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THE STOCK MARKET AND CAPITAL ACCUMULATION

Robert E. Hall

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ABSTRACT

If firms purchase capital up to the point where there is no further marginal benefit, and the firms' securities are equal in value to the capital, then the market value of securities measures the *quantity* of capital. I explore the implications of this hypothesis using data from U.S. non-farm, non-financial corporations over the past 50 years. The hypothesis implies 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 only a modest increase in the productivity of capital in the 1990s.

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I. Introduction

A basic first-order condition holds that firms invest in produced capital to the point that its discounted return is equal to its production cost. How effective are firms in satisfying this condition? The *endogenous investment hypothesis* considered in this paper holds that the condition applies as a workable approximation, if not from year to year, at least over longer periods. Under the reasonable assumption that the securities issued by a firm are claims on its capital and therefore have a total value equal to the value of the capital, the observed value of the securities reveals the *quantity* of capital. The endogenous investment hypothesis implies that securities markets provide a way to measure intangible capital accumulated by the corporate sector, where both the flow of investment and the stock of capital are not directly observed. There are good reasons to believe that otherwise unmeasureable intangible capital is an important part of the capital of a modern economy.

The endogenous investment hypothesis involves more than the proposition that the stock market capitalizes future shareholder returns. Capitalization occurs whether the returns earned by firms are exogenous or endogenous. Claims on endowments are valued in the stock market according to principles set forth in Lucas [1978]. But there is no investment in the endowment economy. The endogenous investment hypothesis holds that firms will purchase newly produced physical capital whenever such a purchase generates an expected gain, with suitable discounting for risk. In that case, there is feedback from financial markets to the substantive activities of firms, via the discount rate. Capital accumulation and stock market valuations are jointly determined. A key implication of the hypothesis is that, in equilibrium with zero expected discounted profit, the value

of the stock market and other securities equals the production cost of corporate assets. In other words, we can read the quantity of produced capital from the value of the securities of a firm or a sector. This paper considers the ramifications of that conclusion, using data from the U.S. non-farm, non-financial corporate sector.

I formulate the polar opposite of the endogenous investment hypothesis as the *endowment hypothesis.* Here, the productive facilities of a firm or sector are fixed and exogenous, and the flow of value derived from the facilities is an endowment flow. Although the problem of valuing corporate securities under the endowment hypothesis was formulated and solved in Lucas's celebrated paper, I make no claim that Lucas or any other economist actually believes that the endowment hypothesis is a useful way to characterize the U.S. economy. Rather, the endowment hypothesis plays a role in the explanation of the testable implications of the endogenous investment hypothesis.

Under the endogenous investment hypothesis, the quantity of capital is endogenous and its price is exogenous. Capital earns no rent because it is in perfectly elastic supply. Under the endowment hypothesis, the quantity of capital is exogenous and its price is endogenous. The price of capital is determined entirely by the rents that capital earns.

Although the endogenous investment hypothesis is not a statement about the values of securities in relation to the returns paid by the securities, nonetheless, I will examine the data used in this paper within modern valuation theory. If there are anomalies in the valuation of corporate securities, they become anomalies in the measurement of produced capital, under the endogenous investment hypothesis.

With important exceptions—notably Cochrane [1991, 1996]—financial economics has not emphasized real capital. On the other hand, the theory of the stock market implicit in all macroeconomic models in the Dynamic Stochastic

General Equilibrium tradition that now dominates macroeconomic theory links the stock market directly to the real produced assets accumulated by firms. In fact, because the size of the capital stock is always equal to the value of the stock market—thanks to instantaneous satisfaction of the first-order condition—many DSGE models do not refer to the stock market explicitly. Even in DSGE models where capital can earn rent because of adjustment costs, the resulting fluctuations in the price of capital are transitory. Over the longer run, securities markets reveal the quantity of capital.

The endogenous investment hypothesis and its corollary, the revelation of the quantity of capital in securities values, is an old idea. In particular, it was stated clearly by Baily [1981] in the context of the events of the 1970s, events shown to be important in this paper as well.

I believe that there is strong evidence that a general-equilibrium understanding of the stock market requires consideration of produced capital. The reason is that a general equilibrium model without produced capital cannot make sense out of the data on the flow of value from corporations to their owners. In three of the years since 1945, resources flowing from corporations to their owners have been *negative*. In other years, the flow has been positive and highly variable. It would strain credibility past the breaking point to suggest that the flow is exogenous—a predetermined endowment. Rather, the interplay between corporations and their owners—as determined in securities markets—causes the flows to respond to the forces that perturb general equilibrium.

I also report econometric results that support the hypothesis that corporate payouts are endogenous, that is, responsive to changes arising outside corporations. I find that payouts increase during periods of military buildup. This evidence is consistent with the view that corporations accumulate capital at rates depending on the relative value of capital within the corporation and outside it.

The evidence is unfavorable to the endowment hypothesis, where the capital within a corporation is not subject to those induced changes.

I read the evidence to support the view that firms retain shareholder value as endogenous capital. And they issue debt to increase their holdings of produced capital. Given the evidence that firms choose their stocks of produced capital, it is a short step to the view that they satisfy the first-order condition for optimal accumulation, as a reasonable approximation.

It does not appear to be possible to test the endogenous investment hypothesis directly. Modern financial economics tests asset pricing theory by asking if the properly discounted returns from an asset are equal to its market price. The test rests on the observability of the returns to each asset. But the returns to corporate capital are not observed directly: Conditional on the endogenous investment hypothesis, the data show conclusively 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—as inferred under the endogenous investment hypothesis—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 appropriate inference is that the firm has produced and accumulated the additional capital. The extra production is not included in accounting records of returns. Consequently, the return to produced capital is not observed—it is not possible to infer the actual earnings of capital as a residual of revenue over expenses. Hence, the standard approach of testing the hypothesis that expected discounted returns equal price cannot be applied.

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.

The primary goal of this paper is to appraise the view 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 to see if the hypothesis of optimal accumulation of real capital holds up, when the quantity of capital is measured from the value of securities. I concentrate not on the stock market, but on the combined value of equity and debt. By and large, I conclude that the evidence supports the hypothesis. At all times over the past half century, there has been substantial noise in the relation between the stock market and the capital stock. Interestingly, the only major outlier in the relation occurred not in the late 90s, but in 1974, when the data suggest a significant fraction of the capital stock effectively disappeared.

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 well under one (in the period from 1974 to 1982) to as high as 1.7 (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 more subtle than a moving average of past measured investments.

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 9.8 percent. That is, a unit of capital produces .098 units of output beyond what is needed to exchange for labor and other inputs and to replace worn capital. Corporations divide this bonus between accumulating more capital at a rate of 6.0 percent per year and paying their owners 3.8 percent of the current value of the capital.

It is an interesting implication of this view that U.S. corporations are generally self-perpetuating. At the end of 1945, non-farm, non-financial corporations had capital worth $799 billion in 1998 dollars. Shareholders and debt holders have been drawing out of this capital at an average rate of 3.8 percent per year. The power of compounding is awesome—the $799 billion nest egg became $10.7 trillion by the end of 1998, despite substantial invasion by shareholders and debt holders in most years. The evolution of the capital stock is described by an endogenous growth model, applied to corporations rather than the entire economy. The idea that securities markets channel funds from savers to corporations is almost completely off the point for corporations as a whole. Rather, the function of securities markets is to divide the surplus from endogenous growth into a component that is paid out to owners and a remainder that is reinvested.

Spectacular increases in stock-market/capital values in 1994-1998 are associated with only modest increases in the net product of capital. The average for the 1990s of 17 percent is not far above the 13 percent in another period of growth and prosperity, the 1950s. I discuss some evidence linking the higher product of capital in the 1990s to information technology.

II. Conditions for Securities Values to Reveal the Quantity of Capital

The following argument is a modern formulation of ideas in Hall [1977], Brainard, Shoven, and Weiss [1980], and Baily [1981]. Define the following notation:

v_t	=	value of securities in consumption units, at the beginning of the period, after payouts to owners (*ex dividend*)
$\bar{v}_t$	=	value of securities in consumption units, at the beginning of the period, before payouts to owners (*cum dividend*)
k_t	=	quantity of capital held for productive use during the period
$\bar{k}_t$	=	capital and newly produced output held by the firm at the beginning of the period, before payouts to owners
$p_t(k_t)$	=	the restricted profit function showing the firm's maximized profit as a function of its capital stock, with all other inputs variable
$s_{t,t}$	=	the economy's universal stochastic discounter, in the sense of Hansen and Jagannathan [1991], from period t back to period t
x_t	=	investment in new capital, in consumption units
d	=	depreciation rate of capital

I assume constant returns, competition, and immediate adjustment of all factors of production. Consequently, the restricted profit function has the form $p_t(k_t) = z_t k_t$ where the product of capital, z_t, depends on the prices of non-capital inputs. At the beginning of period t, the firm has resources $\bar{k}_t$ to divide

between capital k_t and payouts to its owners, $\bar{k}_t - k_t$. In future years, payouts are profit less investment, $z_{t+t}k_{t+t} - x_{t+t}$. The value of the firm is the present value of the future payouts:

$$\bar{v}_t = \bar{k}_t - k_t + E_t\left[s_{t,t}\left(z_t k_t - x_t\right) + s_{t,t+1}\left(z_{t+1}k_{t+1} - x_{t+1}\right) + \cdots\right] \tag{2.1}$$

The capital stock evolves according to:

$$k_{t+1} = x_t + \left(1-d\right)k_t \ , \tag{2.2}$$

so the value of the firm can be written in terms of the capital stock alone as

$$\begin{aligned}&\bar{v}_t = \bar{k}_t - k_t + \\ &E_t\left\{s_{t,t}\left[z_t k_t - k_{t+1} + \left(1-d\right)k_t\right] + s_{t,t+1}\left[z_{t+1}k_{t+1} - k_{t+2} + \left(1-d\right)k_{t+1}\right] + \cdots\right\}\end{aligned} \tag{2.3}$$

and this in turn can be written as

$$\begin{aligned}&\bar{v}_t = \bar{k}_t + E_t\left[s_{t,t}\left(z_t + 1 - d\right) - 1\right]k_t \\ &+ E_t\left[s_{t,t+1}\left(z_{t+1} + 1 - d\right) - s_t\right]k_{t+1} + \cdots\end{aligned} \tag{2.4}$$

A standard perturbation argument establishes that the first-order condition associated with a present or future value of the capital stock, k_{t+t}, $t \geq 0$, is

$$E_t\left[s_{t,t+t}\left(z_{t+t} + 1 - d\right) - s_{t,t+t-1}\right] = 0 \tag{2.5}$$

Note that this is a restriction on the factor prices embedded in z_{t+t} and on the stochastic discounter—it does not involve the capital stock itself. The basic story of this condition is that the wage rises to the point of extinguishing profit as firms expand to exploit a positive value of expected profit.

Substitution of the first order condition into the expression for the value of the firm, equation 2.4, yields the conclusion that $\bar{v}_t = \bar{k}_t$. Further, since the *ex dividend* value of the firm is $v_t = \bar{v}_t - \left(\bar{k}_t - k_t\right)$, the conclusion also follows that the *ex dividend* values are equal: $v_t = k_t$. I summarize as

> *Theorem (Quantity Revelation)* With competition and constant returns to scale, and no adjustment costs, the *value* of the firm equals the *quantity* of capital.

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, first, the absence of monopoly rents that would otherwise be capitalized in the firm's value, and, second, the absence of scarcity rents associated with capital. These conditions rule out the possibility that capital is non-produced (such as land) or that resources are required to adjust the capital stock.

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 the 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.

Baily [1981] formulated and proved a version of the quantity revelation theorem. His assumptions included a Cobb-Douglas technology, because he assumed a vintage structure in which capital aggregation is permissible only with that technology. My approach is less restrictive with respect to technology, but does require capital aggregation.

This paper asks if the value of corporate securities, interpreted as a measure of the quantity of capital, behaves reasonably. The answer is basically yes.

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. These firms do not satisfy the conditions described above for market value to reveal the quantity of 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

My data are taken from the flow of funds accounts maintained by the Federal Reserve Board.[1] The data are for all non-farm, non-financial corporations. I measure the value of their financial securities as the market value of outstanding equities plus the reported value of financial liabilities less financial assets, all divided by the consumption deflator from the U.S. National Income and Product Accounts. I measure payouts to security holders as the flow of dividends plus the

[1] http://www.federalreserve.gov/releases/z1/data.htm

flow of purchases of equity by corporations plus the interest paid on debt (imputed at Moody's AAA bond rate) less the increase in the real volume of net financial liabilities, again divided by the consumption deflator. Figures 1 through 4 display the data for the value of securities, payouts, and the payout yield (the ratio of payouts to market value).

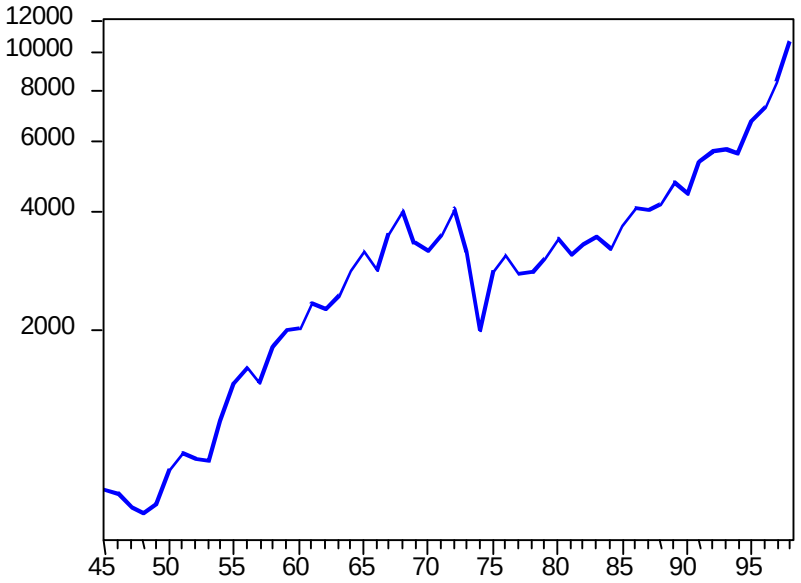

Figure 1. Value of the Securities of Non-Farm, Non-Financial Corporations in Billions of 1998 Dollars, Log Scale

In 1990, the real value of the sector's securities was about the same as in 1968. By 1998, it had almost tripled its 1990 level. As Figure 2 shows, the sector began and ended the period without little debt in relation to equity. But debt was more than 35 percent of the total value of securities at its peak in 1981.

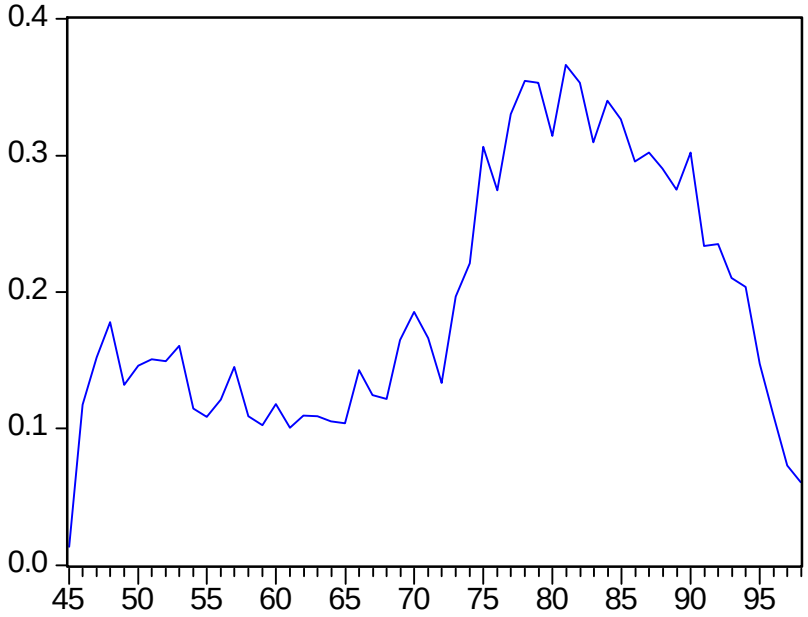

Figure 2. Ratio of Debt to Total Value of Securities.

Figure 3 shows the cash flows to the owners of corporations. 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.

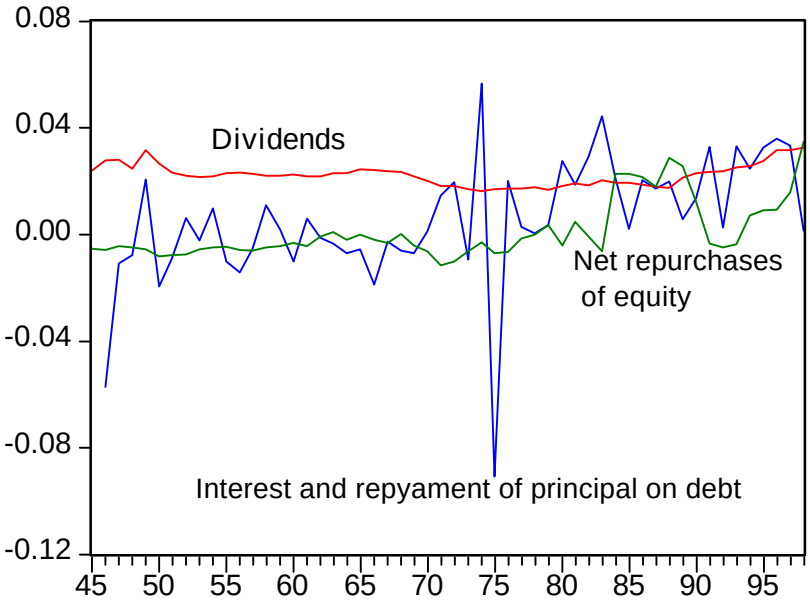

Figure 3. Components of Payouts, as Fractions of GDP.

Payouts to debt holders have been remarkably erratic, as the solid line in Figure 3 shows. The jumps upward in 1974 and downward in 1975 looks suspiciously like a data error, so I have examined the details of the data that account for these movements. The volatility comes entirely from the volume of debt-type liabilities of the sector. The relevant data are, in billions of nominal dollars:

	Assets	*Liabilities*
1973	575	761
1974	620	765
1975	778	1087

Since the price level rose dramatically in 1974, the real value of debt liabilities fell correspondingly. The decline was concentrated in trade payables, which fell from $228 billion in 1973 to $165 billion in 1974 in nominal terms. Suppliers of inputs from other sectors lowered their lending in the form of payables. There was little offsetting reduction in the sector's receivables. I see no signs of any data errors in 1974—rather, the data reflect the extreme conditions of the financial crisis of that year.

The huge increase in 1975 was entirely in the category "miscellaneous liabilities," which rose from $20 billion in 1974 to $313 in 1975. Although I have not yet been able to determine what is included in this category, I have no reason to think that the numbers are incorrect. Rather, it appears that there was a massive outflow of funds, in real terms, from the sector in 1974 and an even larger inflow in 1975.

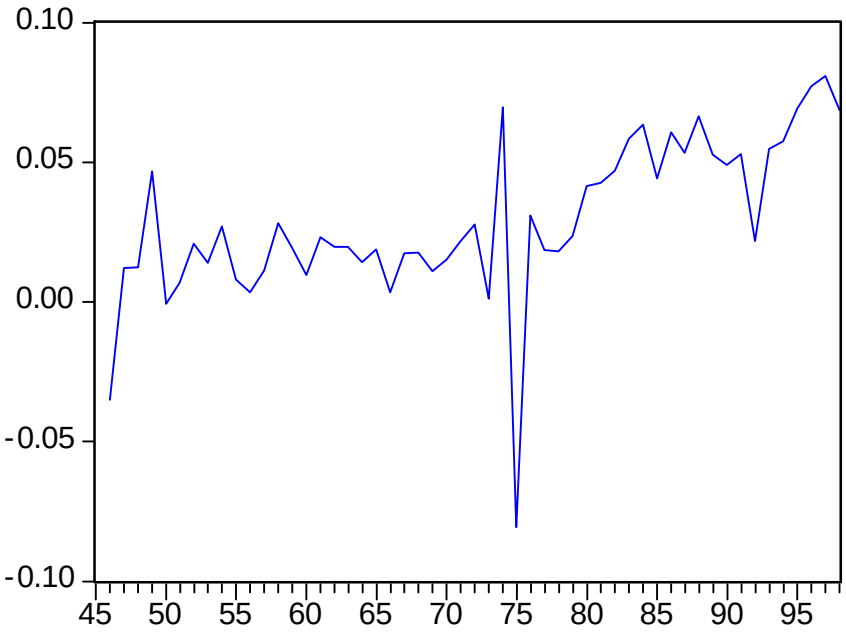

Figure 4. Total Payouts to Owners, as a Fraction of GDP

Figure 4 shows total payouts to equity and debt holders in relation to GDP. Note the disturbances in 1974-75 and 1999 and the remarkable growth since 1980. Cash flowing from corporations to their shareholders and debt holders was about 4 percent of GDP in 1980 and reached a peak of over 8 percent in 1997. A primary source of the conclusion that large amounts of capital built up in corporations during that period is the growth of the actual flow of cash out of corporations. Note that there were three years when the owners of corporations contributed resources to them, rather than receiving resources—1946, 1950, and 1975. And in 1992, both debt holders as a group and shareholders took out far less cash than normal.

Figure 5 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 9.3 percent in 1949, 14.1 percent in 1974, and 10.5 percent in 1984. As the lower line shows, much of the variability comes from debt. The 1998 level of the yield, 4.9 percent, is below its general level for the period since 1980 but above its postwar average of 3.8 percent. This finding 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 3 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 in future payouts. 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 uninteresting 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.

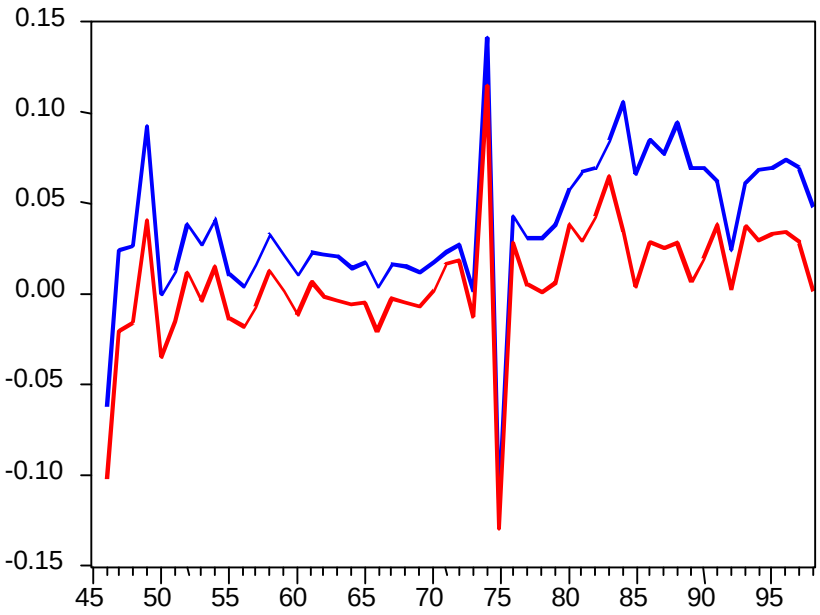

Figure 5. Payout Yield (Ratio of Payout to Value of Securities)
The upper line is the total payout to equity and debt holders and the lower line is the payout to debt holders only, as a ratio to the total value of securities.

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. The total overstatement does not appear to be very large, however. The average annual equity return in the data for the non-farm, non-financial sector

is less than a percentage point higher than the annual return from holding the S&P 500, as measured by Ibbotson Associates [1999].

IV. Valuation

Although, as I noted earlier, the endogenous investment hypothesis is not a statement about the relation between the value of a security and its future earnings, it is useful as a preliminary matter to look at valuation. If modern ideas about valuation do not apply, it would alter the interpretation of the endogenous investment hypothesis. 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. Figure 4 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	=	value of securities in consumption units
d_t	=	cash paid out to holders of these securities

$$R_{t+1} = \frac{v_{t+1} + d_t}{v_t} \qquad = \qquad \text{return ratio}$$

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

$$E_{t-1}\left[R_t s_t\right] = 1 \tag{4.1}$$

(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; this form was developed by Hansen and Jagannathan [1991].

I am interested in the valuation residual or expectation error in the return,

$$e_t = R_t - E_{t-1}R_t \tag{4.2}$$

From equation 4.1,

$$\left[E_{t-1}R_t\right]\left[E_{t-1}s_t\right] + Cov_{t-1}\left[R_t, s_t\right] = 1 \tag{4.3}$$

so

$$E_{t-1}R_t = \frac{1 - Cov_{t-1}\left[R_t, s_t\right]}{E_{t-1}s_t} \tag{4.4}$$

Now consider the return to a safe investment, $\tilde{R}_t$, known in advance: $E_{t-1}\tilde{R}_t s_t = 1$, so

$$E_{t-1}s_t = \frac{1}{\tilde{R}_t} \tag{4.5}$$

Let $f = -Cov(R_t, s_t)$, assumed to be approximately constant. Then $E_{t-1}R_t = (1+f)\tilde{R}_t$ and, finally,

$$R_t = (1+f)\tilde{R}_t + e_t \tag{4.6}$$

The parameter f is identified by this condition.

As a measure of $\tilde{R}$ I take the one-year Treasury bill rate less the rate of inflation. Thus I treat the rate of inflation as known in advance. I believe this is a reasonable approximation. OLS resulted in an estimate of the risk premium f of 0.085 with a Newey-West standard error of 0.014. 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 6 shows the residuals, the surprise element of the value of securities. The residuals show fairly uniform dispersion over the entire period. The four consecutive positive residuals in 1995-98 are a little unusual, but not large.

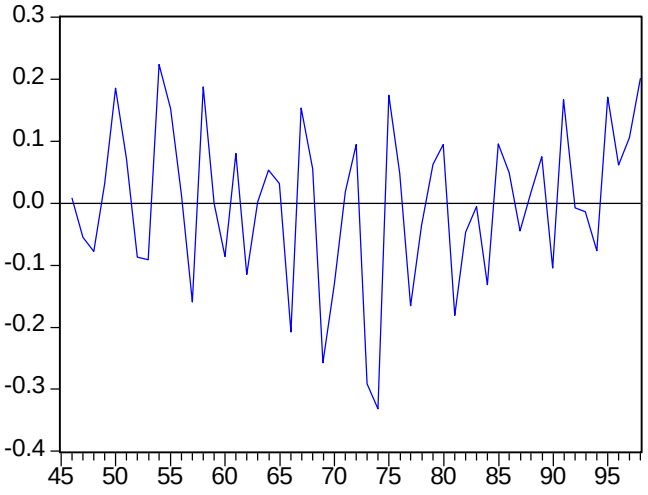

Figure 6. Valuation Residuals.

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.

V. Evidence about the Endogenous Investment Hypothesis

One approach to evaluating the evidence about the endogenous investment hypothesis is to consider the polar alternative, the endowment hypothesis. Again, I make no claim that any economist believes in the endowment hypothesis. It is a way to explain some of the implications of the endogenous investment hypothesis. But I note than any economist who explains persistent changes in the value of the stock market as reflecting variations in the discount rate applied to the stream of future profits is rejecting the endogenous investment hypothesis. Similarly, any theory that attributes the value of a particular firm to some unique source of profit—rather than the accumulation of past investment and the retention of its returns—is also rejecting the endogenous investment hypothesis.

The endowment hypothesis holds that the flow of value a corporation earns is exogenous and not the earnings of purchased capital. A corporation with purely exogenous earnings from its operations may still hold financial securities. But these holdings only affect the division of the flow of value between debt and equity and do not alter the proposition that the total cash received by all securities holders is the exogenous flow. To see this, let

d_t = Endowment flow

b_t	=	end of period debt outstanding (if positive) or debt held (if negative)
r_t	=	interest rate on debt
c_t	=	cash paid out to shareholders (dividends plus repurchases of stock)

The corporate sector's budget constraint is:

$$b_{t+1} = (1 + r_t)b_t - d_t + c_t) \quad . \tag{5.1}$$

The total cash paid out to debt and shareholders is

$$c_t + r_t - b_{t+1} + b_t = d_t \quad . \tag{5.2}$$

Thus, the endowment flow is always observed as the total cash payout of the corporate sector. The holders of the sector's securities, as a group, cannot use the firm as a bank, where resources can be invested. Observed cash payouts to securities holders collectively measure endowment returns exactly.

I believe that Figure 4 effectively disposes of the endowment hypothesis and thus supports the hypothesis that capital formation is endogenous. The fluctuations in payouts—and particularly the negative values—seem compelling evidence that resources move in and out of corporations in the same way that funds move in and out of a bank. The 50 percent decline in payouts in 1992 is especially significant. Nobody thinks that corporations suffered a large decline in net output in that year. Rather, it was a year when the conditions within corporations and in the rest of the economy made it appropriate for owners to extract rather less cash than in the years just before or just after.

The endowment hypothesis holds that payouts to corporate owners are invariant to conditions in the rest of the economy. In particular, payouts are

invariant to the amount of government purchases of goods and services. By contrast, the endogenous investment hypothesis predicts that corporations accumulate capital less rapidly—and thus raise payouts—when government purchases rise. The government can divert resources from other uses, such as corporate capital accumulation, by purchasing more output. This proposition is particularly true for military purchases, which tend to be transitory. The following regression tests the invariance hypothesis using data on the ratio of military purchases to total GDP (m_t / y_t):

$$\begin{array}{rll} d_t / y_t = & 0.031 + & 0.23 \left(m_t / y_t - m_{t-1} / y_{t-1} \right) \\ & (.006) & (.05) \end{array}$$

Newey-West standard errors are in parentheses. Although this regression strongly rejects invariance in the direction favoring the endogenous investment hypothesis, other specifications yielded weaker evidence.

Another approach to testing the endowment hypothesis against the endogenous investment hypothesis is to consider the relation between payouts, considered as an exogenous variable according to the endowment hypothesis, and endogenous aggregate variables. In particular, in almost any general equilibrium model, an exogenous increase in output will lower the short-term interest rate. The lower rate induces intertemporal substitution toward the present in order to absorb the extra resources. But the bivariate relation between the realized real one-year Treasury bill rate, r_t , and the ratio of corporate payouts to GDP is:

$$\begin{array}{rll} r_t = & -0.008 + & 0.69 \; d_t / y_t \\ & (.006) & (.15) \end{array}$$

Payouts are strongly positively associated with the interest rate, contrary to the implication of the endowment hypothesis. This finding would make sense under the endogenous investment hypothesis, where an increase in the demand for funds from outside the corporate sector would raise the interest rate and payouts at the same time. Although there is a possibility of a small amount of bias in the estimated relationship because interest rates enter the construction of the payout, this influence is nowhere near strong enough to explain the finding.

VI. The Capital Accumulation Model

Under the endogenous investment hypothesis, the value of corporate securities measures the quantity of the capital stock. 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). The quantity of capital is the value of corporate securities in units of output, v_t. Thus output is $z_t v_t$. Output is defined as the resources remaining after using gross output to pay for other variable inputs and to replace worn-out older capital. It is the same as profit as defined in Section 2, but at this point I drop the reference to other factors of production. Output is divided between the payout to the owners of corporations, d_t, and capital accumulation:

$$z_t v_t = d_t + v_{t+1} - v_t \tag{6.1}$$

The value of the productivity index can be calculated from observed data as

$$z_t = \frac{d_t + v_{t+1} - v_t}{v_t} \tag{6.2}$$

Note that this is exactly the one-period return from holding a stock whose price is v_t and whose dividend is d_t.

The linear technology has the important property that depreciation is not distinct from productivity. To see this, consider the economy with securities value v_t and payouts to owners, d_t. Instead of equation 6.1, this economy is hypothesized to suffer depreciation of its capital at rate d, so that its capital accumulation equation is

$$\tilde{z}_t v_t = d_t + v_{t+1} - (1-d)v_t \ . \tag{6.3}$$

But this can be written in the form of equation 6.1 as

$$(\tilde{z}_t - d)v_t = d_t + v_{t+1} - v_t \ . \tag{6.4}$$

So it is completely equivalent to consider the first economy with productivity index z_t and no depreciation or the second economy with productivity index $\tilde{z}_t = z_t + d$ and depreciation at rate d. For simplicity, I will normalize depreciation at zero.

If there are diminishing returns to capital, so the technology is not linear, then the calculated value of the productivity index z_t will decline during periods when capital is accumulated faster than other factors, such as the decade of the 1990s. The data considered in this paper do not support diminishing returns, however.

The capital accumulation model overcomes the implausible implications of the endowment hypothesis by adding 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 were years when market value rose. Again, the inclusion of any consideration of retention of resources in corporations is prohibited by the assumptions of the endowment hypothesis.

Equation 6.2 shows that the productivity of capital can be calculated as the ratio of net output to capital, again measured as the market value of the corresponding securities. Figure 7 shows the result of the calculation.

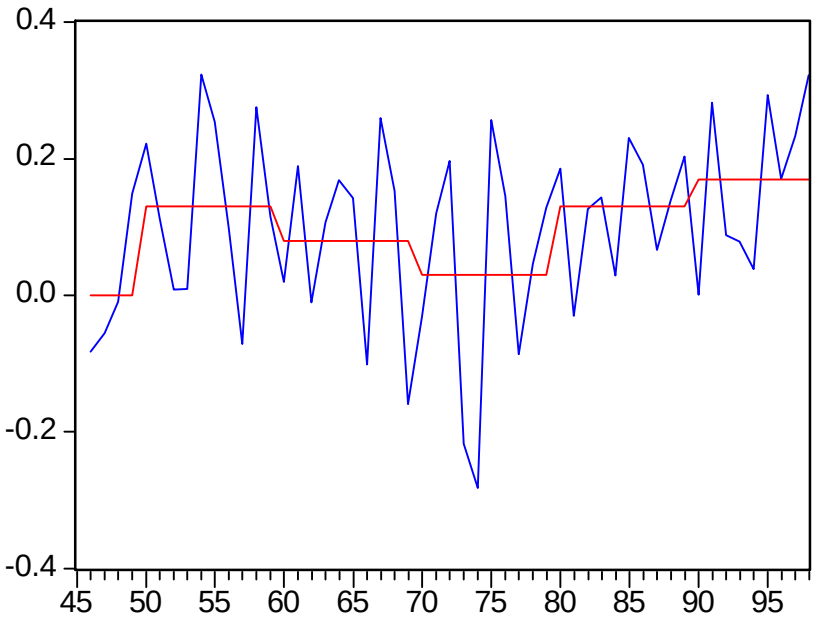

Figure 7. Estimated Net Product of Capital, by Year and by Decade

[2] The idea that capital gains measures 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.

Apart from noise, Figure 7 says the following: the product of capital implicit in securities markets has been roughly constant around its mean of 0.098 units of output per year per unit of capital. The marginal product has been higher during the good years since 1994, but then it was almost as high in the good years of the 1950s. The most notable event recorded in the figure was the deeply negative value of the marginal product in 1974. That finding is consistent with the idea that the huge increase in energy prices in that year effectively demolished a good deal of capital (see Baily [1981]).

The noise in Figure 7 appears to arise primarily from the valuation noise reported in Figure 6. 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. Much of this noise can be eliminated by taking averages over decades, as shown in the figure.

VII. The Nature of Accumulated Capital

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. Decades of research in the framework of Tobin's *q* have confirmed that the categories other than plant and equipment must be important (for example, Brainard, Shoven, and Weiss [1980]). 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 8 shows my calculations for the non-farm, non-financial corporate sector, based on 10 percent annual depreciation of its investments in 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. The difference could reasonably be attributed to intangibles. A capital catastrophe occurred in 1974, which drove securities values well below the reproduction cost of plant and equipment. Under the hypotheses advanced in this paper, the explanation would have to be that adverse developments in 1974 destroyed large amounts of capital, both physical and intangible.

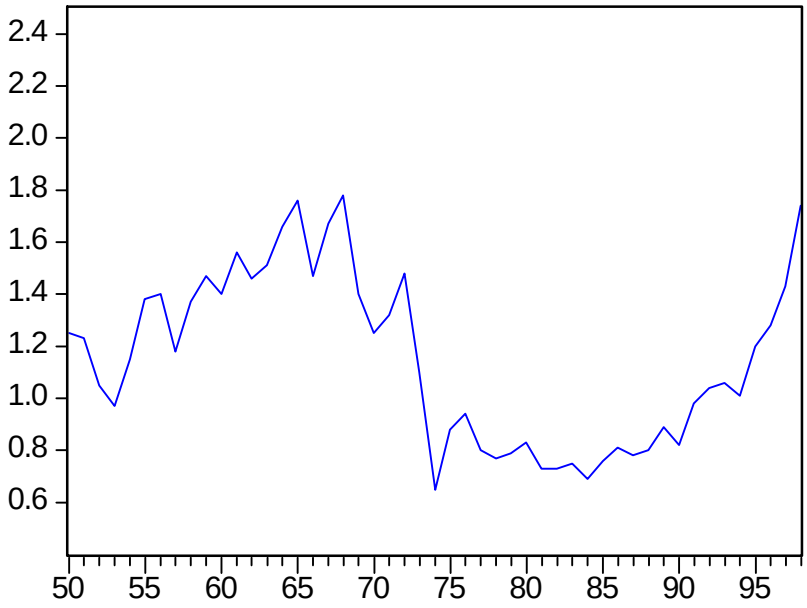

Figure 8. Tobin's *q*—Ratio of Market Value to Reproduction Cost of Plant and Equipment

Greenwood and Jovanovic [1999] have proposed another explanation of the capital 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 is 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…computer use is com-

plementary to new workplace organizations which include more decentralized line workers."

VIII. The Speed of Adjustment

The proposition that the value of corporate securities measures the proposition cannot apply literally in the short run, because purchasing and installing capital takes time. During the interval between the detection of an existing capital earns rents, and the value of these rents is incorporated in the value of securities. Abel [1990] provides a detailed and clear explanation of the are a convex function of the flow of investment.

I believe that it is generally accepted that the pattern of movements of over time as shown in Figure 8 are beyond the reach of an explanation based exclusively on adjustment costs (see, for example, Summers [1981]). Most q sometimes remains above one for a decade or more. Adjustment costs inferred q are far higher than seem reasonable.

as one of the many sources of noise in the calculation of the product of capital. Like valuation noise, scarcity rents average to zero over longer spans of time. averages over several years, I do not believe that refinements to recognize scarcity rents would alter the basic message of the calculations.

IX. Concluding Remarks

I believe that the evidence supports the endogenous investment hypothesis, though the support is less than definitive at this stage. The data tell a sensible and interesting story conditional on the hypothesis. Because the hypothesis makes the total capital stock of corporations observable as the total value of securities, it is possible to quantify otherwise elusive concepts that appear to be central to the modern economy. These are technology, organization, business practices, software, and the other produced elements of the successful modern corporation.

Corporate capital has grown at a high rate during the 1990s. Interpreted within the endogenous investment framework, the reasons are, first, the high return to capital, which averaged 17 percent per year during the decade. An important contribution to the high average was the absence of any notable capital disaster—a contrast to the 1970s. Second, most of the return has been reinvested. Securities holders have been extracting only about 5 percentage points, leaving 12 percent per year for capital and output growth.

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