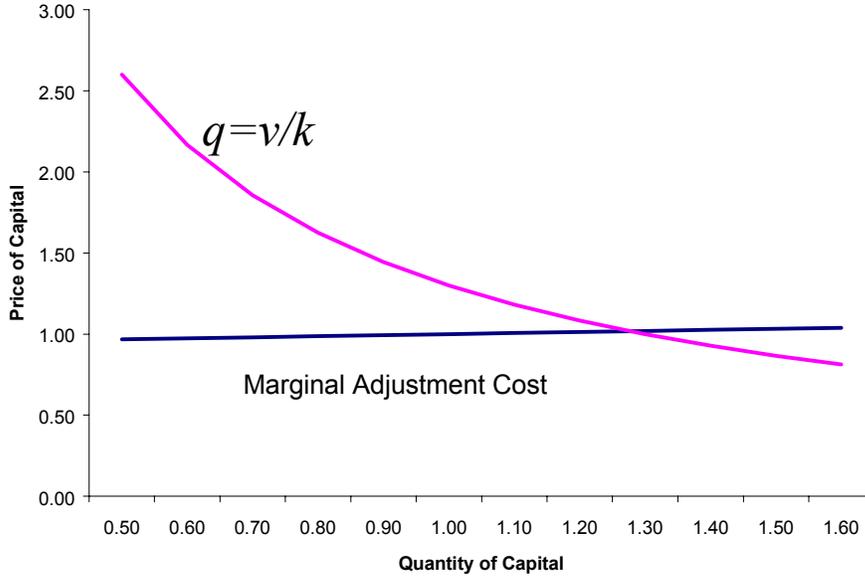

Figure 1. Solving for the quantity of capital and the price of capital.

The position of the marginal adjustment cost schedule depends on the earlier level of the capital stock, k_{t-1}. Hence the strategy proposed here for inferring the quantity of capital results in a recursion in the capital stock. Except under pathological conditions, the recursion is stable in the sense that $\frac{dk_t}{dk_{t-1}}$ is well below 1. Although the procedure requires choosing an initial level of capital, the resulting calculations are not at all sensitive to the initial level.

Measuring the quantity of capital is particularly simple when there are no adjustment costs. In that case, the marginal adjustment cost schedule in Figure 1 is flat at zero, and the quantity of capital is the value of the firm stated in units of

capital goods. Baily [1981] developed the quantity revelation theorem for the case of no adjustment costs.

B.   Interpretation

It is always true that the value of the firm equals the value of its capital stock, assuming that ownership of the capital stock is equivalent to ownership of the firm. But only under limited conditions does the value of the capital stock reveal the quantity of capital. These conditions are the absence of monopoly or Ricardian rents that would otherwise be capitalized in the firm's value. In addition, there must be only a single kind of capital with a measured acquisition price (here taken to be one). Capital could be non-produced, such as land, provided that it is the only type of capital and its acquisition price is measured. Similarly, capital could be intellectual property, with the same provisions.

As a practical matter, firms have more than one kind of capital and the acquisition price of capital is not observed with much accuracy. The procedure is only an approximation in practice. I believe it is an interesting approximation because the primary type of capital with an acquisition price that is not pinned down on the production side is land, and land is not an important input to the non-farm corporate sector. For intellectual property and other intangibles, there is no reason to believe that there are large discrepancies between its acquisition price and the acquisition price of physical capital. Both are made primarily from labor. It is key to understand that it is the acquisition price—the cost of producing new intellectual property—and not the market value of existing intellectual property—that is at issue here.

Intellectual property may be protected in various ways—by patents, copyrights, or as trade secrets. During the period of protection, the property will earn rents and may have value above its acquisition cost. The role of the adjustment cost specification, then, is to describe the longevity of protection. Rivals incur adjustment costs as they develop alternatives that erode the rents

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without violating the legal protection of the intellectual property. When the protection ends—as when a patent expires—other firms compete away the rents by the creation of similar intellectual property. The adjustment cost model is a reasonable description of this process. When applying the model to the case of intellectual property, the specification of adjustment costs should be calibrated to be consistent with what is known about the rate of erosion of intellectual property rents.

The adjustment cost function $c\left(\dfrac{x_t}{k_{t-1}}\right)$ is not required to be symmetric. Thus the approach developed here is consistent with irreversibility of investment. If the marginal adjustment cost for reductions in the capital stock is high in relation to the marginal cost for increases, as it would be in the case of irreversible investment, then the procedure will identify decreases in value as decreases in the price of capital, while it will identify increases in value as mostly increases in the quantity of capital. The specification adopted later in this paper has that property.

The key factor that underlies the quantity revelation theorem is that markets—in the process of discounting the cash flows of corporations—anticipate that market forces will eliminate pure rents from the return to capital. Hall [1977] used this principle to unify the seeming contradiction between the project evaluation approach to investment—where firms invest in every project that meets a discounted cash flow criterion that looks deeply into the future—and neoclassical investment theory—where firms are completely myopic and equate the marginal product of capital to its rental price. The two principles are identical when the projection of cash flows anticipates that the neoclassical first-order condition will hold at all times in the future. The formalization of q theory by Abel [1979], Hayashi [1982], and others generalized this view by allowing for delays in the realization of the neoclassical condition.

Much of the increase in the market values of firms in the past decade appears to be related to the development of successful differentiated products, protected to some extent from competition by intellectual property rights relating to technology and brand names. I have suggested above that the framework of this paper is a useful approximation for studying intellectual property along with physical capital. It is an interesting question—not to be pursued in this paper—whether there is a concept of capital for which a more general version of the quantity revelation theorem would apply. In the more general version, monopolistic competition would replace perfect competition.

III. Data

This paper rests on a novel accounting framework, suited to studying the issues of the paper. On the left side of the balance sheet, so to speak, I place all of the non-financial assets of the firm—plant, equipment, land, intellectual property, organizational and brand capital, and the like. On the right side, I place all financial obligations: bonds and other debt, shareholder equity, and other obligations of a face-value or financial nature, such as accounts payable. Financial assets of the firm, including bank accounts and accounts receivable, are subtractions from the right side. I posit equality of the two sides, and enforce this as an accounting identity by measuring the total value of the left side by the known value of the right side. It is of first-order importance in understanding the data I present to consider the difference between this framework and the one implicit in most discussions of corporate finance. There, the left side includes—in addition to physical capital and intangibles—all operating financial obligations such as bank accounts, receivables, and payables and the right side includes selected financial obligations such as equity and bonds.

I use a flow accounting framework based on the same principles. The primary focus is on cash flows. Some of the cash flows equal the changes in the corresponding balance sheet items excluding non-cash revaluations. Cash flows from firms to securities holders fall into four accounting categories:

1. Dividends paid, net of dividends received

2. Repurchases of equity, purchases of equity in other corporations, net of equity issued and sales of equity in other corporations

3. Interest paid on debt less interest received on holdings of debt

4. Repayments of debt obligations less acquisition of debt instruments

The sum of the four categories is cash paid out to the owners of corporations. A key feature of the accounting system is that this flow of cash is exactly the cash generated by the operations of the firm—it is revenue less cash outlays including purchases of capital goods. There is no place that a firm can park cash or obtain cash that is not included in the cash flows listed here.

The flow of cash to owners differs from the return earned by owners because of revaluations. The total return comprises cash received plus capital gains.

I take data from the flow of funds accounts maintained by the Federal Reserve Board.[1] These accounts report cash flows and revaluations separately and thus provide much of the data needed for the accounting system used in this paper. The data are for all non-farm, non-financial corporations. Details appear in Appendix 2. The flow of funds accounts do not report the market value of long-term bonds or the flows of interest payments and receipts—I impute these quantities as described in the appendix. I measure the value of financial securities as the market value of outstanding equities as reported plus my calculation of the

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[1] http://www.federalreserve.gov/releases/z1/data.htm. Fama and French [1999] present similar data derived from Compustat for a different universe of firms.

market value of bonds plus the reported value of other financial liabilities less financial assets. I measure payouts to security holders as the flow of dividends plus the flow of purchases of equity by corporations plus the interest paid on debt (imputed at interest rates suited to each category of debt), less the increase in the volume of net financial liabilities. Figures 2 through 5 display the data for the value of securities, payouts, and the payout yield (the ratio of payouts to market value).
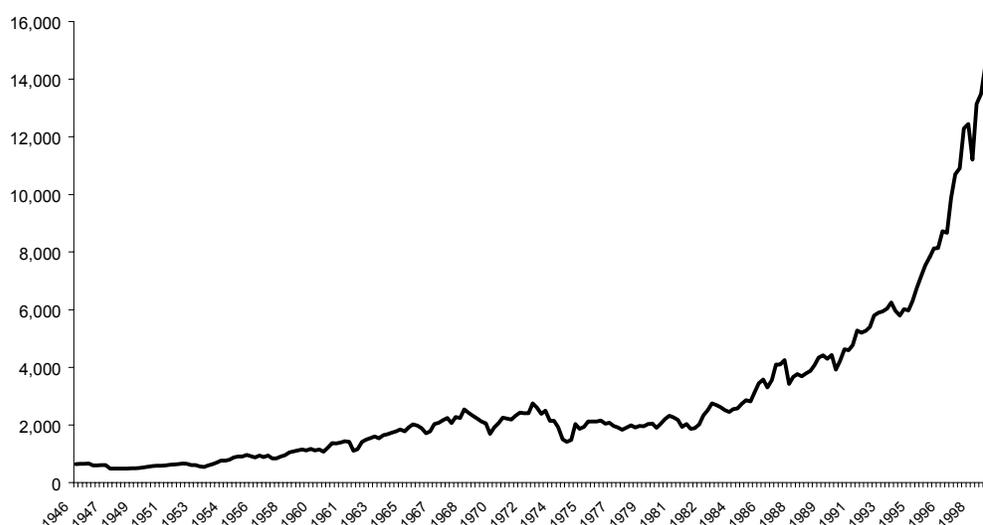

Figure 2. Value of the Securities of Non-Farm, Non-Financial Corporations in Billions of 1996 Dollars

Nominal value divided by the implicit deflator for private fixed nonresidential investment

In 1986, the real value of the sector's securities was about the same as in 1968. By 1999, it had more than tripled its 1990 level. As Figure 3 shows, the sector began and ended the period without little debt in relation to equity. But debt was 35 percent of the total value of securities at its peak in 1982. Again, I note that the concept of debt in this figure is not the conventional one—bonds— but rather the net value of all face-value financial instruments.
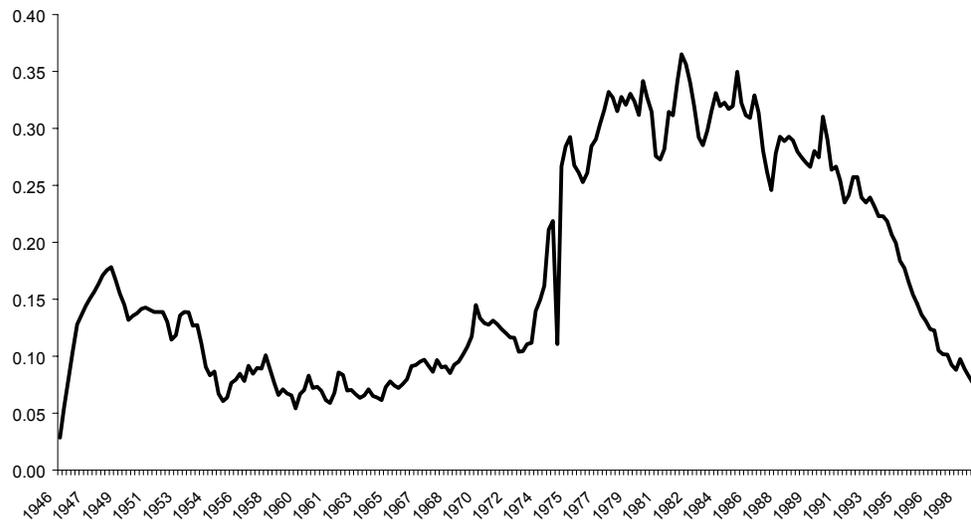
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Figure 3. Ratio of Debt to Total Value of Securities.

Figure 4 shows the cash flows to the owners of corporations scaled by GDP. It breaks payouts to shareholders into dividends and net repurchases of shares. Dividends move smoothly and all of the important fluctuations come from the other component. That component can be negative—when issuance of equity exceeds repurchases—but has been at high positive levels since the mid-1980s, with the exception of 1991 through 1993.
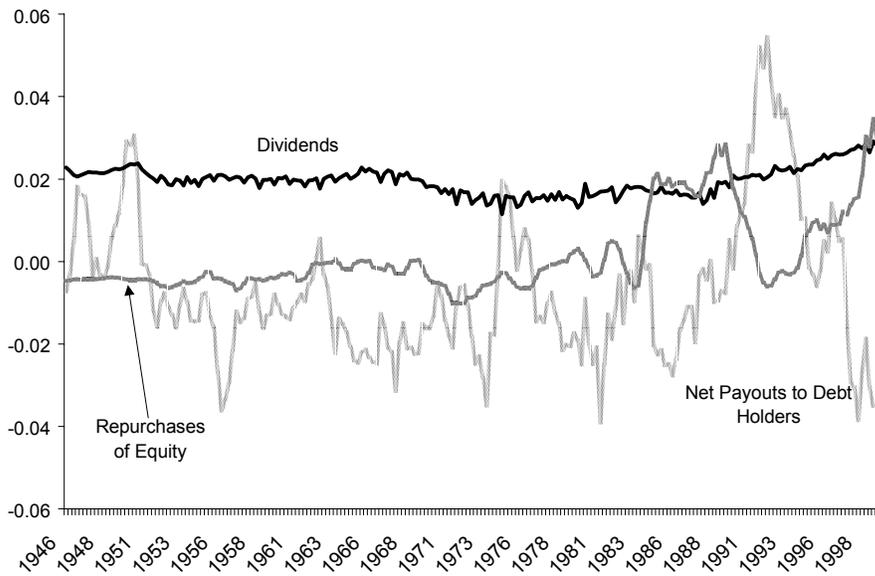
Figure 4. Components of Payouts, as Fractions of GDP.

Payouts to debt holders have been remarkably erratic, as the solid line in Figure 4 shows.
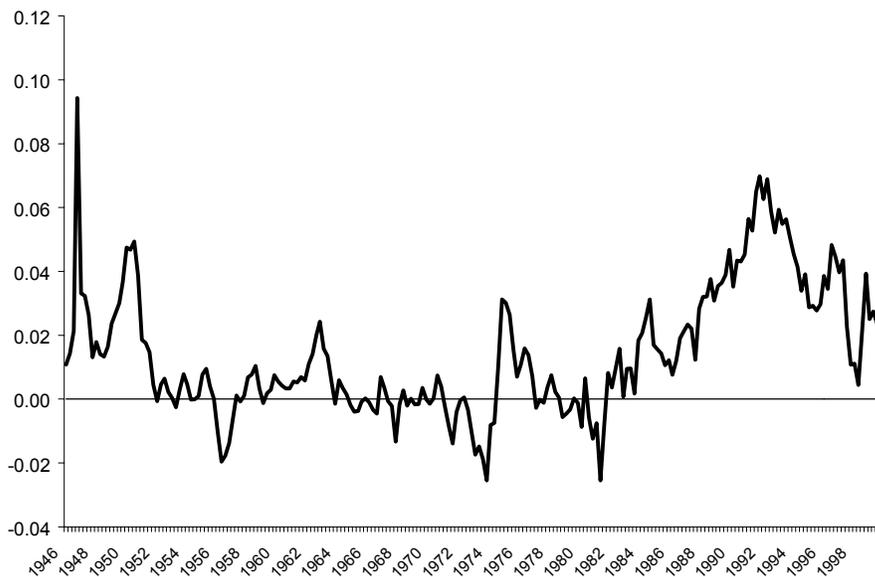

Figure 5. Total Payouts to Owners, as a Fraction of GDP

Figure 5 shows total payouts to equity and debt holders in relation to GDP. Note the remarkable growth since 1980. By 1993, cash was flowing out of corporations into the hands of securities holders at a rate of 4 to 6 percent of GDP. Payouts declined at the end of the 1990s.

Figure 6 shows the payout yield, the ratio of total cash extracted by securities owners to the market value of equity and debt. The yield has been anything but steady. It reached peaks of about 10 percent in 1951, 7 percent in 1976, 7 percent in 1986, and 8 percent in 1993. As the lower line shows, much of the variability comes from debt.
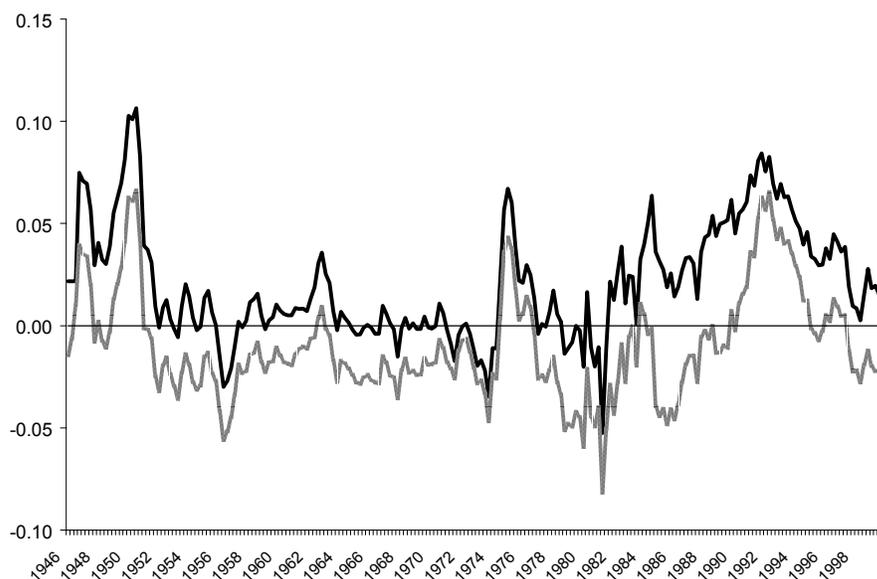

Figure 6. Payout Yield (Ratio of Payout to Value of Securities)
The upper line is the total payout to equity and debt holders and the lower line is the payout to debt holders only, as a ratio to the total value of securities.

Although the payout yield fell to a low level by 1999, the high average level of the yield through the 1990s should be compared to the extraordinarily low level of the dividend yield in the stock market, the basis for some concerns that the stock market is grossly overvalued. As the data in Figure 4 show, dividends are

only a fraction of the story of the value earned by shareholders. In particular, when corporations pay off large amounts of debt, there is a benefit to shareholders equal to the direct receipt of the same amount of cash. Concentration on dividends, or even dividends plus share repurchases, gives a seriously incomplete picture of the buildup of shareholder value. It appears that the finding of Campbell and Shiller [1998]—that the dividend yield of stocks has dropped far below its historical level—has the neutral explanation that dividends have declined as a method of payout, rather than the exciting conclusion that the value of the stock market is too high to be sustained. Fama and French [1998] make the same point. In addition, the high volatility of payouts helps explain the volatility of the stock market, which may be a puzzle in view of the stability of dividends if other forms of payouts are not brought into the picture.

It is worth noting one potential source of error in the data: Corporations frequently barter their equity for the services of employees. This occurs in two important ways. First, the founders of corporations generally keep a significant fraction of the equity. In effect, they are trading their managerial services and ideas for equity. Second, many employees receive equity through the exercise of options granted by their employers, or receive stock directly as part of their compensation. The accounts should treat the value of the equity at the time the barter occurs as the issuance of stock, a deduction from what I call payouts. The failure to make this deduction results in an overstatement of the apparent return to corporations. Liang and Sharpe [1999] estimate the overstatement in a sample of 144 firms in the S&P 500, selected on the basis of the adequacy of their disclosure of employee stock options. They find that firms currently grant options at a rate of about 1.4 percent of outstanding shares per year. Cancellations are about 0.2 percent per year, so net grants are in the range of 1.2 percent per year. They estimate the value at grant to be about 30 percent of market (the typical employee stock option has an exercise price equal to the market value at the time of the

grant and an exercise date about 5 years in the future). The grant value is the appropriate value for my purpose here, as the increases in value enjoyed by employees after grant accrue to them as contingent shareholders. Thus the overstatement of the return in the late 1990s is about 0.36 percentage points, not large in relation to the level of return of about 17 percent. This flow of option grants was almost certainly higher in the 1990s than in earlier years, and may overstate the rate for other firms, because the adequacy of disclosure is likely to be higher for firms with more option grants. It does not appear that employee stock options are a quantitatively important part of the story of the returns paid to the owners of corporations. I believe the same conclusion applies to the value of the stock held by founders of new corporations, though I am not aware of any quantification. As with employee stock options, the value should be measured at the time the stock is granted. From grant forward, corporate founders are shareholders and are properly accounted for in this paper.

IV. Valuation

The foundation of valuation theory is that the market value of securities measures the present value of future payouts. To the extent that this proposition fails, the approach in this paper will mis-measure the quantity of capital. It is useful to check the valuation relationship over the sample period to see if it performs suspiciously. Many commentators are quick to declare departures from rational valuation when the stock market moves dramatically, as it has over the past few years.

Some reported data related to valuation move smoothly, particularly dividends. Consequently, economists—notably Robert Shiller [1989]—have suggested that the volatility of stock prices is a puzzle given the stability of dividends. The data discussed earlier in this paper show that the stability of

dividends is an illusion. Securities markets should discount the cash payouts to securities owners, not just dividends. For example, the market value of a flow of dividends is lower if corporations are borrowing to pay the dividends. Figure 5 shows how volatile payouts have been throughout the postwar period. As a result, rational valuations should contain substantial noise. The presence of large residuals in the valuation equation is not by itself evidence against rational valuation.

Modern valuation theory proceeds in the following way. Let

$$v_t \quad = \quad \text{value of securities, } \textit{ex dividend,} \text{ at the beginning of period } t$$

$$d_t \quad = \quad \text{cash paid out to holders of these securities, at the beginning of period } t$$

$$R_t = \frac{v_{t+1} + d_{t+1}}{v_t} \quad = \quad \text{return ratio}$$

As I noted earlier, finance theory teaches that there is a family of stochastic discounters, s_t, sharing the property,

$$E_t \left(s_t R_t \right) = 1 \tag{4.1}$$

(I drop the first subscript from the discounter because I will be considering only one future period in what follows.) Kreps [1981] first developed an equivalent relationship; Hansen and Jagannathan [1991] developed this form.

Let $\widetilde{R}_t$ be the return to a reference security, known in advance (I will take the reference security to be a 3-month Treasury bill). I am interested in the valuation residual or excess return on capital relative to the reference return,

$$\varepsilon_t = \frac{R_t - E_t R_t}{\widetilde{R}_t} \tag{4.2}$$

Note that this concept is invariant to choice of numeraire—the returns could be stated in either monetary or real terms. From equation 4.1,

$$\left(E_t R_t\right)\left(E_t s_t\right) + Cov_t\left(R_t, s_t\right) = 1 \tag{4.3}$$

so

$$E_t R_t = \frac{1 - Cov_t\left(R_t, s_t\right)}{E_t s_t} \tag{4.4}$$

Now $E_t\left(\tilde{R}_t s_t\right) = 1$, so

$$E_t s_t = \frac{1}{\tilde{R}_t} \tag{4.5}$$

Let $\phi = -Cov(R_t, s_t)$, assumed to be approximately constant. Then $E_t R_t = \left(1 + \phi\right)\tilde{R}_t$ and, finally,

$$\frac{R_t}{\tilde{R}_t} = 1 + \phi + \varepsilon_t \tag{4.6}$$

The risk premium ϕ is identified by this condition as the mean of $\dfrac{R_t}{\tilde{R}_t} - 1$.

The estimate of the risk premium ϕ is 0.077 with a standard error of 0.020. This should be interpreted as the risk premium for real corporate assets, related to what is called the "asset beta" in the standard capital asset pricing model.

Figure 7 shows the residuals, the surprise element of the value of securities. The residuals show fairly uniform dispersion over the entire period.
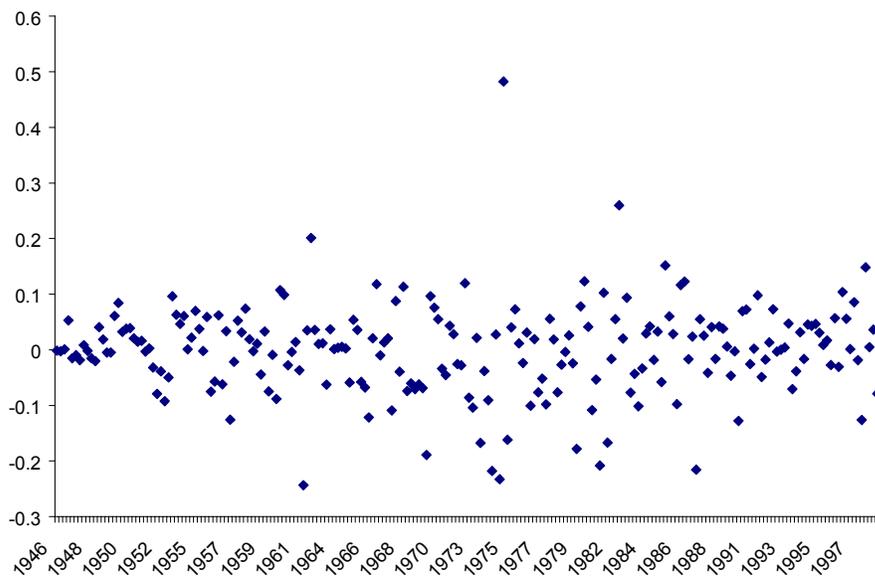
Figure 7. Valuation Residuals.

I see nothing in the data to suggest any systematic failure of the standard valuation principle—that the value of the stock market is the present value of future cash payouts to shareholders. Moreover, the recent surge in the stock market—though not completely explained by the corresponding behavior of payouts—is within the normal amount of noise in valuations. The valuation equation is symmetric between the risk-free interest rate and the return to corporate securities. To the extent that there is a mystery about the behavior of financial markets in recent years, it is either that the interest rate has been too low or the return to securities too high. The average valuation residual in Figure 7 for 1994 through 1999 is 7.7 percent at annual rates, with a standard error of 3.7 percent. Though this is a 2-sigma event, it should not be considered unusual, in view of the fact that the period over which it is estimated was chosen after seeing the data.

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V. The Quantity of Capital

To apply the method developed in this paper, I need evidence on the adjustment cost function. I take its functional form to be piecewise quadratic:

$$c\left(\frac{x_t}{k_{t-1}}\right) = \frac{\alpha^+}{2} P\left(\frac{k_t - k_{t-1}}{k_{t-1}}\right)^2 + \frac{\alpha^-}{2} N\left(\frac{k_t - k_{t-1}}{k_{t-1}}\right)^2 \tag{5.1}$$

where P and N are the positive and negative parts. To capture irreversibility, I assume that the downward adjustment cost parameter α^- is substantially larger than the upward parameter α^+.

My approach to calibrating the adjustment cost function is based on evidence about the speed of adjustment. That speed depends on the marginal adjustment cost and on the rate of feedback, in general equilibrium, from capital accumulation to the product of capital, z. Although a single firm sees zero effect from its own capital accumulation, in all but the most unusual case there will be a negative relation between accumulation and product in general equilibrium.

To develop a relationship between the adjustment cost parameter and the speed of adjustment, I assume that the marginal product of capital, in the aggregate non-farm, non-financial sector, has the form

$$z - \gamma k_t \tag{5.2}$$

For simplicity, I will assume for this analysis that discounting can be expressed by a constant discount factor, β. Then the first equation of the dynamical system equates the marginal product of installed capital to the service price:

$$z - \gamma k_t = q_t - \beta(1-\delta)q_{t+1} \tag{5.3}$$

The second equation equates the marginal adjustment cost to the shadow value of capital less its acquisition cost of 1:

$$\alpha\left(\frac{k_t - k_{t-1}}{k_{t-1}}\right) = q_t - 1 \qquad (5.4)$$

I will assume for the moment that the two adjustment-cost coefficients α^+ and α^- have the common value α. The adjustment coefficient that governs the speed of convergence to the stationary point of the system is the smaller root of the characteristic polynomial,

$$\alpha(1-\lambda)[1-\beta(1-\delta)\lambda] - \gamma\lambda \qquad (5.5)$$

I calibrate to the following values at a quarterly frequency:

Parameter	Role	Value
β	Discount factor	0.975
δ	Depreciation rate	0.025
γ	Slope of marginal product of installed capital	$(0.5)(0.7)[1-\beta(1-\delta)]$
λ	Adjustment speed of capital	0.841 (0.5 annual rate)
z	Intercept of marginal product of installed capital	$1 + \gamma - \beta(1-\delta)$

The calibration for γ places the elasticity of the return to capital in the non-farm, non-financial corporate sector at half the level of the elasticity in an economy with a Cobb-Douglas technology and a labor share of 0.7. The adjustment speed is chosen to make the average lag in investment be two years, in line with results reported by Shapiro [1986]. The intercept of the marginal product of capital is chosen to normalize the steady-state capital stock at 1, without loss of generality. The resulting value of the adjustment coefficient, α, from equation (5.5) is 0.455. For my calculations, I use $\alpha^+ = 0.455$ and $\alpha^- = 4.55$. Because Shapiro's estimates were made during a period of generally positive net

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investment, I interpret his results to reveal primarily the value of the coefficient for expanding the capital stock.

Figure 8 shows the resulting values for the capital stock and the price of installed capital, q, based on the value of capital shown in Figure 2 and the values of the adjustment cost parameter from the adjustment speed calibration. Most of the movements are in quantity and price vibrates in a fairly tight band around the supply price, one.
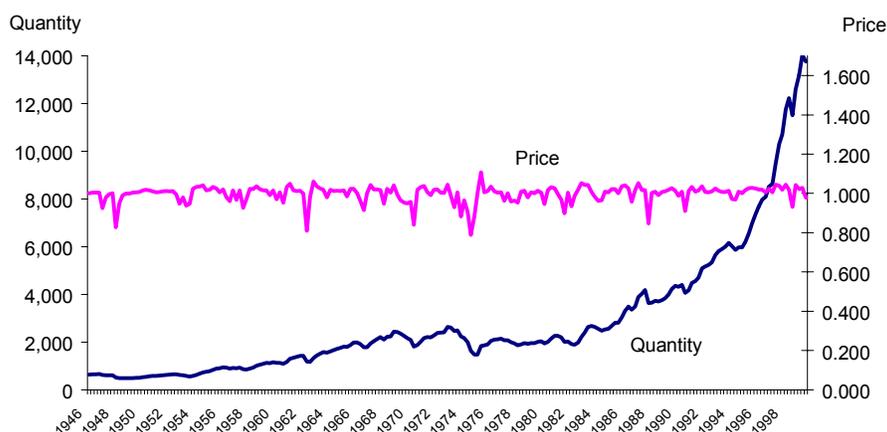

Figure 8. Quantity and Price of Capital, with Annual Adjustment Rate of 0.50

Hamermesh and Pfann [1996] survey the literature on adjustment costs with the general conclusion that adjustment speeds are lower then Shapiro's estimates. Figure 9 shows the split between price and quantity implied by a speed of adjustment of 10 percent per year rather than 50 percent per year, a figure at the lower limit of the reasonable. Again, I take α^- to be 10 times α^+. The path of the quantity of capital is closer to smooth exponential growth and variations in price account for almost the entire decline in 1973-74 and much of the increase in the 1990s.
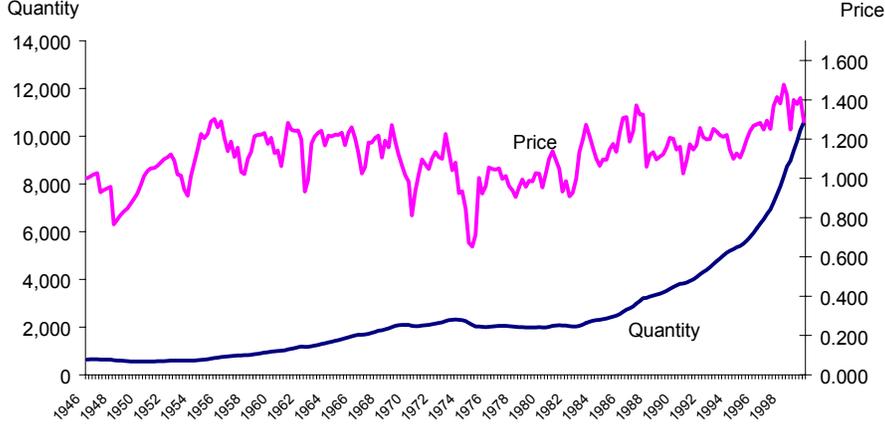
24

Figure 9. Quantity and Price of Capital, with Annual Adjustment Rate of 0.10

VI. The Capital Accumulation Model

Under the hypotheses of the zero-rent economy, the value of corporate securities provides a way to measure the quantity of capital. To build a simple model of capital accumulation under the hypothesis, I redefine z_t as an index of productivity. The technology is linear—it is what growth theory calls an "Ak" technology—and gross output is $z_t k_t$. At the beginning of period t, output is divided among payouts to the owners of corporations, d_t, capital accumulation, replacement of deteriorated capital, and adjustment costs:

$$z_{t-1}k_{t-1} = d_t + \left(k_t - k_{t-1}\right) + \delta k_{t-1} + c_t \qquad (6.1)$$

Here $c_t = c\left(\dfrac{k_t}{k_{t-1}}\right)k_{t-1}$. This can also be written as

$$\tilde{z}_{t-1}k_{t-1} = d_t + k_t - k_{t-1} \qquad (6.2)$$

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where $\quad \tilde{z}_t = z_t - c\left(\dfrac{k_t}{k_{t-1}}\right) - \delta \quad$ is productivity net of adjustment cost and deterioration of capital. The value of the net productivity index can be calculated from:

$$\tilde{z}_t = \frac{d_{t+1} + k_{t+1} - k_t}{k_t} \tag{6.3}$$

Note that this is the one-period return from holding a stock whose price is k and whose dividend is d.

The productivity measure adds increases in the market value of corporations to their payouts to measure output.[2] The increase in market value is treated as a measure of corporations' production of output that is retained for use within the firm. Years when payouts are low are not scored as years of low output if they are years when market value rose.

Figures 10 and 11 show the results of the calculation for the 50 percent and 6 percent adjustment rates. The lines in the figures are kernel smoothers of the data shown as dots. Though there is much more noise in the annual measure with the faster adjustment process, the two measures agree fairly closely about the behavior of productivity over decades.

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[2] The idea that capital gains measure capital formation was advocated by Bradford [1991] and has been explored recently by Gale and Sablehaus [1999]. In addition to adding capital gains to output, they should be added to income and saving.
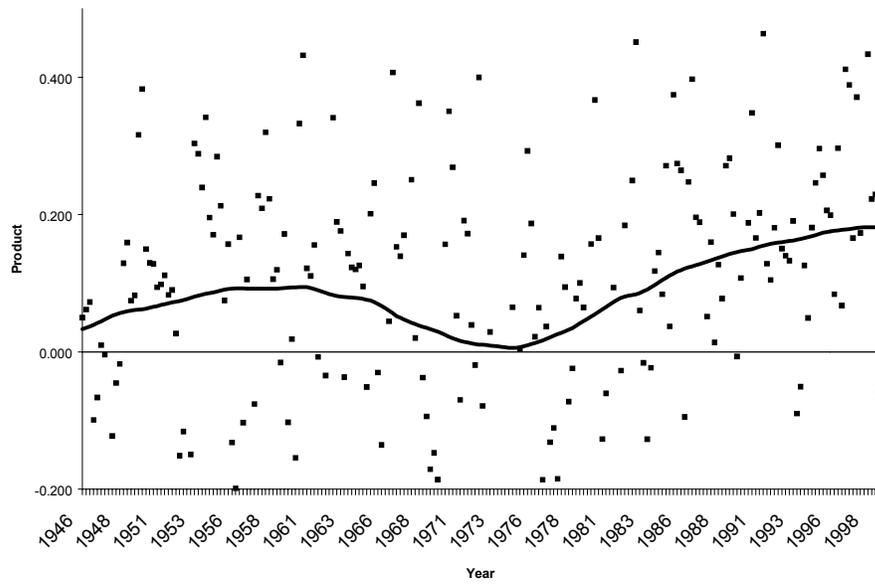
Figure 10. Estimated Net Product of Capital, by Quarter and Smoothed, 50 Percent Annual Adjustment Rate
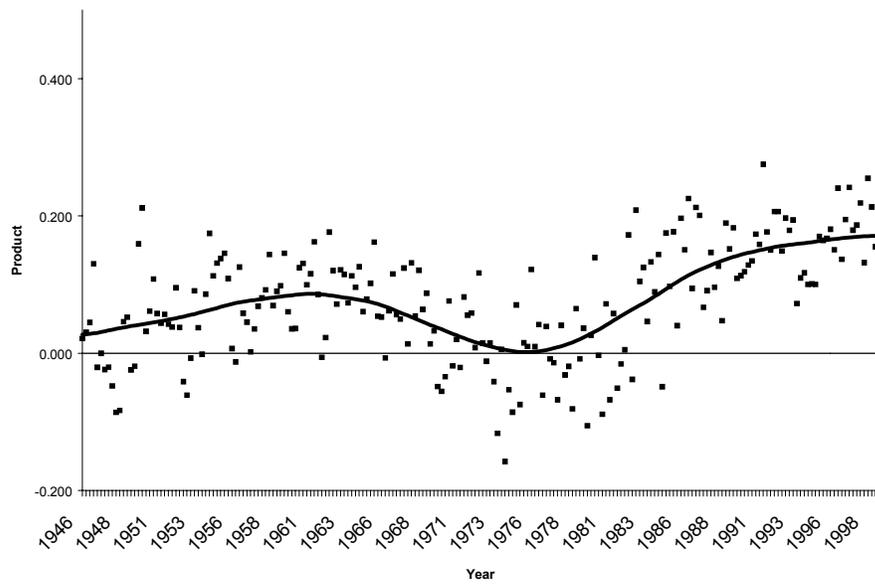

Figure 11. Estimated Net Product of Capital, by Year and by Decade, 10 Percent Annual Adjustment Rate

Table 1 shows the decade averages of the net product of capital and standard errors. The product of capital averaged about 0.08 units of output per year per unit of capital. The product reached its postwar high during the good years since 1994, but it was also high in the good years of the 1950s and 1960s. The most notable event recorded in the figures is the low value of the marginal product in the 1970s. Baily [1981] interprets stock-market data for the 1970s as showing that the huge increase in energy prices in 1973 and 1974 effectively demolished a good deal of capital.

	50 percent annual adjustment speed		10 percent annual adjustment speed	
	Average net product of capital	*Standard error*	*Average net product of capital*	*Standard error*
1950s	0.092	0.034	0.070	0.013
1960s	0.072	0.034	0.080	0.013
1970s	0.005	0.034	-0.004	0.013
1980s	0.113	0.034	0.095	0.013
1990s	0.173	0.036	0.166	0.014
All years, 1946-99	0.084	0.015	0.075	0.006

Table 1. Net Product of Capital by Decade

The noise in Figures 10 and 11 appears to arise primarily from the valuation noise reported in Figure 7. Every change in the value of the stock market—resulting from reappraisal of returns into the distant future—is incorporated into the measured product of capital. Smoothing, as shown in the figures, can eliminate much of this noise.

VII. The Nature of Accumulated Capital

The concept of capital relevant for this discussion is not just plant and equipment. It is well known from decades of research in the framework of Tobin's q that the ratio of the value of total corporate securities to the reproduction cost of the corresponding plant and equipment varies over a range from well under one (in the period from 1974 to 1982) to well above one (in the 1960s and 1990s). A concept of intangible capital is essential to the idea that the stock market measures the quantity of capital. In addition, the view needs to include capital disasters of the type that seems to have occurred in 1974. The relevant concept of reproduction cost is subtler than a moving average of past measured investments.

Firms own produced capital in the form of plant, equipment, and intangibles such as intellectual property. Hall [1999] suggests that firms also have organizational capital resulting from the resources they deployed earlier to recruit the people and other inputs that constitute the firm. Research in the framework of Tobin's q has confirmed that the categories other than plant and equipment must be important. In addition, the research has shown that the market value of the firm or of the corporate sector may drop below the reproduction cost of just its plant and equipment, when the stock is measured as a plausible weighted average of past investment. That is, the theory has to accommodate the possibility that an event may effectively disable an important fraction of existing capital. Otherwise, it would be paradoxical to find that the market value of a firm's securities is less than the value of its plant and equipment.

Tobin's q is the ratio of the value of a firm or sector's securities to the estimated reproduction cost of its plant and equipment. Figure 12 shows my calculations for the non-farm, non-financial corporate sector, based on 10 percent annual depreciation of its investments in plant and equipment. I compute q as the ratio of the value of ownership claims on the firm less the book value of inventories to the reproduction cost of plant and equipment. The results in the figure are

completely representative of many earlier calculations of *q*. There are extended periods, such as the mid-1950s through early 1970s, when the value of corporate securities exceeded the value of plant and equipment. Under the hypothesis that securities markets reveal the values of firms' assets, the difference is either movements in the quantity of intangibles or large persistent movements in the price of installed capital.

Figure 12 Tobin's *q*—Ratio of Market Value to Reproduction Cost of Plant and Equipment

Figure 12 resembles the price of installed capital with slow adjustment as shown earlier in Figure 9. In other words, the smooth growth of the quantity of capital in Figure 9 is similar to the growth of physical capital in the calculations underlying Figure 12. The inference that there is more to the story of the quantity of capital than the cumulation of observed investment in plant equipment is based on the view that the large highly persistent movements in the price of installed

capital in Figures 9 and 12 are implausible—that the adjustment rate cannot be as low as 10 percent per year.

A capital catastrophe occurred in 1974, which drove securities values well below the reproduction cost of plant and equipment. Greenwood and Jovanovic [1999] have proposed an explanation of the catastrophe—that the economy first became aware in that year of the implications of a revolution based on information technology. Although the effect of the IT revolution on productivity was highly favorable, in their model, the firms destined to exploit modern IT were not yet in existence, and the incumbent firms with large investments in old technology lost value sharply.

Brynjolfsson and Yang [1999] have performed a detailed analysis of the valuation of firms in relation to their holdings of various types of produced capital. They regress the value of the securities of firms on their holdings of capital. They find that the coefficient for computers is over 10, whereas other types of capital receive coefficients below 1. They replicate Bronwyn Hall's [1993] finding that the coefficient on research and development capital is well below one. The authors are keenly aware of the possibility of adjustment of these elements of produced capital, citing Gordon [1994] on the puzzle that would exist if investment in computers earned an excess return. They explain their findings as revealing a strong correlation between the stock of computers in a corporation and unmeasured—and much larger—stocks of intangible capital. In other words, it is not that the market values a dollar of computers at $10. Rather, the firm that has a dollar of computers typically has another $9 of related intangibles.

Brynjolfsson and Yang discuss the nature of the unmeasured capital in detail. One element is software—purchased software may account for one of the extra $9 in valuation of a dollar invested in computers, and internally developed software another dollar. But they stress that a company that computerizes some aspects of its operations are developing entirely new business processes, not just

turning existing ones over to computers. They write, "Our deduction is that the main portion of the computer-related intangible assets comes from the new business processes, new organizational structure, and new market strategies, which each complement the computer technology… [C]omputer use is complementary to new workplace organizations which include more decentralized decision making, more self-managing teams, and broader job responsibilities for line workers."

Bond and Cummins [2000] question the hypothesis that the high value of the stock market in the late 1990s reflected the accumulation of valuable intangible capital. They reject the hypothesis that securities markets reflect asset values in favor of the view that there are large discrepancies or noise in securities values. Their evidence is drawn from stock-market analysts' projections of earnings 5 years into the future, which they state as present values.[3] These synthetic market values are much closer to the reproduction cost of plant and equipment. More significantly, the values are related to observed investment flows in a more reasonable way than are market values.

I believe that Bond and Cummins's evidence is far from dispositive. First, accounting earnings are a poor measure of the flow of shareholder value for corporations that are building stocks of intangibles. The calculations I presented earlier suggest that the accumulation of intangibles was a large part of that flow in the 1990s. In that respect, the discrepancy between the present value of future accounting earnings and current market values is just what would be expected in the circumstances described by my results. Accounting earnings do not include the flow of newly created intangibles. Second, the relationship between the present value of future earnings and current investment they find is fully compatible with the existence of valuable stocks of intangibles. Third, the failure of their equation relating the flow of tangible investment to the market value of the firm is not

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[3] The version presented to the Brookings Panel on Economic Activity did not cite Brainard, Shoven, and Weiss [1980], presented to the same panel 20 years earlier, which used a similar method.

reasonably interpreted as casting doubt on the existence of large stocks of intangibles. Bond and Cummins offer that interpretation on the basis of an adjustment they introduce into the equation based on observed investment in certain intangibles—advertising and R&D. But the adjustment rests on the unsupported and unreasonable assumption that a firm accumulates tangible and intangible capital in a fixed ratio. Further, advertising and R&D may not be the important flows of intangible investment that propelled the stock market in the late 1990s.

Research comparing securities values and the future cash likely to be paid to securities holders generally supports the rational valuation model. The results in section IV of this paper are representative of the evidence developed by finance economists. On the other hand, research comparing securities values and the future accounting earnings of corporations tends to reject the model based a rational valuation on future earnings. One reasonable resolution of this conflict—supported by the results of this paper—is that accounting earnings tell little about cash that will be paid to securities holders.

An extensive discussion of the relation between the stocks of intangibles derived from the stock market and other aggregate measures—productivity growth and the relative earnings of skilled and unskilled workers—appears in my companion paper, Hall [2000].

VIII. Concluding Remarks

Some of the issues considered in this paper rest on the speed of adjustment of the capital stock. Large persistent movements in the stock market could be the result of the ebb and flow of rents that only dissipate at a 10 percent rate each year. Or they could be the result of the accumulation and decumulation of intangible capital at varying rates. The view based on persistent rents needs to

explain what force elevated rents to the high levels seen today and in the 1960s. The view based on transitory rents and the accumulation of intangibles has to explain the low measured level of the capital stock in the mid-1970s.

The truth no doubt mixes both aspects. First, as I noted earlier, the speed of adjustment could be low for contractions of the capital stock and higher for expansions. It is almost certainly the case that the disaster of 1974 resulted in persistently lower prices for the types of capital most adversely affected by the disaster.

The findings in this paper about the productivity of capital do not rest sensitively on the speed of adjustment. The smoothed figures in Figures 10 and 11 and the two columns of Table 1 tell much the same story, despite the difference in the adjustment speed. Counting the accumulation of additional capital, output per unit of capital (net of payments to other factors) was high in the 1950s, 1960s, and 1980s, and low in the 1970s. Productivity reached a postwar high in the 1990s. This remains true even in the framework of the 10-percent adjustment speed, where most of the increase in the stock market in the 1990s arises from higher rents rather than higher quantities of capital.

Under the 50 percent per year adjustment rate, the story of the 1990s is the following: The quantity of capital has grown at a rapid pace of 16.2 percent per year. In addition, corporations have paid cash to their owners equal to 1.1 percent of their capital quantity. Total net productivity is the sum, 17.3 percent. Under the 10 percent per year adjustment rate, the quantity of capital has grown at 15.3 percent per year. Corporations have paid cash to their owners of 1.4 percent of their capital. Total net productivity is the sum, 16.6 percent. In both versions, almost all the gain achieved by owners has been in the form of revaluation of their holdings, not in the actual return of cash.

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Appendix 1. Unique Root

The goal is to show that the difference between the marginal adjustment cost and the value of installed capital,

$$x(k) = c'\left(\frac{k - k_{t-1}}{k_{t-1}}\right) + 1 - \frac{v_t}{k}$$

has a unique root. The function x is continuous and strictly increasing. Consider first the case $v_t > k_{t-1}$. Here $x(k_{t-1}) < 0$ and $x(v_{t-1}) > 0$. Hence there is a unique root between k_{t-1} and v_t. The other case is $v_t \leq k_{t-1}$. Then $x(k_{t-1}) \geq 0$ and $x(v_{t-1}) \leq 0$. Then there is a unique root between v_t and k_{t-1}.

Appendix 2. Data

I obtained the quarterly Flow of Funds data and the interest rate data from www.federalreserve.gov/releases. The data are for non-farm, non-financial business. I extracted the data for balance-sheet levels from ltabs.zip, downloaded at http://www.federalreserve.gov/releases/z1/Current/data.htm. I obtained the GDP and the investment deflator data from the NIPA downloaded from the BEA website.

The Flow of Funds accounts use a residual category to restate total assets and liabilities at the level reported by the Internal Revenue Service in *Statistics of Income.* I omitted the residual in my calculations because there is no information about returns that are earned on it. I calculated the value of all securities as the sum of the reported categories other than the residual, adjusted for the difference between market and book value for bonds.

I made the adjustment for bonds as follows: I estimated the value of newly issued bonds and assumed that their coupons were those of a non-callable 10-year bond. In later years, I calculated the market value as the present value of the

remaining coupon payments and the return of principal. To estimate the value of newly issued bonds, I started with Flow of Funds data on the net increase in the book value of bonds and added the principal repayments from bonds issued earlier, measured as the value of newly issued bonds 10 years earlier. For the years 1946 through 1955, I took the latter to be one 40th of the value of bonds outstanding in January 1946.

To value bonds in years after they were issued, I calculated an interest rate in the following way. I started with the yield to maturity for Moody's long-term corporate bonds (BAA grade). The average maturity of the corporate bonds used by Moody's is approximately 25 years. Moody's attempts to construct averages derived from bonds whose remaining lifetime is such that newly issued bonds of comparable maturity would be priced off of the 30-year Treasury benchmark. Even though callable bonds are included in the average, issues that are judged susceptible to early redemption are excluded (see "Corporate Yield Average Guidelines" in Moody's weekly *Credit Survey*). Next I determined the spread between Moody's and the long-term Treasury Constant Maturity Composite. Although the 30-year constant maturity yield would match Moody's more closely, it is available only starting in 1977. The series for yields on long-terms is the only one available for the entire period. The average maturity for the long-term series is not reported, but the series covers all outstanding government securities that are neither due nor callable in less than 10 years.

To estimate the interest rate for 10-year corporate bonds, I added the spread described above to the yield on 10-year Treasury bonds. The resulting interest rate played two roles. First, it provided the coupon rate on newly issued bonds. Second, I used it to estimate the market value of bonds issued earlier which was obtained as the present value, using the current yield, of future coupon and principal payments on the outstanding imputed bond issues.

The stock of outstanding equity reported in the Flow of Funds Accounts is conceptually the market value of equity. In fact, the series tracks the S&P 500 closely.

All of the flow data were obtained from utabs.zip at http://www.federalreserve.gov/releases/z1/Current/data.htm. All of the interest rate data were taken from http://www.federalreserve.gov/releases/H15/data.htm.

I measured the flow of payouts as the flow of dividends plus the interest paid on debt plus the flow of repurchases of equity less the increase in the volume of financial liabilities.

I estimated interest paid on debt as the sum of the following:

1. Coupon payments on corporate bonds and tax-exempt securities, discussed above.

2. For interest paid on commercial paper, taxes payable, trade credit, and miscellaneous liabilities, I estimated the interest rate as the 3-month commercial paper rate, which is reported starting in 1971. Before 1971, I used the interest rate on 3-month Treasuries, plus a spread of 0.7 percent (the average spread between both rates after 1971).

3. For interest paid on bank loans and other loans, I used the prime bank loan rate. Before 1949, I used the rate on 3-month Treasuries plus a spread of 2.0%.

4. For mortgage interest payments, I applied the mortgage interest rate to mortgages owed net of mortgages held. Before 1971, I used the average corporate bond yield.

5. For tax-exempt obligations, I applied a series for tax-exempt interest rates to tax-exempt obligations (industrial revenue bonds) net of holdings of tax exempts.

I estimated earnings on assets held as

1. The commercial paper rate applied to liquid assets.

2. A Federal Reserve series on consumer credit rates applied to holdings of consumer obligations.

3. The realized return on the S&P 500 to equity holdings in mutual funds and financial corporations and direct investments in foreign enterprises.

4. The tax-exempt interest rates applied to all holdings of municipal bonds.

5. The mortgage interest rate was applied to all mortgages held.

Further details and files containing the data are available from http://www.stanford.edu/~rehall.