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Predicting Stock Returns in an Efficient Market

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ABSTRACT

An intertemporal general equilibrium model relates financial asset returns to movements in aggregate output. The model is a standard neoclassical growth model with serial correlation in aggregate output. Changes in aggregate output lead to attempts by agents to smooth consumption, which affects the required rate of return on financial assets. Since aggregate output is serially correlated and hence predictable, the theory suggests that stock returns can be predicted based on rational forecasts of output. The empirical results confirm that stock returns are a predictable function of aggregate output and also support the accompanying implications of the model.

A RAPIDLY GROWING BODY of research documents forecastable components in security returns. The extent of predictability is a function of the return horizon, with predictable variation in aggregate returns ranging from around 3 percent for shorter horizons to above 25 percent for longer horizons. One of the most successful attempts in predicting security returns is Fama and French (1988b). Other papers demonstrating predictability are, for example, Fama and Schwert (1977), Keim and Stambaugh (1986), Campbell (1987), French, Schwert, and Stambaugh (1987), Campbell and Shiller (1988), and Lo and MacKinlay (1988).

Potential explanations for the predictability of returns fall, primarily, into two areas: 1) some form of general or limited irrationality, such as fads, speculative bubbles, or noise trading or 2) some form of general equilibrium model that provides for variation in real rates of return over time. Although substantial literature exists debating the "irrational" alternative (see Summers (1986), Poterba and Summers (1988), or West (1988)), we are not aware of work that provides an explanation in the context of a parsimonious and empirically robust general equilibrium model.

It is important to emphasize, as Fama and French (1988a), and others have noted, that, in the context of intertemporal models, predictability is *not* necessarily inconsistent with the concept of market efficiency. The purpose of this paper is to present a general equilibrium theory relating returns on financial assets to macroeconomic fluctuations in a context that is consistent with efficient markets in that no excess-profit opportunities are available. Accordingly, we show that, within an efficient market framework, stock prices need not follow a

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random walk and that changes in the equilibrium return on stocks can be predicted to the extent that there is predictability in aggregate output.

The intuition underlying our theoretical model arises from consumption smoothing by investors. Consumption opportunities are linked to output, and, consistent with conventional macroeconomic models, output is serially correlated and hence predictable. To maximize utility, investors attempt to smooth consumption by adjusting their required rate of return for financial assets. For example, investors anticipating lower output in the next period will attempt to transfer wealth to this anticipated period of scarcity and therefore will accept a lower rate of return in order to smooth consumption over time. As a result of the predictability of output and the linkage between output and returns, returns should have a predictable component that is related to aggregate output. In this context, the predictability of returns is consistent with the general notion of market efficiency, since attempts to exploit the predictability will increase variation in consumption, thus decreasing expected utility. A testable proposition resulting from the proposed model is that current period output measures should predict part of the intertemporal variability in future asset returns. Consistent with this proposition, our empirical results document a significant relation between lagged output and returns that persists under a variety of measurement specifications. Additionally, the relation between output and returns is shown to dominate the relation between dividend yield and returns found in Fama and French (1988b).

In Section I the theoretical core is developed by defining a representative firm and a representative investor and then solving the general equilibrium model. Section II derives the theoretical implications of the model and presents specific empirical counterparts. Three testable propositions are developed: stock returns are predictable; stock returns depend negatively on current output; and stock returns incorporate the information embodied in current output in a manner consistent with the theoretical model.

In Section III we empirically test the three propositions generated by the model using annual data on output and returns from the period 1947–1987. We find that current period measures of output can predict more than 20 percent of the variability in subsequent security returns. Furthermore, current output has a significantly negative effect on stock returns as predicted by the theory, and a cross-equation restriction imposed by the theory is upheld by the data. Sections IV and V examine the empirical and theoretical robustness of the model. Additional empirical tests are performed using various holding periods, alternative data sources, international data, and extended time series. The theoretical propositions are shown to be robust to generalizations of the initial specification, and the model appears to be sufficiently malleable for a variety of extensions that could, for instance, provide insights into arbitrage pricing. In Section VI, we present our conclusions.

I. The Model

A general equilibrium model that relates asset prices to movements of macroeconomic variables is considered. The model is a simple adaptation of Brock's

(1982) neoclassical growth model with asset-price determination. Our version of Brock's model extends the approach in Sargent (1987) (based on Lucas (1978)) by allowing production to become endogenous. As such, the model relates the basic determinants of aggregate savings and aggregate investment to provide a theory for movements of asset returns and aggregate production over time. The model considers common stock traded in a perfect capital market and a multipurpose good that can be used as a consumption good as well as a capital good. For simplicity one representative infinitely lived consumer is considered as well as one representative firm.

A. The Representative Firm

A firm determines its level of investment each period to maximize shareholder wealth. According to the second separation principle in Fama and Miller (1972, p. 176), shareholder wealth maximization implies that the firm maximizes the expected present value of real net cash flow. All net cash flow is paid to shareholders in the form of dividends, d_t. Dividends and all other variables in the paper are measured in real terms (with the consumption good as the numeraire) as the difference between output, y_t, and investment, i_t. Output is produced by a stochastic, decreasing returns, Cobb-Douglas technology with multiplicative, serially uncorrelated uncertainty, θ_t, such that $E(\theta_t) = 1$, and with capital, k_t, as the only input. Technological progress increases the productivity of capital over time.[1]

An important characteristic needed to represent the macro economy is autocorrelation in output. To introduce this characteristic we adopt the time-to-build physical capital assumption, which is a hallmark of real business cycle models (see McCallum (1988)). For simplicity, capital is assumed to depreciate fully each period. There is a gestation lag of one period before investment becomes productive as capital in the production function. Thus, current investment, i_t, is identical to next period's capital stock, k_{t+1}. The firm observes the current stochastic output shock, θ_t, before it determines investment, i_t.

The timing of events implied by the previous description is presented in Figure 1. Output, y_t, materializes at time t. At that time the firm divides the output into dividends, d_t, and investment, i_t. The investment becomes productive as capital one period later, k_{t+1}, and leads to production y_{t+1} after the random productivity shock θ_{t+1} is revealed. The dividends, d_{t+1}, are paid to the investors and, together with changes in share prices, $p_{t+1} - p_t$, determine the gross realized return, R_{t+1}, on stock held in the interval from t to $t + 1$. Given these timing conventions, the firm each period chooses investment (next period's

[1] The assumption of a decreasing returns technology and its inherent indivisibilities provide a motive for the existence of a share-issuing firm. As noted by Breeden (1986), in the case of a constant returns technology there is no reason for the firm to exist.

Intertemporal specifications of production functions, following Solow (1957), typically consider technological progress as some function of time. A recent example is Baltagi and Griffin (1988), who use the general specification $B(t)f(k_t, \ldots)$ for output, with $f(\cdot)$ a translog production function. For analytical convenience we use the specific form $B^t k_t^\alpha$, which implies a constant rate of technological progress.

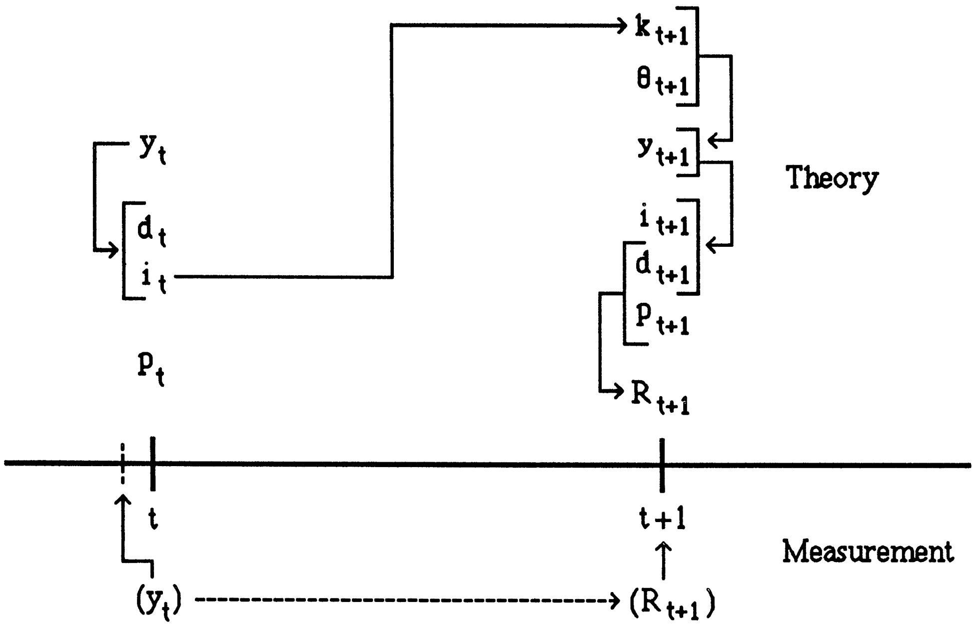

Figure 1. Time line. y_t = output at time t, d_t = dividends, i_t = investment, p_t = share price, k_t = physical capital, θ_t = random productivity shock, and R_{t+1} = realized return on shares from the period t to $t + 1$. Note that investment (i_t) becomes productive as capital one period later (k_{t+1}); thus, $i_t = k_{t+1}$. The schema portrayed above the time line characterizes the timing of the variables in the theoretical model and provides a simplified overview of the theoretical linkage between output and returns. As depicted in the lower portion of the time line, output for time t is measured using levels publicly reported before the beginning of the holding period over which returns are measured. For example, the output level for 1970 is represented by November's level since December's data are not publicly available until 1971. (This ensures that measurement periods for y_t and R_{t+1} do not overlap.)

capital stock, k_{t+1}) to maximize

$$E_0 \sum_{t=0}^{\infty} \left[\prod_{i=0}^{t} (R_i)^{-1} \right] d_t \tag{1}$$

subject to

$$d_t = y_t - i_t = y_t - k_{t+1}, \tag{2}$$

$$y_t = AB^t \theta_t k_t^{\alpha}, \tag{3}$$

where A and B are positive constants, α is less than one, and R_t is one plus the appropriate discount rate. R_t is endogenously determined in the general equilibrium model (R_0 is set equal to one). Substituting equations (2) and (3) into (1) and differentiating with respect to k_{t+1} yields the stochastic Euler condition:

$$E_t[(R_{t+1})^{-1} \alpha(y_{t+1}/k_{t+1})] = 1 \qquad \text{for all } t. \tag{4}$$

That is, the expectation of the marginal product of investment, properly discounted, must equal the one unit of the consumption good sacrificed in favor of investment.

B. The Representative Consumer

The consumer maximizes the present value of utility from consumption of the all-purpose good. The utility function is time-additive. The consumer may transfer purchasing power through time by holding shares in the representative firm. The state of the economy is fully described by current output, y_t, as a sufficient statistic for the only stochastic element in the model, θ_t, and the current capital stock, k_t (to be fully depreciated by the end of the period), with $u(\cdot)$ indicating concave one-period utility as a function of one-period consumption, c_t, and β as the consumer's discount factor for utility. Notice that β and $1/R_t$ (defined below equation (3)) are conceptually different discount factors. Whereas β discounts utility units, $1/R_t$ discounts consumption (net real cash flow). The consumer maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \, u(c_t) \tag{5}$$

subject to

$$c_t + p_t(y_t)s_{t+1} = [p_t(y_t) + d_t(y_t)]s_t. \tag{6}$$

The budget constraint is formulated in real terms. $d_t(y_t)$ represents the dividends per share, paid at the beginning of the period; $p_t(y_t)$ is the price per share in state y_t immediately after dividends d_t are paid; and s_t is the number of shares held at the beginning of period t.

Maximization by the representative consumer yields the following Euler equation with respect to the choice variable s_{t+1}:

$$p_t(y_t)u'(c_t) = \beta E_t\{[p_{t+1}(y_{t+1}) + d_{t+1}(y_{t+1})]u'(c_{t+1})\}. \tag{7}$$

The Euler equation relates the price and return of a share to the cost (or benefit) of delaying consumption, where we define

$$R_{t+1}(y_{t+1},y_t) \equiv [p_{t+1}(y_{t+1}) + d_{t+1}(y_{t+1})]/p_t(y_t) \tag{8}$$

as the realized holding period return on shares. Equation (7) represents the desire of the consumer to smooth consumption. It states that the consumer will choose current consumption such that, at the margin, the utility of current consumption equals the expected discounted return of buying a stock times the marginal utility of consumption when the stock is sold in the next period. If consumption were constant over time, then the discounted return, βR_{t+1}, would be one at each point in time. Generally, however, returns will vary since consumption varies due to the randomness in aggregate output.

For future reference, solving equation (7) forward yields a general expression for "ex-dividend" share prices:[2]

$$p_t = E_t \sum_{i=1}^{\infty} \beta^i [u'(c_{t+i})/u'(c_t)] d_{t+i}. \tag{9}$$

[2] Diba and Grossman (1987) demonstrate that equation (9) is not a unique solution since a bubble, F_t, can be added to (9) as long as $EF_{t+1} - (1 + r)F_t = 0$. However, West (1988) points out that both the evidence and theory are inconsistent with rational bubbles.

C. The General Equilibrium Model

To solve the general equilibrium model analytically we assume a logarithmic utility function:[3]

$$u(c_t) = a \ln (c_t). \tag{10}$$

The general equilibrium model is now solved to yield stochastic processes for output and asset prices in terms of exogenous variables. Shares may be interpreted as a share in the representative firm's dividends, and thus the supply of shares may be appropriately normalized to one so that, at each time, $s_t = 1$ clears the market for shares. Under this market-clearing condition the consumer's budget constraint implies that $c_t = d_t$; i.e., the demand for consumption goods equals the net supply to the consumers of the multi-purpose good.

Using the fact that $u'(c_t) = a/c_t$ and the last result that $c_t = d_t$, the share pricing equation (9) yields

$$p_t = E_t \sum_{i=1}^{\infty} \beta^i d_t = [\beta/(1-\beta)]d_t. \tag{11}$$

The fact that p_t does not depend on future dividends is an artifact of the logarithmic form of the utility function.[4] The simple expression for share prices implies a simple form for share returns which become, from equation (11) for share prices and equation (8) defining returns,

$$R_{t+1} = (1/\beta)(d_{t+1}/d_t). \tag{12}$$

At time t the return R_{t+1} is stochastic depending on the realization θ_{t+1} which determines d_{t+1}. Taking expectations conditional on information at time t on both sides of equation (12) yields the interpretation that, when dividends at the end of the holding period are expected to be higher than current dividends, investors require a higher return in order to be willing to transfer purchasing power from now to the end of the period and thus follow a less smooth consumption pattern.

Equations (2), (3), (4), and (12) characterize the dynamic path for d_t, k_t, y_t, and R_t. An explicit solution may be obtained in standard fashion through the method of undetermined coefficients. The posited solution where investment is proportional to output then yields $k_{t+1} = \alpha\beta y_t$, which implies from equation (2) that $d_t = (1 - \alpha\beta)y_t$. Accordingly, equation (12) becomes

$$R_{t+1} = (1/\beta)(y_{t+1}/y_t). \tag{13}$$

Substitution of equation (13) into equation (4) verifies that the posited solution is correct. Since future output depends on current investment, it can be predicted

[3] The robustness of the theoretical model to this and other specific assumptions is considered in Section V.

[4] In general, expected increases in dividends will lead to two effects. First, future purchasing power increases due to higher future dividends, raising share prices. Second, and more subtly, future dividends are discounted more heavily as the marginal utility of future purchasing power decreases (the incentive for consumption smoothing). In the special case of the log utility function, these effects cancel exactly.

from current observations. The solution $k_{t+1} = \alpha\beta y_t$ implies that

$$y_{t+1} = \theta_{t+1}\gamma B^t y_t^\alpha, \tag{14}$$

where $\gamma \equiv AB(\alpha\beta)^\alpha$. Equations (13) and (14) together explain the principle of return predictability in our model. Realized returns depend on the realization of next period's output relative to current output. Next period's output, however, can be forecast based on current output, and, accordingly, returns can be predicted based on currently available information. In spite of the predictability, no excess profit opportunities are available. The prediction of, say, a higher return implies a possible advantage to the investor which is exactly offset by the disadvantage of a less smooth consumption pattern.[5]

In summary, it is important to emphasize that our work is not unique in predicting asset returns, modeling macroeconomic fluctuations, or modeling intertemporal asset pricing. Clearly the assumption of consumption smoothing is similar to Breeden's (1979) characterization of diminishing marginal utility of consumption or the general scenario described by Fama and French (1988a) to explain return predictability.[6] The contribution of our work is to provide a parsimonious equilibrium model that explicitly accounts for the predictability in asset returns, in this case as a result of the predictability of aggregate output, and generates a series of empirically testable propositions.

II. From Theory to Measurement

The remainder of the paper examines the implications of the theoretical model. The model exposes relations in general equilibrium between share returns and aggregate output that provide indirect tests pertaining to rational predictions of share returns over time. Since capital, which is an explanatory variable in the general equilibrium model, is traditionally hard to measure, it will be bypassed in our estimation procedures. Similarly, observed dividends may not properly represent a firm's actual net cash flow due to the use of dividends as a signalling device and other dividend policies practiced by firms. As a result, the relevant relations for the empirical model are the ties of share returns to aggregate output and the movement of aggregate output over time.

Equations (13) and (14) are the only equations used in the empirical model. A logarithmic transformation yields

$$\ln y_{t+1} = (\ln \gamma - \lambda) + (\ln B)\, t + \alpha \ln y_t + \epsilon_{t+1}, \tag{15}$$

$$\ln R_{t+1} = -\ln \beta + \ln y_{t+1} - \ln y_t, \tag{16}$$

[5] The combination of predictability and absence of excess profit opportunities continues to hold if more assets are available. The reason is that the returns on all assets move together due to macroeconomic factors so that arbitrage across assets is not profitable. A working paper which includes the full spectrum of contingent securities is available from the authors.

[6] Breeden (1986), in his consumption-based asset pricing model, demonstrates how the optimal decisions of representative consumers change as a result of changes in production. Breeden's work evolves from a rich history of work in this area. (See, for example, Merton (1973), Constantinides (1980), Grossman and Shiller (1982), Michener (1982), Cox, Ingersoll, and Ross (1985), or Cecchetti, Lam, and Mark (1988).) Cochrane (1988b) develops the opposite side of the general equilibrium model by explaining how the return on stocks responds to the investment decisions of producers.

where the constant λ is chosen such that $E(\epsilon_{t+1}) \equiv E(\ln \theta_{t+1}) + \lambda = 0$. (It follows from Jensen's inequality that $\lambda \geq 0$ since $E(\ln \theta_{t+1}) \leq \ln E(\theta_{t+1}) = 0$.) Equation (15) states that aggregate output is serially correlated with a time trend. Equation (16) shows that share returns vary over time due to the desire of consumers to smooth consumption.

Consistent with the theoretical model, equation (16) implies that R_{t+1} is known with certainty once y_{t+1} is known. It is the predictability of y_{t+1} in equation (15) that suggests the appropriate empirical relation for future returns based only on current information. The predictable component of y_{t+1} can be incorporated in an empirical counterpart, based on equation (16), to predict returns; i.e., substituting $\ln y_{t+1}$ from (15) into (16) provides

$$\ln R_{t+1} = (\ln \gamma - \lambda - \ln \beta) + (\ln B)\, t + (\alpha - 1) \ln y_t + \epsilon_{t+1}. \quad (17)$$

If our model is correct, several implications should hold true. First, equation (17) using current information should be significant in predicting future share returns; second, the coefficient of the log of current aggregate output, $\alpha - 1$, must be negative. Third, since t and y_t are only relevant in predicting share returns to the extent that they predict future output, $\ln y_{t+1}$, restricted estimates that use $E_t(\ln y_{t+1})$ from the regression in (15) to estimate (16) should not be significantly different from unrestricted estimates obtained by directly estimating (17).

A standard F-test is used to verify the last implication. The residuals from the unrestricted estimation of (17) are compared to the residuals formed from the restricted regressions, where, theoretically,

$$\ln R_{t+1} = -\ln \beta + z_t + \epsilon_{t+1} \quad (18)$$

and z_t is defined as the forecasted growth rate of output:

$$z_t \equiv E_t(\ln y_{t+1} - \ln y_t) = (\ln \gamma - \lambda) + (\ln B)\, t + (\alpha - 1) \ln y_t. \quad (19)$$

A significant F-statistic in this comparison is inconsistent with our model since this result implies that the derived linkage between output and returns is incomplete or inappropriate.[7]

In short, we focus on three empirical hypotheses offered by the theory: predictability of share returns; a negative relation between future returns and current output; and coefficient restrictions implicit in the specification relating output to returns.

III. Results

Measures of output, share returns, and inflation rates are required to test the empirical propositions generated from the theory. In this initial series of tests we use annual data from 1947 to 1987. Data on industrial production (not seasonally adjusted) for the United States were provided by the St. Louis Federal

[7] Given that future returns are predictable from current information, failure to reject the model based on this test is consistent with the hypothesis that markets efficiently incorporate all relevant publicly available information in spite of the predictability of future stock returns. A more detailed discussion of tests of cross-equation restrictions using this approach is provided in Mishkin (1983).

Reserve Bank. The CRSP value-weighted return series (NYSE) provides the measure of share returns. Inflation rates, which are necessary to convert nominal returns into real terms (as the theoretical model is in real terms), are measured by the change in the CPI as reported on the CRSP index files. To account for reporting lag, the index number used for industrial production in a given year is based on the value reported for October in cases prior to 1950 and November for all subsequent observations. (After 1950, figures for a given month were released to the public about midway into the subsequent month.) Thus, the measure of industrial production used to forecast, for example, 1987 stock returns is based on industrial production data publicly available in December of 1986. The timing of these measurements in relation to the theoretical model is illustrated in Figure 1. In a subsequent section of the paper we consider the sensitivity of the results to alternative measures, time intervals, and lag structures.

The empirical counterparts to the three testable propositions derived from the theory and corresponding to equations (15), (17), and (18) are, respectively,

$$\ln y_{t+1} = a_0 + a_1 t + a_2 \ln y_t + e_{t+1}, \tag{20}$$

$$\ln R_{t+1} = b_0 + b_1 t + b_2 \ln y_t + u_{t+1}, \tag{21}$$

$$\ln R_{t+1} = c_0 + c_1 z_t + v_{t+1}, \tag{22}$$

where a_i, b_i, and c_i are estimated regression parameters and e_{t+1}, u_{t+1} and v_{t+1} are estimated regression errors (z_t is defined in equation (19)).[8]

Again, the theoretical model posits that 1) current information in equation (21) should be significant in predicting returns, 2) the coefficient on the log of current output in equation (21) should be significant and negative, and 3) equation (21) should not be significantly different from equation (22) if current output predicts returns based on the linkages implied by the model.

The estimation results for equations (20) thru (22) are presented in Table I. As expected, the time-series model for predicting levels of industrial production provides a relatively high adjusted R^2 of 0.98.[9] As predicted by the model, the coefficient on current output in predicting share returns is significant and

[8] Strict interpretation of the theory implies the restrictions $c_1 = 1$ and $b_2 = a_2 - 1$ due to the simplifying assumption of logarithmic preferences (relative risk aversion of one). However, we do not intend to test the assumption of logarithmic utility; hence these restrictions are not imposed. On the other hand, we do test the restriction embodied in equation (22), which does not depend on the assumption of logarithmic preference. Estimating equation (22) using z_t is equivalent to estimating equations (20) and (21) with the restriction that $a_1 b_2 = (a_2 - 1)b_1$.

[9] The level of autocorrelation was not significant at the 0.05 level in any of the three regressions (using a Durbin h-statistic for the industrial production regression containing a lagged dependent variable and a Durbin-Watson statistic for the two return regressions). In the regression reported in Table I for industrial production, we are able to reject the unit root null hypothesis at the 0.05 level using both the τ_μ and τ_τ statistics of Fuller (1976). Using a Breusch-Godfrey test with four lags, there was no evidence of higher-order autocorrelation. (The first four autocorrelations for the industrial production regression residuals were 0.003, −0.064, −0.100, and 0.078.) Durlauf and Phillips (1988) indicate that the absence of significant positive autocorrelation provides additional evidence against a unit root. To the extent that a portion of the industrial production time series is a random walk, as Cochrane (1988a) argues may be the case for GNP, this will simply add to the unpredictable movement in stock returns.

Table I

Empirical Tests of the Equilibrium Model Using Annual Data for the Period 1947–1987

Each regression is based on 40 annual observations. As detailed in the text, y_t is the most recently reported level of non-seasonally adjusted industrial production available in December of year t. The return on shares over the period t to $t+1$ (R_{t+1}) is measured using one plus the return on the CRSP value-weighted market portfolio. z_t is the rational forecast of output growth; i.e., $z_t \equiv E_t(\ln y_{t+1} - \ln y_t)$, where $E_t(\ln y_{t+1})$ is predicted from the regression results in row 1. As the theoretical model is developed in real terms, all of the return variables are reduced by the percentage change in the CPI for each period. The reported R^2 is adjusted for degrees of freedom. t-Statistics appear in parentheses.

Dependent Variable	Constant	Trend	$\ln y_t$	z_t	$R^2_{adj.}$
1. $\ln y_{t+1}$	1.150	0.012	0.673		0.983
	(2.75)	(2.51)	(5.43)		
2. $\ln R_{t+1}$	3.828	0.039	−1.096		0.206
	(3.37)	(3.01)	(−3.26)		
3. $\ln R_{t+1}$	−0.057			3.463	0.221
	(−1.30)			(3.48)	

negative. Notably, the model is able to predict more than 20 percent of the variation in returns. The F-statistic comparing the unrestricted model of equation (21) with the restricted model of equation (22) is 0.261, which is not significant at any reasonable level.

In summary, the empirical tests are in all cases consistent with the predictions of the theory. Additionally, the level of return predictability implied by the model is competitive with previous theoretical results.

IV. Empirical Robustness

A. Measurement Issues

The robustness of the empirical results relating lagged output to returns [equation (21)] is considered in this section using alternative return horizons and non-U.S. data. We first consider different return horizons. This is an important alternative to examine since our theoretical model does not specify any particular measurement interval. Using the same measures of output as before, tests are reported for return horizons from one month to five years in the first five rows of Table II. As might be expected from the results of Fama and French (1988a), when the measurement interval is reduced to shorter time intervals, the random walk component of returns becomes more dominant. Hence, we see the adjusted R^2 drop from the previously reported 0.20 to 0.08 and 0.03, respectively, for quarterly and monthly data. Alternatively, for the 5-year return horizon, the adjusted R^2 is greater than 50 percent.[10]

[10] As in Fama and French (1988b), the 3- and 5-year returns are based on overlapping data. As noted by Richardson (1988), interpreting the various return horizons collectively can be misleading since the estimates are interdependent. It is not clear, however, what the power of his proposed joint test is under a number of interesting alternatives.

Table II

Alternative Tests of the Relation between Output and Share Returns

$$\ln R_{t+1} = b_0 + b_1 t + b_2 \ln y_t + u_{t+1}$$

The return on shares (R_t) is measured using one plus the return on the CRSP value-weighted market portfolio minus the change in the CPI for regressions on the United States data. N represents the number of time-series observations. The reported R^2 is adjusted for degrees of freedom. Regressions for the three- and five-year horizons are based on overlapping data; thus, the reported t-statistics are adjusted using the method of Hansen and Hodrick (1980). For the United States data, y_t is measured by the Federal Reserve time series for industrial production (not seasonally adjusted). The international data for industrial production, share returns, and inflation are taken from the International Financial Statistics files. An autoregressive model with a one-period lag was estimated for the three non-U.S. cases. In all cases, industrial production for period t is based on the most recently reported level available in that period. t-Statistics appear in parentheses.

Specification	b_0	b_1	b_2	N	$R^2_{adj.}$
Panel A: United States Data: 1947–1987					
Alternative Return Horizons					
1. Monthly	0.338	0.0003	−0.097	490	0.028
	(3.79)	(3.47)	(−3.69)		
2. Quarterly	1.101	0.0026	−0.290	162	0.072
	(3.78)	(3.45)	(−3.68)		
3. 1 Year	3.828	0.039	−1.096	40	0.206
	(3.37)	(3.01)	(−3.26)		
4. 3 Years	6.007	0.057	−1.701	38	0.298
	(3.21)	(2.55)	(−2.99)		
5. 5 Years	10.305	0.102	−2.997	36	0.510
	(4.16)	(3.31)	(−3.89)		
Panel B: International Data					
Country/Time Interval					
6. Canada	1.179	0.0027	−0.326	115	0.087
Quarterly 59:II–87:IV	(2.80)	(2.23)	(−2.81)		
7. United Kingdom	3.149	0.0031	−0.761	123	0.097
Quarterly 57:I–87:IV	(3.26)	(2.62)	(−3.28)		
8. Japan	0.508	0.0039	−0.196	115	0.067
Quarterly 59:I–87:IV	(2.34)	(2.81)	(−2.65)		

Clearly our model should not be restricted to the United States experience. To test the generality of our results, we estimate equation (21) for Canada, the U.K., and Japan. Data for industrial production, share returns, and inflation are taken from the International Financial Statistics (IFS) files. We were able to determine that industrial production is currently reported with a one-month lag in all three countries. As we could not determine this for the entire time series, we assumed a two-month reporting lag throughout to be conservative. Since the number of annual observations was substantially lower, we used quarterly intervals to test the relation. Preliminary tests indicated significant autocorrelation in the non-U.S. regressions; thus, we report results for an autoregressive model with one lag. The results of these tests appear in the last three rows of Table II. As predicted by the theory, the coefficient on lagged output is negative and statistically significant for each country. The adjusted R^2 values range from 0.067 to 0.097, which is consistent with the quarterly results from the U.S. data.[11]

In summary, the relation between returns and lagged output and the associated predictability seems to persist under a variety of conditions. The increasing level of predictability associated with longer measurement intervals is consistent with the results of Fama and French (1988a,b). The results also are consistent across the three countries examined in addition to the U.S.

B. Lag Structures, Causality, and Alternative Predictors

In this section we consider the sensitivity of the results to less structured specification. We do so by expanding the lag structure in an atheoretical context and testing dividend yield as a competing predictor. For brevity, we test only annual data.

There are a variety of reasons for focusing on the lag specification in modeling output (equation (20)) and returns (equation (21)): (a) Although the theoretical model indicates that only one lag is relevant, it does not specify the measurement interval. (b) The simple lag structure of the theoretical model is partially attributable to our assumption that capital is fully depreciated over a single period. (c) In the interest of parsimony, a variety of potentially important macroeconomic variables (e.g., monetary shocks) were excluded from the model. (d) We would not argue that the relation between output and returns is entirely as simple and unilateral as implied by the literal application of the theory presented here. Stylized facts suggest that returns are a leading indicator of output (e.g., Fischer and Merton (1984) or Eichenbaum and Singleton (1986)).

[11] Another potential criticism of our initial tests in Table I is that the industrial production measure has been modified and corrected subsequent to when it was first reported. Thus, the ex ante data can be said to be contaminated since they include ex post modifications. To address this issue, we collected annual data from the *Federal Reserve Bulletin* so that the measure of industrial production for a given period was based on the most current reported figure by the Fed. Using this measure to estimate equation (21), we found no notable effects, although the adjusted R^2 is somewhat lower than reported in Table I (0.16 vs. 0.20).

Also examined, but not reported in the table, was the effect of firm size on the results. The decile returns reported by CRSP were substituted for the market index in equation (21). The results indicate that, for the annual data, the significant relation between returns and lagged output holds across size portfolios, with the adjusted R^2 increasing from 0.05 to 0.23 as we move from small to large firms.

Such a secondary effect is not inconsistent with the implications of our theoretical model. It does, however, raise the issue of econometric exogeneity, which also can be addressed in a more general lag structure. (e) Finally, additional lags will allow for the autocorrelation observed in Fama and French (1988a), to the extent that it was not fully captured in the initial empirical specification.

To generalize equations (20) and (21), we use Hsiao's (1981) Final Prediction Error (FPE) criterion to determine the appropriate number of lagged observations of output and returns to be appended to the original specifications. The FPE statistic was examined over all possible combinations of up to three lags of each variable. The statistic was minimized where the output equation was extended to include one lag of returns, and the returns equation was extended to include two lagged values of returns. Additional lags of output were not significant in either equation.

Given that the extended output equation now includes the effect of returns on output, we can compare the generalized empirical counterparts of equations (21) and (22) to determine whether output still has a significant effect on returns after accounting for the effect of returns on output (i.e., the issue of reverse causality). The results of these experiments are presented in Panel A of Table III. Not surprisingly, lagged returns are found to have a significant effect on output, as suggested by the estimated coefficient on R_t appearing in the first row.

Row 2 of Table III presents the generalized test of the relation between returns and output. The trend and output variables remain significant, as before. Interestingly, the coefficients on lagged returns are negative, which, although consistent with the autocorrelation structure reported in Fama and French (1988a), is not consistent with the implied relation from row 1, where lagged returns are positive. Again, this suggests that the relation between output and returns is relatively complex. Although the adjusted R^2 is 0.34, we are cautious in interpreting this in the presence of lagged dependent variables and an atheoretical estimation strategy.

The issue of causality can be addressed by comparing row 2 with row 3. If the relation from returns to output is fully captured in the rational forecasts from the model in row 1, then the coefficient on z_t (z_t is now the rational forecast based on the extended model of row 1) should no longer be significant. In fact, the coefficient is positive as predicted and is still significant at a p-level of less than 0.001. This confirms that, even after accounting for the effects of returns on output, output is still useful in predicting subsequent returns. Once again, there is no significant difference between the restricted and unrestricted models.

Fama and French (1988b) show that dividend yield is a significant predictor for stock returns. To examine this variable in the context of our model, we consider the natural log of one plus the dividend yield.[12] Dividend yield is measured as the difference between the annual value-weighted CRSP stock returns reported with and without dividends. Panel B of Table III presents results for the regression of the dividend yield measure (DY) on returns and for the case where DY is appended to the return/output regressions of equations (21) and (22).

[12] To be consistent with our return measure, we used the log form of dividend yield. The results are virtually identical if we do not use the log transformation.

Table III

Empirical Tests of the Equilibrium Model Using Alternative Lag Structures and Return Specifications Including Dividend Yield

Each regression is based on 40 annual observations. t-Statistics appear in parentheses. R_t is one plus the return on the CRSP value-weighted market portfolio minus the change in the CPI. y_t is the Federal Reserve time series for industrial production. The reported R^2 is adjusted for degrees of freedom. In row 3, z_t is the rational forecast of the growth rate of y_{t+1} based on the predicted values from the regression in row 1 (i.e., the definition of z_t is extended to include R_t). In row 6, z_t is based on predicted values from the regression in row 1 of Table I. Dividend yield (DY_t) is measured as the natural log of one plus the difference between the CRSP value-weighted market portfolio returns including and excluding dividends.

Dependent Variable	Constant	Trend	$\ln y_t$	z_t	$\ln R_t$	$\ln R_{t-1}$	DY_t	$R^2_{adj.}$
Panel A: Alternative Lag Structures								
1. $\ln y_{t+1}$	0.812	0.009	0.769		0.134			0.985
	(1.98)	(1.85)	(6.36)		(2.61)			
2. $\ln R_{t+1}$	4.349	0.042	−1.225		−0.231	−0.311		0.340
	(3.88)	(3.34)	(−3.72)		(−1.64)	(−2.33)		
3. $\ln R_{t+1}$	−0.044			5.472	−0.936	−0.277		0.306
	(−0.95)			(3.75)	(−3.36)	(−2.05)		
Panel B: Tests Including Dividend Yield								
4. $\ln R_{t+1}$	−0.105						3.766	0.069
	(−1.13)						(1.97)	
5. $\ln R_{t+1}$	3.615	0.037	−1.042				0.564	0.185
	(2.57)	(2.47)	(−2.62)				(0.26)	
6. $\ln R_{t+1}$	−0.081			3.251			0.689	0.203
	(−0.95)			(2.71)			(0.33)	

The results in row 4 for the simple regression of DY_t on ln R_{t+1} are consistent with those of Fama and French (1988b), who report, for a similar regression, a slope of 4.4 and an R^2 of 0.09.[13] These estimates compare favorably with our estimated slope of 3.8 and adjusted R^2 of 0.07. However, in row 5, where the variables from equation (21) are included in the model (t and ln y_t), DY_t is no longer significant. Similarly, in row 6, DY_t is insignificant when z_t is included as an alternative measure of the expected growth of output. Thus, the dividend yield effect reported by Fama and French appears to be captured by our equilibrium model.

C. Pre-1947 Data

The use of post-1946 data in the sample is consistent with much of the empirical macroeconomic literature. The pre-1947 data are subject to several problems resulting from a number of unusual economic periods, including the Great Depression and World War II. During World War II the United States government attempted to control both interest rates and prices in addition to the government allocation of scarce resources. These government interventions resulted in substantial contamination of the return, Industrial Production Index, and CPI data. There was also a major revision in the Industrial Production Index, increasing the number of sampled industries by 75 percent beginning in 1947.[14] With these reservations, we tested the output/returns relation using pre-1947 data.

Industrial production data for the period 1899–1918 are taken from Fabricant (1940). Pre-CRSP stock returns and inflation data (1871–1925) are taken from Wilson and Jones (1987). To obtain an even longer period of observation, in a separate regression we substitute real GNP for the measure of production. Real GNP is measured for 1870–1929 using a simple average of the data reported in Romer (1989) and Balke and Gordon (1989). Subsequent real GNP data are taken from the *Survey of Current Business.*

The results for these tests are reported in Table IV. The relation between industrial production and returns is once again statistically significant; however, the WWII slope dummy indicates a complete reversal in the relation during the war period. This result is not unexpected, given the restrictions on consumption and the nature of production during the war. Using real GNP as an alternative measure of production allows the model to be tested over the 117-year interval from 1870 to 1987. The results for real GNP are almost identical to those for industrial production, with the hypothesized relation being significantly negative during the non-war years.

In summary, the empirical generalizations suggest that the relation between output and returns is relatively complex; however, these generalizations have no

[13] The comparison is made with their Table 3 results for the CRSP value-weighted index using real returns for the 1941–1986 period.

[14] Furthermore, the number of industries before 1940 varies between 22 and 81, which is less than half the number of industries after 1947. A detailed history of the Industrial Production Index that provides insights into these limitations appears in the Federal Reserve's *Industrial Production 1986 Edition.*

Table IV

Alternative Tests of the Relation between Output and Share Returns Including Pre-1947 Data

$$\ln R_{t+1} = b_0 + b_1 t + b_2 \ln y_t + b_3 d_t + b_4(d_t \ln y_t) + u_{t+1}$$

d_t represents a dummy variable that is set equal to one for the WWII period 1940–1947. Data sources for returns (R) and the two measures of output (y)—industrial production (*IPNSA*) and real GNP (*RGNP*)—are provided in the text.

				WWII Dummy			
Measure	b_0	b_1	b_2	b_3	b_4	N	$R^2_{adj.}$
$y_t = IPNSA$	0.183	0.013	−0.341	−3.027	0.919	88	0.078
1899–1987	(2.18)	(2.57)	(−2.59)	(−2.76)	(2.73)		
$y_t = RGNP$	1.850	0.013	−0.398	−3.061	0.937	117	0.056
1870–1987	(2.42)	(2.30)	(−2.33)	(−2.95)	(2.93)		

effect on the initial conclusions based on an empirical model explicitly derived from the theory. The basic relation between industrial output and share returns appears to be robust with respect to a variety of alternative measures and specifications.

V. Theoretical Robustness

As a logical extension to the extant literature, a parsimonious model was developed in Section I that explains the predictability of stock returns from a general equilibrium perspective. The simplicity and specific parameterization of the model allow a closed form solution that leads to three testable propositions. It is not clear whether inferences concerning the empirical results are limited to the specific theoretical model proposed or whether they are indicative of a more general mechanism underlying the predictability of asset returns. Certainly the basic intuition of our model is consistent with the general relations between consumption, production, and interest rates described in Breeden (1986).

This section of the paper examines the theoretical robustness of our three propositions and argues that the propositions represent economic forces more general than those implied by a strict interpretation of the simple model.[15] We will consider all three of the propositions derived from the theory.

(1) Predictability of Asset Returns

Essentially this proposition rests on two well established economic theses. The first is trend reversion in aggregate output, as most recently underscored by Cochrane (1988a). The second is the life cycle-permanent income (LCPI) hypothesis of Modigliani and Brumberg (1955) and Friedman (1957). Together,

[15] The equity premium puzzle of Mehra and Prescott (1985) has raised questions about the robustness of the entire class of consumption-based asset pricing models of which our model is a member. Recent work by Constantinides (1988) reconciles the equity premium puzzle with the consumption-based asset pricing model by introducing habit formation in preferences. Furthermore, Cochrane (1988b) accounts for the equity premium based on persistence in investment.

these relations directly imply our first proposition. The LCPI hypothesis relates aggregate savings to transitory changes in aggregate output/income. Because of trend reversion, transitory changes in aggregate output are predictable so that aggregate savings are predictable. As aggregate savings relate to real asset returns, these become predictable as well.

The above argument clearly does not rest on the specific assumptions of the model where a simple time-to-build effect causes trend reversion and where a representative consumer with logarithmic preferences smoothes consumption in accordance with the LCPI hypothesis. Instead, the predictability of asset returns is a consequence of two fundamental economic relations.

(2) The Negative Relation Between Future Asset Returns and Current Output

Real market returns are determined in essence by aggregate savings and aggregate investment. Provided that the aggregate investment schedule is relatively stable over time, the negative relation between asset returns for the upcoming period and current output is easily established based on the principles of trend reversion and the LCPI hypothesis. A level of current income above trend is considered transitory due to trend reversion. The LCPI hypothesis then implies a significantly higher level of current savings since agents are more eager to transfer purchasing power to the next period. As the aggregate savings schedule shifts to the right, equilibrium asset returns fall, establishing the proposition.

(3) Predictability of Asset Returns in an Efficient Market

Our third proposition presents a theoretical restriction implied by efficient use of information in predicting asset returns. This proposition is one illustration of the more general principle of market efficiency, which holds theoretically in our specific model. Returns are predictable even though no excess profit opportunities are available. The question arises of whether this inference is still valid in a more general context.

Rubinstein (1974) shows that the representative consumer with logarithmic preferences may be replaced by heterogeneous consumers that differ in the parameters of a generalized logarithmic utility function or in their expectations concerning relevant future variables, as long as the parameters or expectations average to those of the representative consumer. Breeden (1986) provides a similar result in the more general context of exponential utility. If consumers differ more fundamentally, a representative consumer model is not appropriate. One would expect, for instance, that less risk-averse consumers have a larger weight in determining risky asset returns as they are more willing to substitute consumption across time. (See Ingersoll (1987, pp. 217–219).) Even if some consumers were risk neutral, however, in shifting consumption over time, they would be bound by their lifetime budget constraint. Thus, again there is no reason that predictability in returns would disappear due to intertemporal "adjustments". The predictability is essentially due to changes in real returns over time caused by persistence of real shocks. Investors may adjust intertemporal consumption plans based on anticipated real returns, but there is no reason that the adjustment would cause predictable changes in returns to fully disappear.

In summary, the simplifying assumptions in the paper were made to keep the model tractable and to allow the general equilibrium model to be solved analytically. More fundamentally, the theory is based on a general stochastic growth model which incorporates trend reversion in aggregate output and consumption smoothing according to the LCPI hypothesis.

VI. Conclusions

We have attempted to bring together the growing body of literature on predictability of returns, intertemporal asset pricing, and macroeconomic fluctuations, in a simple equilibrium model relating output to consumption opportunities. As consumption opportunities vary following variations in aggregate output, investors are faced with a less smooth consumption pattern. In attempting to smooth consumption, investors adjust their required rate of return on stock. Because of this linkage, returns should be predictable to an extent related to the predictability of aggregate output. The corresponding change in the utility for consumption precludes opportunities for utility-increasing intertemporal transactions. Thus, we have a reasonable scenario in which predictability is consistent with efficient markets.

In spite of the relative simplicity of our model, the empirical results are consistent with each of the propositions generated from the theory. Additionally, the results appear to be robust across alternative modes of testing. As the predictability of returns is a direct function of the predictability of macroeconomic fluctuations, and given limited success in predicting these fluctuations, it would be expected that the observed predictability of returns should be somewhat low. Thus, the 20 percent level of predictability reported for the 1947–1987 period using annual returns and the 50 percent level of predictability for the overlapping 5-year horizon are relatively encouraging.

The generality of the basic model provides a foundation with the potential for a variety of extensions through explicit linkages between macroeconomic variables and share pricing. Extensions of the basic model could provide direct specifications of factors in arbitrage pricing or possibly greater insights into the predictability phenomenon. The temporal variability in the model might also provide partial explanations for temporal anomalies found in stock returns or the excess volatility of returns. Clearly the general relation proposed between production and returns is by no means restricted to common stock returns. The basic model provides a structured foundation from which more sophisticated macroeconomic models can be developed.

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