The Journal of Financial Research • Vol. XVIII, No. 1 • Pages 115–127 • Spring 1995

TIME-TO-BUILD EFFECTS AND THE TERM STRUCTURE

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Abstract

This paper shows that real macroeconomic variables have power to predict movements in the term structure of interest rates. This complements recent evidence that links the term structure to expected stock returns. We find that up to 86 percent of the variation in the term premia are due to the changes in macroeconomic variables. The predictive power can be attributed to the time-to-build effect of investments.

I. Introduction

This paper documents that term premia can be explained by contemporaneous and past real economic activity. Our study complements Harvey (1988, 1989, 1991, 1993). While Harvey focuses on the forecasting power of the term structure on economic growth, we focus on forecasting the term structure using macroeconomic variables.

We find that about 40 percent of the variation in term premia (in terms of the adjusted R^2) can be explained by a single index of leading economic indicators, and about 38 percent of the variation can be explained by a single index of capital investments. Furthermore, additional real macroeconomic variables, such as manufactured new orders for durable good orders, contracts and orders for plant and equipment, housing starts, and after-tax profits can explain up to 86 percent of the variations in the term structure. Using only past information, we can explain 62 percent with these macroeconomic variables, and 80 percent if the lagged term premium is included. Results also indicate that inflation has an insignificant role in determining the term structure, suggesting

We are grateful to Mark Ferris, Decalb Terrell, and especially Campbell Harvey for many helpful comments that substantially improved the paper.

that differences between short-term and long-term interest rates are due to real, not inflationary, phenomena.

We also provide a simple model to show why the term structure can be explained by (past) real macroeconomic variables. The intuition is that the term structure of interest rates is determined by the consumer's wealth and the productive capabilities of the economy (e.g., Cox, Ingersoll, and Ross (1985), Breeden (1986)). If production and capital stock are not instantaneously changed by today's investment, but are instead a function of investment projects initiated in periods past, this time-to-build effect must affect the term structure. Indeed, factories are not built nor do trees bear fruit in a day. As a result, current innovations that influence today's investment decision affect future changes in wealth and consumption because of the production lag. Therefore, incorporating time-to-build effects into the determination of the term structure suggests that it is possible to forecast the term structure by using past real macroeconomic variables that take time before they can influence consumption and gross national product (GNP) and therefore the term structure.

Time-to-build effects are also consistent with the observation that stock market prices lead GNP (Fama (1990), Barro (1990)) as well as the production capital asset pricing model (CAPM) of Cochrane (1991). Balvers, Cosimano, and McDonald (1990) present a model where stock prices are forecastable because of the time-to-build effect of investment. Our study shows that the term structure is also forecastable because of the time-to-build effect of investment.

II. Time-to-Build Effects and the Term Structure

Traditionally, models concerning investment and production view current asset prices as "sufficient statistics" for current investment, where investment decisions are determined by comparing current asset prices with current marginal costs. However, Kydland and Prescott (1982) demonstrate that the sufficiency of current prices for investment rests on the assumption that short-run and long-run investment supply coincide. However, if short-run supply is less elastic than long-run supply because it takes time to move factors of production between industries, current prices are no longer sufficient for investment decisions. Indeed, Topel and Rosen (1988), among others, find that investment returns differ between short run and long run. Summers (1981) shows that both the current and past values of Q investment affect manufacturing.

Since the term structure reflects the endogenous intertemporal process of wealth accumulation and consumption possibilities (Cox, Ingersoll, and Ross (1985)), it not only describes the evolvement of these conditions in the future, but it can also be predicted itself by identifying the underlying shocks and productive technologies that produce these conditions.

If investment takes time to build, changes in the marginal utility of consumption over time will be a function of past investment decisions, since these decisions take time to build and affect production and wealth and, ultimately, consumption. Consumption possibilities are not instantaneously available as a product of today's investment, but are instead a function of former investments. The term structure thus embodies past decisions; for instance, to obtain utility from a tree's fruit from t to T, one must plant a tree $t-n$ periods ago if the tree takes n periods to bear fruit. And since the term structure at time t is a product of decisions made several periods ago, it can be predicted. Events that influence current investment decisions will eventually be embodied in the future term structure. Hence, current news in period t can be used to forecast the term structure at time t+1. As a result, the return on long-term bonds lags current information.

To understand the time-to-build effect, we consider a simple term structure model adapted from Sargent (1987, pp. 102–5). The economy is identical to the one in Lucas (1978). In particular, there is a single representative agent with preferences $u(c_t)$. To smooth the agent's consumption stream, there are markets for one- and two-period riskless bonds, where the gross interest rates R_{1t} and R_{2t} are known with certainty. The agent's income is derived from the output process y_t, which is the returns from investment done in the previous period. The model differs from Sargent's model in that we specify the evolvement of output by assuming investment has a one-period gestation period before it yields this output: $y_t = h(i_{t-1})$, where $h(\bullet)$ is the production function. For simplicity, capital is assumed to depreciate each period; hence, the income y_t is solely a function of last period's investment. Investment i_t follows a Markov process, with transition probabilities given by $\text{prob}\{i_{t+1} \le x' \mid i_t = x\} = F(x', x)$. Accordingly, the representative agent maximizes his/her utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{1}$$

subject to the condition that

$$c_t + L_{1t} + L_{2t} \le y_t + L_{1t-1}R_{1t-1} + L_{2t-2}R_{2t-2} \tag{2}$$

where L_{jt} is the amount loaned for j periods at time t, and R_{jt} is the real gross interest rate for j-period loans. Following the standard solution approach as discussed in Sargent (1987), we obtain the first-order conditions:

$$R_{1t}^{-1} = E_t\beta\frac{u'(y_t + 1)}{u'(y_t)}, \quad R_{2t}^{-1} = E_t\beta^2\frac{u'(y_t + 2)}{u'(y_t)} \tag{3}$$

where we use the general equilibrium property that all income is consumed. For simplicity, we assume log utility, $u(c) = \ln c$, $h(i_{t-1}) = i_{t-1}$, and the evolution of investment is governed by the following stochastic process:

$$i_t = \rho i_{t-1}\theta_t, \quad \rho > 0 \tag{4}$$

where θ_t is a sequence of independent and identically distributed (iid) shocks that are known at time t ($\theta_t \geq 1$ with probability one). Then, the first-order conditions yield:

$$R_{1t}^{-1} = \frac{\beta}{\rho\theta_t}, \quad R_{2t}^{-1} = \frac{\beta^2}{\rho^2\theta_t}\left[E_t\frac{1}{\theta_{t+1}}\right] \tag{5}$$

Equation (5) differs from the traditional term structure derivation (see Sargent (1987)) since the shock to the production function θ_t is known at time t, albeit the shock in the following period is unknown. Traditionally, the interest rate R_{1t} is the evolvement of wealth (output) from period t to t+1, and thus depends on the expectations of how this wealth is changing because of shocks. However, when capital takes time to build, the shock that affects investment today and wealth tomorrow occurs in periods past and is known at time t. The interest rate R_{1t} thus describes the evolvement of consumption possibilities and wealth with certainty. Long-term interest rates, however, do not describe the evolvement of wealth with certainty since this process possesses a greater interval than the known production process. However, the long-term rate includes θ_t; hence, part of its return is forecastable from today's shocks.

The expression $TP_t = R_{1t}^{-1} - R_{2t}^{-1}$ is the (real) yield premium or the yield spread on two bonds of different maturities (if necessary, the model easily accommodates bonds of any fixed maturities). In our study, we consider it also as the holding-period return spread on the two bonds, or the term premia (the latter term is used throughout the rest of this study). By (5), we have:

$$TP_t = R_{1t}^{-1} - R_{2t}^{-1} = \frac{\beta}{\rho\theta_t} - \frac{\beta^2}{\rho^2\theta_t}\left[E_t\frac{1}{\theta_{t+1}}\right] \tag{6}$$

Simple comparative statics show that as long as $\rho > \beta$,

$$\frac{\partial \mathrm{TP}_t}{\partial \theta_t} < 0 \tag{7}$$

so that short-term rates will respond to current shocks more than long-term rates.

The term premia are determined by shocks θ_t and θ_{t+1}. If we assume there is a one-period lag in the production function, it will be affected by θ_{t-1} as well. As a result, past information pertinent to the macroeconomy has forecasting power on the term premia and their changes over time.

In the above model, to emphasize the time-to-build effect, we assume the output process depends only on past investments, so that the current real interest rate can be known (see (5)), a unique case. A more general case would be that the output process depends on both the past and current investments, say $y_t = h(i_{t-1}, i_t) = i_{t-1} + i_t$, then we must have

$$R_{1t}^{-1} = \frac{\beta(1 + \rho\theta_t)}{\rho\theta_t E_t(1 + \rho\theta_{t+1})} \tag{8}$$

Now, the current real interest rate depends not only on the current shocks in the economy, but also on the expectation of future shocks. Despite the unknown nature of the current rate, past information pertinent to the macroeconomy has forecasting power on the term premia and their changes over time.

The first-order conditions (3) are related to those of the model presented by Harvey (1988),

$$\log E_t\left[\beta^j\left[\frac{C_t}{C_{t+j}}\right]^{\alpha} R_{jt}\right] = E_t\left[\log\left[\beta^j\left[\frac{C_t}{C_{t+j}}\right]^{\alpha} R_{jt}\right]\right] + \tfrac{1}{2}\mathrm{var}_t\left[\log\left[\beta^j\left[\frac{C_t}{C_{t+j}}\right]^{\alpha} R_{jt}\right]\right] = 0 \tag{9}$$

where α is the relative risk-aversion parameter. The right-hand side of (9) can be rearranged to be:

$$E_t\Delta C_t = \frac{j}{\alpha}\log\beta + \frac{v_j}{2\alpha} + \frac{1}{\alpha}E_t[\log R_{jt}] \tag{10}$$

where ΔC_t is the log consumption growth rates ($\Delta C_t = \log(C_{t+j} / C_t)$), and v_j is the conditional variance term in (9) assumed constant. Based on (10), Harvey (1988) finds the term structure contains information that can be used to forecast consumption growth. Harvey (1993) further finds the out-of-sample forecast evidence over the most recent business cycle impressive; almost 50 percent of the variance in real gross domestic product growth could be explained, and the forecasts were not beaten by any commercially available projections. Unlike Harvey, we use the macroeconomic variables to forecast the term structure. Notice that (9) can also be rearranged as:

$$E_t[\log R_{jt}] = \alpha E_t \Delta C_t + j\rho - v_j/2 \tag{11}$$

where ρ is the consumer's rate of time preference ($\rho = -\log \beta$). This implies that the term structure is determined, among others, by the conditional expectation of real consumption growth. As a result, related macroeconomic variables will predict the term structure. However, the key difference between (11) and (5) is that we, following Kydland and Prescott (1982), identify the time-to-build effects as the main source of forecastability.

III. Explaining the Term Structure of Interest Rates

Data

Quarterly data for all economic variables are obtained from the Citibase tapes from the first quarter of 1953 to the second quarter of 1991 (168 observations), except for the term structure, which is available from the first quarter of 1954. For simplicity, we adopt the approach of Estrella and Hardouvelis (1991) and use only two interest rates to construct the term premium: the ten-year Treasury maturity and the three-month Treasury bill. Both rates are annualized. The term premium is the difference between these two rates.

We use two sets of variables to reflect the time-to-build effects. The first set is a single variable, of which we have two choices. The first is LD, the government's composite index of eleven leading indicators. The second choice is LC, the government's composite index of capital investment commitments. The second set consists of individual macroeconomic variables chosen because they are components of the above indices and because we believe them to have time-to-build components. They are MD: the value of new manufactured orders for durable good industries in constant 1982 dollars; MC: contracts and orders for plant and equipment in constant 1982 dollars; HS: the number of new private housing starts; PR: after-tax corporate profits in constant 1982 dollars; DV: the annualized dividend yield for the S&P common stock composite; and π: theseasonally adjusted annualized consumer price index. The means, standard deviations, and autocorrelations of the quarterly data are reported in Table 1.

TABLE 1. Summary Statistics.

Name[a]	Obs.	Mean	Std.	ρ_1	ρ_2	ρ_3	ρ_4	ρ_{12}
TP	153	1.19	1.10	0.84	0.66	0.54	0.41	-0.11
LD	166	8.50	3.10	0.98	0.96	0.94	0.92	0.75
LC	148	1.03	0.67	0.97	0.93	0.89	0.84	0.61
MP	168	1.86	0.75	0.97	0.95	0.92	0.88	0.64
MC	168	0.61	0.17	0.98	0.95	0.93	0.91	0.74
HS	168	1.52	0.31	0.90	0.76	0.58	0.43	-0.33
PR	168	0.78	0.49	0.97	0.94	0.90	0.90	0.73
DV	168	1.11	0.83	0.96	0.92	0.89	0.86	0.61
π	168	0.59	0.66	0.84	0.75	0.87	0.73	0.44

Notes: Tables 1 provides the means, standard deviations, and autocorrelations. The data are quarterly from 1950:1 to 1991:2, except for the term structure and index of leading capital commitments, which is from 1953:1 to 1991:2 and 1950:1 to 1987:1, respectively.

[a]TP is the difference between the ten-year Treasury bond yield and the three-month Treasury maturity (the term premia) multiplied by 100. LD is the composite of leading indicators. LC is the index of leading capital commitments. MP is contracts and orders for plant and equipment in 1982 dollars. MC is the value of manufactured new orders for consumer goods and materials in 1982 dollars. HS is the number of new private housing starts in millions of dollars. PR is corporate profits after taxes. DV is the annualized dividend yield for the S&P common stock composite. π is the consumer price index.

Empirical Results

We use the above economic variables to explain the variations of the term premium. Following the practice of many empirical studies (e.g., Fama (1990), Roll (1988)), we measure the explanatory power by the adjusted R^2 of regressions on the economic variables.

Consider first the regression of the term premium on ΔLD, where Δ is the difference operator:

$$TP_t = \alpha + \beta_1 \Delta LD_{t-1} + \beta_2 \Delta LD_{t-4} + \beta_3 \Delta LD_{t-8} + \beta_4 \Delta LD_{t-12} + \varepsilon_t \qquad (12)$$

where TP_t and other variables are overlapping quarterly observations (Fama (1990)). The leading economic indicators and all other macroeconomic variables are log-differenced to eliminate their nonstationarity. The t-statistic is adjusted for heteroskedasticity (Hansen (1982)).

Results for regression (12) and the related regressions are presented in Table 2. The contemporaneous effect of the leading indicator variable has only a 31 percent predictive power. The inclusion of lag effects of the past period, last year, and last two years raised the R^2 to 40 percent. F-tests for the inclusion of past information could not be rejected at the 1 percent level.

Following Harvey (1988), we examine an out-of-sample forecast of the term premium by the leading indicator. Equation (8) is initially estimated with

TABLE 2. Term Premia Regressed on Index of Leading Economic Indicators.

$$TP_t = \alpha + \beta_1\Delta LD_t + \beta_2\Delta LD_{t-1} + \beta_3\Delta LD_{t-4} + \beta_4\Delta LD_{t-8} + \beta_5\Delta LD_{t-12} + \gamma_1\pi_{t-4} + \gamma_2 TP_{t-4} + \varepsilon_t$$

Variables[a]	EQ1[b]	EQ2	EQ3	EQ4	EQ5	EQ6
Constant	3.70	3.13	2.61	2.24	2.78	0.24
	(0.30)[c]	(0.41)	(0.51)	(0.40)	(0.44)	(0.15)
ΔLD_t	0.40	0.77	0.80	0.63		
	(0.05)	(0.11)	(0.11)	(0.11)		
ΔLD_{t-1}		-0.41	-0.41	-0.51		-0.34
		(O.11)	(0.11)	(0.10)		(0.11)
ΔLD_{t-4}		0.25	0.26	-0.03	-0.30	0.29
		(0.06)	(0.06)	(0.07)	(0.06)	(0.14)
ΔLD_{t-8}		0.04	0.04	-0.12	-0.18	-0.20
		(0.05)	(0.05)	(0.05)	(0.05)	(0.11)
ΔLD_{t-12}		-0.06	-0.07	-0.14	-0.21	0.29
		(0.05)	(0.05)	(0.05)	(0.05)	(0.09)
π_{t-4}			0.17	-0.06		
			(0.10)	(0.24)		
TP_{t-4}				0.60	0.80	0.87
				(0.11)	(0.08)	(0.05)
R^2	0.31	0.40	0.41	0.54	0.43	0.74

[a]TP is the term premia and the difference between the ten-year Treasury bond yield and the three-month Treasury maturity. LD is the composite index of eleven leading indicators; ΔLD is the series differenced. π is the consuer price index.
[b]EQ1 uses only past infomation to predict the term structure, and EQ5 uses past quarterly data from all variables.
[c]The standard errors of the parameter estimates are adjusted for heteroskedasticity (Hansen (1982)).

T_1 observations, which are then used to predict the values of the term structure in the remaining T_2 data points. With one year remaining, the Chow forecast test and the likelihood ratio test for the forecastability have p-values of 12 percent and 9 percent, respectively. We cannot reject the null at the usual 5 percent level. With two and three years remaining, the p-values are 34 percent and 23 percent, and 64 percent and 54 percent, respectively. Hence, it appears that the leading indicator performs well, even out of sample.

As an alternative to the regression model (12), consider a vector autoregressive (VAR) framework. In a fourth-order VAR specification, the lagged leading indicator significantly increases the explanatory power of the model. The F-statistic used to test whether all of the coefficients of the indicator are zero is 6.7, with p-value of 1 percent, and all four terms are significant at the 5 percent level. The leading indicators compose 20 percent of the variance decomposition of the term structure. When the leading indicator is replaced by housing starts, profits, and construction orders, we have similar F-statistics and variance decomposition for these variables, approximately 20 percent.

Traditionally, expectations of inflation are thought to be a significant predictor of the term premium (see Modigliani and Shiller (1973)). To examine the effects of inflation on the term premia, we add a lagged inflation variable to the above equation (12). Since expected inflation is unknown, the previous year's inflation is used to proxy for the expected inflation based on the simple expectation hypothesis that the best predictor of current and future inflation is its most recent value. However, the expectation hypothesis is not the best model to obtain the expected inflation. We choose it to simplify the presentation. We also test the effects of alternative lagged inflation and find them be insignificant and have no additional explanatory power. Results thus show that past real macroeconomic factors, and not inflationary factors, influence and predict the contemporaneous term premia.

We then test the effects of lagged term premia in period $t-4$ (to avoid overlapping observations). Lagged term premia have a significant effect and raise the explanatory power to 54 percent. Moreover, despite including the lagged term premium, leading indicators from the previous two and three years are significant at the 1 percent level.

As a comparison, the term structure is tested on quarterly data without the moving average component. The R^2 for the leading indicator in $t-1$ is 11 percent, and in $t-12$ is 13 percent. These results also indicate that past macroeconomic variables have important current information. For the full model, past macroeconomic variables explain 25 percent of the term premium. Inclusion of last period's term premium raises it to 74 percent, where the R^2 for the lagged term premium by itself is 68 percent. Last period, last year, and two years previous are significant predictors of the current term structure at the 5 percent level. F-tests for the inclusion of past information thus could not be rejected at the 1 percent level.

As an alternative to the LD case, consider the regression of the term premium on the government's index of leading capital commitments:

$$TP_t = \alpha + \beta_1 \Delta LC_{t-1} + \beta_2 \Delta LC_{t-4} + \beta_3 \Delta LC_{t-8} + \beta_4 \Delta LC_{t-12} + \varepsilon_t \qquad (13)$$

The results are provided in Table 3. The contemporaneous effect of the leading capital commitments explains 27 percent of the variation in term premia. When the past-period, one-year, two-year, and three-year lags are included, the R^2 increases to 38 percent. Inclusion of last year's inflation has no significant explanatory power; other inflationary specifications similarly are insignificant. Inclusion of last year's term structure is significant and raises the R^2 to 68 percent; current and all past capital commitment variables are significant at the 1 percent level. When only lagged information is tested, 63 percent of the term premium could be explained. The results indicate that past real investment

TABLE 3. Term Premia Regressed on Index of Capital Investment.

$$TP_t = \alpha + \beta_1 \Delta LC_t + \beta_2 \Delta LC_{t-1} + \beta_3 \Delta LC_{t-4} + \beta_4 \Delta LC_{t-8} + \beta_5 \Delta LC_{t-12} + \gamma_1 \pi_{t-4} + \gamma_2 TP_{t-4} + \varepsilon_t$$

Variables[a]	EQ1[b]	EQ2	EQ3	EQ4	EQ5	EQ6
Constant	4.25	4.60	4.36	1.68	1.86	-0.34
	(0.60)[c]	(0.29)	(0.42)	(0.41)	(0.36)	(0.83)
ΔLC_t	0.60	0.64	0.67	0.62		
	(0.08)	(0.17)	(0.17)	(0.13)		
ΔLC_{t-1}		-0.26	-0.26	-0.52		-0.58
		(0.17)	(0.17)	(0.13)		(0.18)
ΔLC_{t-4}		-0.08	-0.07	-0.43	-0.60	0.34
		(0.10)	(0.10)	(0.08)	(0.07)	(0.23)
ΔLC_{t-8}		-0.22	-0.22	-0.31	-0.37	-0.22
		(0.08)	(0.08)	(0.06)	(0.06)	(0.20)
ΔLC_{t-12}		-0.35	-0.36	-0.30	-0.35	0.48
		(0.08)	(0.08)	(0.06)	(0.06)	(0.15)
π_{t-4}			0.09	0.03		
			(0.12)	(0.09)		
TP_{t-4}				0.73	0.74	0.83
				(0.07)	(0.07)	(0.05)
R^2	0.27	0.38	0.38	0.68	0.63	0.74

[a]TP is the term premia and the difference between the ten-year Treasury bond yield and the three-month Treasury maturity. LC is the composite index of capital investment commitments; ΔLC is the series differenced. π is the consumer price index.
[b]EQ1 uses only past infomation to predict the term structure, and EQ5 uses past quarterly data from all variables.
[c]The standard errors of the parameter estimates are adjusted for heteroskedasticity (Hansen (1982)).

variables have predictive and explanatory power, and that inflation has no additional explanatory power.

For comparison, the term structure is regressed on nonadjusted quarterly data. The R^2 is 25 percent for past macroeconomic variables, and increases to 74 percent when the lagged term premium is included. Similar to before, an F-test for the inclusion of lagged capital commitments could not be rejected at the 1 percent confidence level.

Consider now the regression of the term premium on individual macroeconomic variables. We regress the term premium on these contemporaneous values:

$$TP_t = \alpha + \beta_1 MC_t + \beta_2 PR_t + \beta_3 HS_t + \beta_5 DV_t + \varepsilon_t \tag{14}$$

and obtain an R^2 of 37 percent. This suggests the macroeconomic variables possess explanatory power. However, this power is less than when the time-to-build effects are incorporated into the analysis. To use the time-to-build effects, we include the lagged values of the variables in the regression. We first add one lagged value of each of the variables to the regression. When a lag of length four is chosen, which represents information from one year ago, we find that the R^2 increases significantly to 63 percent. The R^2 of only past information is 48 percent, and thus explains more than current information. When a lag length of eight is added, the R^2 increases to 76 percent. When three years of data are used, the R^2 increases to 86 percent. The F-test for the inclusion of either four-, eight-, or twelve-lag values cannot be rejected at the 1 percent significance level. Additionally, when using only past information of one year, two years, and three years, the R^2 is 62 percent. The results suggest that contemporaneous and past values contain important information about the term premium, where past information is even more important than current information. As a comparison, when one- and two-year lags are included, quarterly data with no moving average yield an R^2 of 48 percent.

One problem with the above approach is that it includes all variables regardless of whether they are significant. Exclusion of insignificant variables and contemporaneous variables, and testing of variables in $t-1$ yield the following regression:

$$TP_t = \alpha + \beta_1 MC_{t-12} + \beta_2 HS_{t-4} + \beta_3 HS_{t-8} + \beta_4 PR_{t-4} + \beta_5 PR_{t-12} + \beta_6 DV_{t-1} + \varepsilon_t \qquad (15)$$

The results are reported in Table 4; the R^2 is 81 percent. If last year's inflation on the term structure is additionally tested, the R^2 remains unchanged and inflation has no significant effect. Similarly, the lagged term premium is also tested and found to have no significant effect. This indicates that past macroeconomic activity, not inflationary or lagged term premia, explains the term premium. If only past information of a year or more is used, and thus the $t-1$ term is dropped, the R^2 is 60 percent. Using only quarterly data, the R^2 for past macroeconomic variables is 57 percent, and rises to 75 percent when the lagged term premium is included. Similar to before, although the lagged term premium variable is highly significant, past macroeconomic variables still possess additional significant explanatory power and can be rejected at the 1 percent level.

Our results show that even in a simplified model, past real macroeconomic variables possess significant predictive power for the term premium. Further, exercises show that the regression results do not depend on the exact time-to-build choice; the gestation period can be arbitrarily chosen. The regressors in (15) are representative of variables that contain information in determining the future outcome of the production process. For instance, other variables such as the government's leading indicator for capital investment or inventory investment (Citibase variables 914 and 915) are also significant

TABLE 4. Term Premia Regressed on Individual Macroeconomic Variables.

$$TP_t = \alpha + \beta_1 \Delta MC_{t-12} + \beta_2 PR_{t-4} + \beta_3 PR_{t-12} + \beta_4 HS_{t-8} + \beta_5 DV_{t-1} + \gamma_1 \pi_{t-4} + \gamma_2 TP_{t-4} + \varepsilon_t$$

Variables[a]	EQ1	EQ2	EQ3	EQ4	EQ5
Constant	1.95	0.91	0.73	1.95	0.83
	(1.29)[b]	(0.21)	(0.22)	(0.49)	(0.55)
MC_{t-12}	1.15	1.12	1.17	0.90	0.25
	(0.06)	(0.06)	(0.09)	(0.08)	(0.09)
PR_{t-4}	-0.90	-0.87	-0.97	-1.33	-0.78
	(0.17)	(0.20)	(0.20)	(0.28)	(0.24)
PR_{t-12}	-4.32	-4.20	-4.11	-2.88	-0.71
	(0.34)	(0.31)	(0.46)	(0.44)	(0.40)
HS_{t-4}	-0.89	-0.97	-0.97	-0.53	-0.29
	(0.17)	(0.18)	(0.21)	(0.23)	(0.19)
HS_{t-8}	-2.10	-2.05	-1.53	-1.96	-0.41
	(0.19)	(0.21)	(0.26)	(0.24)	(0.24)
DV_{t-1}	0.67	0.71	-0.70	0.57	0.21
	(0.06)	(0.08)	(0.09)	(0.09)	(0.08)
π_{t-4}		-0.22	-0.35	-0.31	
		(0.19)	(0.21)	(0.18)	
TP_{t-4}			0.01		0.66
			(0.07)		(0.07)
R^2	0.81	0.81	0.81	0.57	0.75

[a]TP is the term premia and the difference between the ten-year Treasury bond yield and the three-month Treasury maturity. MC is the value of manufactured new orders for consumer goods and materials in 1982 dollars. HS is the number of new private housing starts in millions of dollars. PR is corporate profits after taxes. DV is the annualized dividend yield for the S&P common stock composite. π is the consumer price index.
[b]The standard errors of the parameter estimates are adjusted for heteroskedasticity (Hansen (1982)).

predictors of term premia. The high R^2 suggests the importance of the time-to-build effects in determining the term structure of interest rates.

IV. Conclusion

In this paper we examine the effects of past real macroeconomic variables on the term structure, showing that the term structure is predictable from past economic activity because of a time-to-build effect of investment activity. We find that about 40 percent of the variation in term premia (in terms of the adjusted R^2) can be explained by a single index of leading economic indicators, and about 38 percent of the variation can be explained by a single index of capital investments. Furthermore, additional real macroeconomic variables, such as manufactured new orders for durable good orders, contracts and orders for plant and equipment, housing starts, and after-tax profits, can explain up to 86 percent of the variations in term premia. Using only past information, we can explain 62 percent with these macroeconomic variables, and 80 percent when the lagged term premium is included. Our results indicate that multifactor pricing models should be considered for studying the term structure as well as for valuing interest rate derivatives where some or all of the factors are identified as past real macroeconomic variables.

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