Expected Returns and Habit Persistence

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Using a consumption-based asset pricing model with infinite-horizon nonlinear habit formation, Campbell and Cochrane (1999) show that low consumption in surplus of habit should forecast high expected returns. This article argues that the finite-horizon linear habit model also implies an inverse relation between expected returns and surplus consumption. This article also presents empirical evidence, which indicates that expected returns on stocks and bonds vary with surplus consumption implied by the habit models. The volatility of returns and the reward to volatility are also related to surplus consumption. However, less than 30% of the predictable variation of expected returns, using standard lagged information variables, is attributed to surplus consumption.

One of most challenging tasks for financial economists is to explain the dynamic behavior of asset returns using aggregate consumption data. Since the time-separable utility model cannot even fit the unconditional moment of the equity premium, a great deal of empirical work has used more general utility specifications, such as habit formation, to study asset returns. In some studies, habit is assumed to last for 1 month [e.g., Hansen and Jagannathan (1991)], 1 quarter, or 1 year [Ferson and Constantinides (1991), Ferson and Harvey (1992)]. They find that the habit model produces a better fit than the time-separable utility model. In other studies, habit is assumed to be a linear or nonlinear function of an infinite history of past consumption. For example, Heaton (1995) finds that a model with infinite-horizon linear habit formation can predict the autocorrelation pattern of stocks and Treasury bills, but the model cannot at the same time fit the equity premium and the volatility of stock returns. Campbell and Cochrane (1999; hereafter CC) develop an infinite-horizon nonlinear habit model to explain the cyclical variation in expected returns and volatility.

This literature demonstrates that a portion of time-varying expected returns may be explained by asset pricing models with habit formation. In the habit-based model, each agent's period utility function increases with consumption relative to habit. In particular, CC (1999) find that a low level of consumption

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in surplus of habit should forecast high expected returns because risk aversion is inversely related to surplus consumption. However, their study leaves open the interesting question of the empirical relation between stock returns and surplus consumption. The goal of this article is to document to what extent time variation in expected returns can be explained by the cyclic variation in surplus consumption.

I first investigate the theoretical relation between expected returns and surplus consumption, and argue that habit models generally imply an inverse relation between expected returns and surplus consumption. Thus the theoretical prediction is not limited to the model studied in CC (1999). I then examine the empirical relation between expected returns and measures of surplus consumption and the economic significance of the relation by estimating the portion of time variation in the expected returns on stocks and bonds that is associated with cyclical movements in surplus consumption. The empirical results indicate that the long-horizon linear habit model performs better than the short-horizon model and a 5-year linear model fits the countercyclical pattern in expected returns similar to the nonlinear model of CC (1999). When habit is assumed to slowly adjust to a long history of past consumption, the relation between expected returns and surplus consumption is statistically significant for both the linear and nonlinear habit models.

Recent studies document that the price of risk in the stock market is time varying and countercyclical [see, e.g., Harvey (1989,1991), Kandel and Stambaugh (1990,1991), Ferson and Harvey (1991,1993a), Bekaert and Harvey (1995), and He et al. (1996)]. Consistent with this evidence, I find a statistically significant and negative relation between the reward:volatility ratio and surplus consumption. This implies that time variation in the price of risk is explained in part by changing surplus consumption. I also find that for common stocks, the volatility of returns is positively related to surplus consumption, in contradiction to the countercyclical volatility produced by CC (1999) using simulated data. Together with the evidence that expected returns are inversely related to surplus consumption, the negative relation between expected returns and the volatility in the stock market documented in the literature [e.g., Campbell (1987), Glosten, Jagannathan, and Runkle (1993), and Whitelaw (1994)] can be partly attributed to time-varying surplus consumption. Decreases in expected returns associated with increases in the volatility of returns near the peaks of the business cycle can be explained by decreases in the reward to volatility as a result of decreasing risk aversion at these times. However, less than 30% of the predictable variation of expected returns, using standard lagged information variables, is attributed to surplus consumption.

The rest of the article is organized as follows. In Section 1 I outline the implications of habit models for time-varying expected returns. In Section 2 I describe the data sources. In Sections 3 and 4 I present empirical results of estimating the models. In Sections 5 I evaluate the robustness of the results to alternative econometric specifications. Section 6 concludes.

1. The Model

1.1 Preferences

A representative investor is assumed to maximize the objective function

$$\mathrm{E}\sum_{t=0}^{\infty}\delta^{t}\frac{(C_{t}-X_{t-1})^{1-\gamma}-1}{1-\gamma}, \tag{1}$$

where γ is the utility curvature parameter, δ is the subjective discount factor, C_t is the flow of consumption at time t, and X_{t-1} is the level of habit, conditional on information as of time $t-1$. As in Abel (1990) and CC (1999), the habit level X_{t-1} is taken to be exogenous by the representative agent. Exogenous habit is said to be "external." Under external habit formation, Equation (1) implies that the intertemporal marginal rate of substitution or the stochastic discount factor at time t is

$$M_{t}=\delta\left(\frac{C_{t}-X_{t-1}}{C_{t-1}-X_{t-2}}\right)^{-\gamma}. \tag{2}$$

The marginal rate of substitution in Equation (2) is positive if $X_{t-1} < C_t$.

Unlike the ratio-based model of Abel (1990), the representative agent's period utility in Equation (1) is a function of the difference between consumption and habit $(C_t - X_{t-1})$, following Sundaresan (1989) and Constantinides (1990), among others. As CC (1999) point out, the advantage of the difference-based model over the ratio-based model is that the risk aversion in the difference-based model varies with the level of consumption relative to habit.

1.2 A consumption-based CAPM under habit formation

Let R_{it} denote one plus the rate of return on asset i from times $t-1$ to $t(i = 1, 2, \ldots, n)$. For M_t given by Equation (2), the return satisfies the Euler equation of the following form:

$$1=\mathrm{E}_{t-1}\left[\delta\left(\frac{C_{t}-X_{t-1}}{C_{t-1}-X_{t-2}}\right)^{-\gamma}R_{it}\right], \tag{3}$$

where E_{t-1} denotes expectation conditional on information known as of time $t-1$.

Let $C_t^e = C_t - X_{t-1}$ denote consumption in excess of habit. Assume that the joint distribution of R_{it} and C_t^e is conditionally lognormal and let lowercase letters denote the natural logarithms of corresponding uppercase letters. Then Equation (3) implies that the expected return in excess of the riskfree rate which is known as of time $t-1$ satisfies

$$\mathrm{E}_{t-1}[r_{it}]-r_{f,t-1}=-(1/2)\sigma_{i,t-1}^{2}+\gamma\,\mathrm{cov}_{t-1}(r_{it},c_{t}^{e}). \tag{4}$$

The variance term on the right-hand side of Equation (4) is a Jensen's inequality term. This equation implies that the expected excess return on any asset is related to its covariance with c_t^e in the habit model. The time-series and cross-sectional properties of expected excess returns on assets depend on their conditional covariances with c_t^e.

Let

$$S_t \equiv \frac{C_t^e}{C_t} = 1 - \frac{X_{t-1}}{C_t} \tag{5}$$

denote the surplus consumption ratio. Under the restriction $X_{t-1} < C_t, 0 < S_t < 1$. CC (1999) argue that S_t should increase with consumption and move with the business cycle. They show that the representative agent's risk aversion is inversely related to S_t. As a result, expected returns and the price of risk in the aggregate stock market should vary with the surplus consumption ratio.

Let s_t denote the log surplus consumption ratio. Then Equation (5) implies $c_t^e = c_t + s_t$. The conditional covariance of r_{it} with c_t^e on the right-hand side of Equation (4) is

$$\text{cov}_{t-1}(r_{it}, c_t^e) = \text{cov}_{t-1}(r_{it}, c_t) + \text{cov}_{t-1}(r_{it}, s_t). \tag{6}$$

From Equation (5), s_t is a function of $c_t : s_t = s(c_t)$. Assume that consumption C_t is conditionally lognormal. Then Stein's lemma implies that the second covariance on the right-hand side of Equation (6) is

$$\text{cov}_{t-1}(r_{it}, s_t) = \text{E}_{t-1}\left[\frac{\partial s_t}{\partial c_t}\right]\text{cov}_{t-1}(r_{it}, c_t) = \lambda_{t-1}\text{cov}_{t-1}(r_{it}, c_t), \tag{7}$$

where

$$\lambda_{t-1} \equiv \text{E}_{t-1}\left[\frac{\partial s_t}{\partial c_t}\right] \tag{8}$$

is the conditional sensitivity of surplus consumption (ratio) to consumption.[1]

Substituting Equations (6) and (7) into Equation (4) yields

$$\text{E}_{t-1}[r_{it}] - r_{f,t-1} = -(1/2)\sigma_{i,t-1}^2 + [\gamma(1 + \lambda_{t-1})]\text{cov}_{t-1}(r_{it}, c_t). \tag{9}$$

Equation (9) is consumption-based asset pricing model with the time-varying price of risk, $\gamma(1+\lambda_{t-1})$, which is positively related to the sensitivity function

[1] In CC (1999), the period t utility is a function of $C_t - X_t$ and the surplus consumption ratio is $S_t = 1 - X_t/C_t$, where X_t depends on C_t. It is straightforward to see that Equation (7) remains valid in this case.

λ_{t-1}. If λ_{t-1} is negatively related to s_{t-1}, as in CC (1999), a low surplus consumption ratio should forecast high expected returns.

1.3 Specification of linear habit

In the linear habit model, the habit level X_{t-1} is proportional to a weighted average of past consumption expenditures:

$$X_{t-1} = \alpha\left(\frac{1-\varphi^m}{1-\varphi^{Jm}}\right)\sum_{j=1}^{J}\varphi^{(j-1)m}C_{t-j}. \qquad (10)$$

Here $0 < \varphi < 1$ is the *persistence parameter*, which indicates the speed at which habit adjusts to past consumption, and the integer m is the number of months elapsed between times $t-1$ and t. When $\varphi \to 1$, X_{t-1} approaches an equal-weighted average of past consumption expenditures. The integer $J \geq 1$ is the *duration* of habit, which determines how long habit reacts to past consumption. The coefficient $0 < \alpha < 1$ controls the level of habit relative to current consumption.

Using a one-period model with $J = 1$, Ferson and Constantinides (1991), Hansen and Jagannathan (1991), and Ferson and Harvey (1992) find that a positive α produces a better fit than a time separable utility model ($\alpha = 0$) or a "durable goods" model ($\alpha < 0$). Taking into account the effect of time aggregation, Heaton (1995) studies an infinite-horizon habit model ($J = \infty$) and finds large values of α and φ to be consistent with the Hansen and Jagannathan (1991) bounds. With $\alpha = 0.98$ or lower for monthly and quarterly data and $\alpha = 0.84$ or lower for annual data, I find that the habit level given by Equation (10) always falls below consumption and the intertemporal marginal rate of substitution given by Equation (2) remains positive and finite for any $0 < \varphi \leq 1$ and $J \geq 1$ for the dataset to be described later in this article. In the rest of the article I assume that the coefficient α is fixed at $\alpha = 0.98$ for monthly and quarterly data and $\alpha = 0.84$ for annual data. The results in the article are not sensitive to the precise choices of α.[2]

For any difference-based external habit model, including the linear habit specification in Equation (10), where the habit level X_{t-1} for the period t utility function does not depend on contemporaneous consumption C_t, the

[2] The coefficients α and φ may be estimated jointly by using Equations (3). Similar to the findings of Heaton (1995), these coefficients are not precisely estimated in this way. However, estimating the Euler equation for each fixed value of φ indicates that the estimated values of α in most cases are close to the choices given here.

sensitivity function λ_{t-1} given by Equation (8) can be obtained explicitly. Using the surplus consumption ratio S_t defined by Equation (5), it can be shown that[3]

$$\lambda_{t-1} = \mathrm{E}_{t-1}\left[\frac{1}{S_t}\right] - 1. \tag{11}$$

Since $0 < S_t < 1$, $\lambda_{t-1} > 0$. The surplus consumption ratio S_t should increase with current consumption. Equation (11) implies that if S_t is expected to fall as a result of declining consumption, λ_{t-1} will rise.

It is known that consumption growth is negatively autocorrelated in the monthly data and positively autocorrelated in the quarterly data. To account for the autocorrelation in consumption data, I assume that consumption growth follows a homoscedastic AR(1) process. For a given set of parameters of the habit level in Equation (10), the conditional expectation in Equation (11) will be evaluated through numerical integration, using the assumed distribution of the consumption process. In this way the sensitivity function λ_{t-1} evolves only with the history of consumption up to date $t-1$. See Appendix A for a detailed description.

1.4 Specification of nonlinear habit

The linear habit model will be compared with the nonlinear model of CC (1999), where consumption growth is i.i.d. and the log surplus consumption ratio s_t follows a heteroscedastic AR(1) process with the autocorrelation coefficient φ^m measuring the level of habit persistence. In the CC (1999) model, the sensitivity function λ_{t-1} [consistent with Equation (8)] is proportional to the conditional volatility of s_t. They choose λ_{t-1} by imposing the conditions that the riskfree rate is constant and habit is predetermined at the steady state $s = \bar{s}$ and moves nonnegatively with contemporaneous consumption elsewhere. The resulting choice of λ_{t-1} is negatively related to s_{t-1}, similar to what Equation (11) predicts for the linear habit model, where habit depends only on past consumption and S_t is mean reverting. In a modification to CC (1999), I assume that consumption growth is described by an AR(1), as in the linear habit model. As in CC (1999), I choose the curvature parameter $\gamma = 2$ in the calculation of the steady-state value of s_t. With s_t starting at the steady state $\bar{s}$, I use the actual consumption series to compute

[3] Equation (5) implies

$$\frac{\partial S_t}{\partial C_t} = \frac{X_{t-1}}{C_t^2} = \frac{X_{t-1}/C_t}{C_t} = \frac{1-S_t}{C_t}.$$

Thus

$$\frac{\partial s_t}{\partial c_t} = \frac{\partial \ln S_t}{\partial \ln C_t} = \frac{C_t \partial S_t}{S_t \partial C_t} = \frac{1-S_t}{S_t} = \frac{1}{S_t} - 1.$$

s_t and λ_{t-1} recursively. A detailed description of s_t and λ_{t-1} for the nonlinear model is also given in Appendix A.

2. The Data

2.1 Asset returns and consumption

Monthly and quarterly returns are used for the value-weighted (VW) and equally weighted (EW) portfolios of all stocks traded on the New York Stock Exchange (NYSE), a long-term corporate bond portfolio (CB), and a long-term government bond portfolio (GB). Monthly excess returns are returns with continuous compounding in excess of the beginning-of-the-month rate of the Treasury bill that is closest to 1 month to maturity. These data are from the Center for Research in Securities Prices (CRSP) from the University of Chicago. Quarterly excess returns are constructed by summing the monthly returns.

The monthly and quarterly data series for consumption are per capita, seasonally adjusted real consumption expenditures on nondurables and services. The seasonally adjusted real consumption expenditures are deflated by U.S. resident population data to obtain per capita consumption expenditures. The consumption expenditures and population data are available from the Citibank database (CITIBASE). The monthly consumption series covers the period from January 1959 to December 1995, while the quarterly consumption series starts in January 1947 and ends in December 1995.

In additional to the monthly and quarterly data, I examine a century-long annual dataset of the S&P 500 stock index, along with per capita real consumption (1889–1992) from Campbell (1996) and CC (1999). The annual interest rate used to calculate the excess return on this index is the return from 6-month commercial paper bought in January and rolled over in July, as in Campbell (1996) and CC (1999). I extend this dataset to the end of 1995.

Empirical evidence indicates that time aggregation affects the volatility and other time-series properties of consumption data [e.g., Heaton (1993) and Porter and Wheatley (1999)]. While this article does not address the issue of time aggregation directly, by comparing the results obtained from the monthly, quarterly, and annual data of consumption and returns, one can examine the sensitivity of the results to the sampling frequencies. Ferson and Harvey (1992, 1993b) find that the seasonality matters in the studies of the consumption-based asset pricing models under habit formation. Unlike the results based on the monthly and quarterly data, the analysis based on the annual data is not affected by the seasonal adjustment procedure for consumption series. Thus by comparing the results from different sampling frequencies, one can also examine the robustness of empirical results to the seasonal adjustment procedure.

2.2 Information variables

For the monthly and quarterly data, I assume that conditioning information is captured by the following information variables:[4] a constant, the excess return on the value-weighted portfolios of all NYSE stocks (VW), the excess return on the 3-month bill (XB3), the yield spread between Moody's Aaa-rated bonds and the 1-month Treasury bill rate (YSP), the dividend yield on the S&P 500 composite stock index (DIV), and the 1-month Treasury bill rate (TB1). The Aaa and the S&P dividend yield data are obtained from CITIBASE.[5] The rest are provided by the CRSP. For the annual data, the availability of data limits the information variables to a constant and the dividend yield on the S&P 500 composite stock index (DIV).[6] The information variables for each dataset except the constant are beginning-of-period observations and normalized to have zero means and unit variances to facilitate the interpretation of the estimated coefficients.

3. Preliminary Results

3.1 Summary statistics

As shown in Table 1, the summary statistics for asset returns and consumption growth resemble those from earlier studies. The first-order autocorrelations of the consumption growth rates are -0.25, 0.34, and -0.12 for the monthly, quarterly, and annual data, respectively, and are statistically significant for the monthly and quarterly data. Possible explanations for the large variation in the autocorrelations here include differences in the sample periods between the datasets and the time aggregation problem. The AR(1) process should be able to take into account the autocorrelation in consumption data.[7]

The consumption-based model given by Equation (9) suggests that the price of risk and expected returns are time varying. Table 1 reports the adjusted R^2s from regressions of excess returns on the information variables. The predictive power of the information variables for asset returns is also consistent with earlier studies. Using the monthly data, the adjusted R^2s are 8–12% for the stock portfolios and 5–7% for the bond portfolios. The quarterly data produce similar adjusted R^2s for the stock portfolios, but considerably higher adjusted R^2s (8–12%) for the bond portfolios. Finally, the

[4] The choice of the information variables follows the literature including Harvey (1989), Ferson and Constantinides (1991), Ferson and Harvey (1991), and Campbell (1996). The lagged stock return is used here to capture the time variation in the conditional volatility of returns, in addition to the time variation in expected returns.

[5] The CITIBASE data are monthly averages of daily yield data. As pointed out by Whitelaw (1994), the averaged data have the advantage of reducing noise and the disadvantage of being slightly stale.

[6] I find that the lagged excess return on the S&P 500 stock index and the lagged annual interest rate are insignificant in forecasting annual stock returns. When these two additional variables are included as information variables, the results using annual data are qualitatively similar.

[7] It is well known that if the flow of consumption follows an AR(1), the time-aggregated consumption becomes ARMA(1,1) [see Brewer (1973)]. The results of article will not change in any substantial way if the consumption growth is assumed to be ARMA(1,1)

Table 1
Summary statistics for asset returns and consumption growth

	Mean	Std. dev.	Autocorrelation	Adjusted R^2
Monthly data 1964:1–1995:12 (384 observations)				
Excess return (%), $r_i - r_f$				
Value-weighted NYSE index, VW	0.355	4.292	0.049	0.085
Equally-weighted NYSE index, EW	0.529	5.250	0.161	0.118
Long-term corporate bonds, CB	0.114	2.627	0.159	0.070
Long-term government bonds, GB	0.095	2.936	0.059	0.045
Consumption growth (%), $c_t - c_{t-1}$	0.170	0.390	−0.247	
Quarterly data 1952:1–1995:12 (176 observations)				
Excess return (%), $r_i - r_f$				
Value-weighted NYSE index, VW	1.511	7.847	0.100	0.084
Equally-weighted NYSE index, EW	1.867	9.899	0.036	0.086
Long-term corporate bonds, CB	0.292	4.645	0.015	0.120
Long-term government bonds, GB	0.203	4.938	−0.037	0.084
Consumption growth (%), $c_t - c_{t-1}$	0.501	0.469	0.339	
Annual data 1894–1995 (102 observations)				
Excess return (%), $r_i - r_f$				
S&P 500 stock index	5.029	18.518	0.013	0.053
Consumption growth (%), $c_t - c_{t-1}$	1.736	3.329	−0.117	

The monthly and quarterly excess returns $r_i - r_f$ are for following assets: the value-weighted (VW) and equally weighted (EW) indexes of all stocks traded on the NYSE, a long-term corporate bond portfolio (CB), and a long-term government bond portfolio (GB). Monthly returns with continuous compounding are in excess of the beginning-of-the-month rate of the Treasury bill that is closest to 1 month to maturity. Quarterly excess returns are constructed by summing monthly excess returns. $c_t - c_{t-1}$ is the change in the log of per capita, seasonally adjusted real consumption of nondurables plus services. The adjusted R^2 is from regressing each asset's excess return on the following information variables: a constant, the excess return on the value-weighted NYSE index (XVW), the return for holding a 90-day bill for 1 month less the 1-month Treasury bill rate (XB3), the yield on Moody's Aaa-rated bonds less the 1-month Treasury bill rate (YSP), the dividend yield on the S&P 500 stock index (DIV), and the 1-month Treasury bill rate (TB1). The annual excess return $r_i - r_f$ is for the S&P 500 stock index with continuous compounding in excess of the return on commercial paper bought in January and rolled over in July. The adjusted R^2 for annual data is from regressing each asset's excess return on the following information variables: a constant and the dividend yield on the S&P 500 stock index (DIV). All information variables are beginning-of-period values.

regression of the annual stock return on the S&P dividend yield produces an adjusted R^2 of 5.3%, similar to the findings of Campbell and Shiller (1988), Fama and French (1988), and Hodrick (1992). The lower R^2 from the annual data is partly due to the use of the dividend yield as the single forecasting variable. According to the result in Forster, Smith, and Whaley (1997, Table 1, p. 598), the values of R^2s together with the sample size (e.g., 384 observations for the monthly data) suggest that the predictability of returns is unlikely the result of data mining.

Table 2 presents summary statistics for the surplus consumption ratio. For the linear habit model, I consider durations of 1 quarter, 1 year, 3 years, and 5 years along with the persistence parameter $\varphi = 0.75, 0.99, 0.9999$. For each decision interval, the mean and standard deviation of the surplus consumption ratio increase with the duration and persistence of habit. In particular, for the monthly and quarterly data, the results from the linear habit model indicate that between 2% and 7% of consumption is in excess of habit, whereas between 17% and 20% of consumption is in excess of habit for the annual data. The first-order autocorrelation of the log surplus consumption ratio s_t exhibits a similar monotonic pattern and approaches the persistence parameter as the habit duration increases. For the annual data, the nonlinear models are not well defined with $\varphi = 0.9999$ since $\bar{S} > 1$. In other cases, the nonlinear models produce summary statistics similar to the 5-year linear model. Notice that the unconditional autocorrelation of s_t here is different from the persistence parameter φ because s_t is heterocedastic and calculated from a finite sample.

The time-series patterns of the sensitivity functions λ_t implied by the various habit models are illustrated in Figures 1 and 2, based on the quarterly and the annual consumption data, respectively. The plot using the monthly data is not shown since it is similar to what the quarterly data produce. The solid, short, and long dashed lines in each figure are for the 5-year linear model, the nonlinear model of CC (1999), and a modified model of CC (1999), respectively. The persistence parameter for each model takes the value of $\varphi = 0.99$. As described in Sections 1.3 and 1.4, in the CC (1999) model,

Table 2
Summary statistics for surplus consumption ratio

	Habit in the linear model is assumed to last for					
φ	1 quarter	1 year	3 years	5 years	CC model	Modified CC model
			Monthly data			
Mean (%)						
0.75	2.301	2.600	2.665	2.665	1.272	1.149
0.99	2.332	3.062	4.882	6.519	6.512	5.993
0.9999	2.333	3.082	5.059	7.001	57.94	27.13
Std. Dev. (%)						
0.75	0.396	0.534	0.558	0.558	0.498	0.535
0.99	0.413	0.803	1.545	1.975	2.128	2.454
0.9999	0.414	0.815	1.623	2.138	1.130	1.438
First-order autocorrelation $s_t = \log(S_t)$						
0.75	0.390	0.715	0.745	0.746	0.790	0.870
0.99	0.483	0.890	0.967	0.980	0.983	0.985
0.9999	0.486	0.893	0.970	0.992	0.976	0.980
			Quarterly data			
Mean (%)						
0.75	2.495	2.788	2.852	2.852	0.983	1.104
0.99	2.495	3.211	4.929	6.571	4.473	4.559
0.9999	2.495	3.229	5.161	7.036	43.27	40.46
Std. dev. (%)						
0.75	0.487	0.613	0.631	0.631	0.548	0.565
0.99	0.487	0.841	1.428	1.768	1.704	1.268
0.9999	0.487	0.851	1.492	1.902	2.045	1.507
First-order autocorrelation $s_t = \log(S_t)$						
0.75	0.235	0.422	0.438	0.438	0.656	0.370
0.99	0.235	0.593	0.771	0.790	0.954	0.933
0.9999	0.235	0.599	0.782	0.803	0.984	0.978

Table 2
(continued)

φ	Habit in the linear model is assumed to last for: 1 quarter	1 year	3 years	5 years	CC model	Modified CC model
			Annual data			
Mean (%)						
0.75		17.40	17.45	17.45	6.788	6.222
0.99		17.40	18.66	19.79	15.78	15.52
0.9999		17.40	18.77	20.11	NA	NA
Std. dev. (%)						
0.75		2.738	2.731	2.731	9.322	6.973
0.99		2.738	3.255	3.766	3.854	4.095
0.9999		2.738	3.340	3.976	NA	NA
First-order autocorrelation $s_t = \log(S_t)$						
0.75		−0.035	0.003	0.003	0.085	0.224
0.99		−0.035	0.589	0.725	0.817	0.843
0.9999		−0.035	0.605	0.748	NA	NA

The surplus consumption ratio is $S_t = 1 - (X_{t-1}/C_t)$, where X_{t-1} is the level of habit and C_t is per capita, seasonally adjusted real consumption of nondurables plus services. The habit level X_{t-1} in the linear habit model is a weighted average of past consumption with weights declining at a monthly rate of φ:

$$X_{t-1} = \alpha\left(\frac{1-\varphi^m}{1-\varphi^{Jm}}\right)\sum_{j=1}^{J}\varphi^{(j-1)m}C_{t-j},$$

where $\alpha = 0.98$ for monthly and quarterly data and $\alpha = 0.84$ for annual data. The integer m takes the value of 1, 4, and 12 for monthly, quarterly, and annual data. The nonlinear models include the Campbell and Cochrane (1999) model, where consumption growth is i.i.d., and the modified Campbell and Cochrane model, where consumption growth follows a homoscedastic AR(1) process.

consumption growth is i.i.d., while in the linear model and modified CC (1999) model, consumption growth follows an AR(1) process. The mean, standard deviation, and autocorrelation of consumption growth reported in Table 1 are assumed to be given. In this way, the sensitivity function for each habit model is calculated from the history of consumption data only.

The sensitivity functions generally increase during recessions (the shaded area), for example, 1973–1975, 1981–1982, 1990–1991, but decrease during some of the expansions. Dramatic increases in the sensitivity functions are observed during the Great Depression (1929–1933). CC (1999) acknowledge that the worst performance of their nonlinear model in fitting the price: dividend ratio occurs in the last few years, which is also evident in Figure 1, where the sensitivity function from their model keeps rising during this most recent cyclical expansion. In contrast, the linear model produces a consistent and negative relation between the sensitivity and the stage of the business cycle, including this period. This suggests that the poor performance of the CC (1999) model in the 1990s is more likely due to the particular specification of their model rather than to the consumption measurement problems suggested by CC (1999).

In the rest of the analysis, the results from the CC (1999) model with i.i.d. consumption growth and the modified model with an AR(1) process are

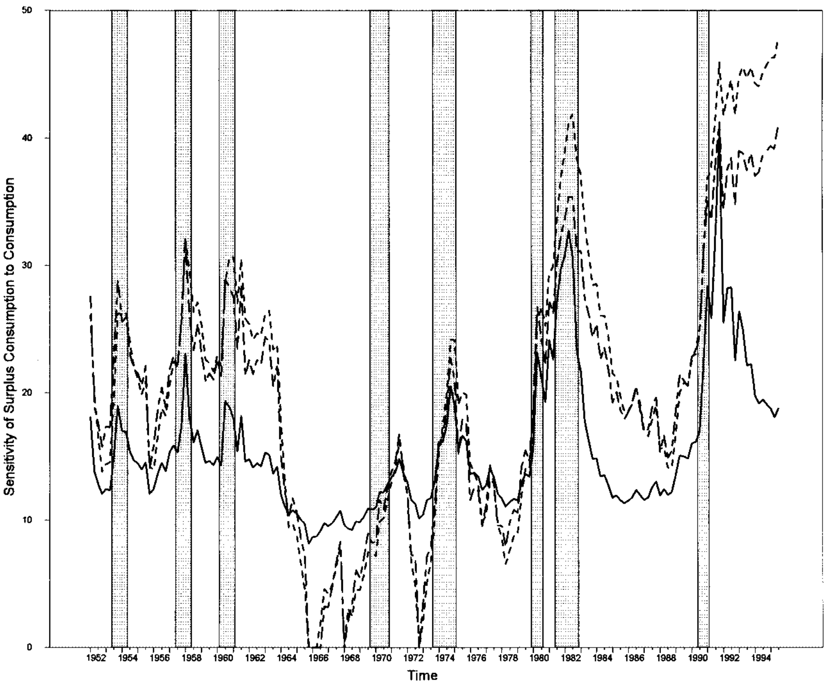

Figure 1
The sensitivity of surplus consumption to consumption: quarterly data
The solid, short, and long dashed lines are the quarterly values of the sensitivity of surplus consumption to consumption from the 5-year linear habit model, the nonlinear model of Campbell and Cochrane (1999), and a modified model of Campbell and Cochrane (1999), respectively. The sensitivity from each model is calculated from the history of consumption data only. In the nonlinear model of Campbell and Cochrane (1999), consumption growth is i.i.d. In the 5-year linear habit model and the modified model of Campbell and Cochrane (1999), consumption growth follows a homoscedastic AR(1) process. The persistence parameter is $\varphi = 0.99$. The shaded areas indicate recessions.

similar. Since the analysis of the modified model employs the same AR(1) process for consumption growth as the linear model, I will only report the results from the modified model and compare them with the results of estimating the linear model.

3.2 Covariance of returns with consumption

The consumption-based model suggests that the expected excess return on an asset is related to its conditional covariance with consumption. I begin with an analysis of the time-series properties of the covariance to examine whether the time-varying expected return is attributed to the covariance. It is known that the covariance of the return on each asset with consumption can be written as the consumption beta of the asset times the consumption volatility. Alternatively, the covariance can be expressed as the volatility

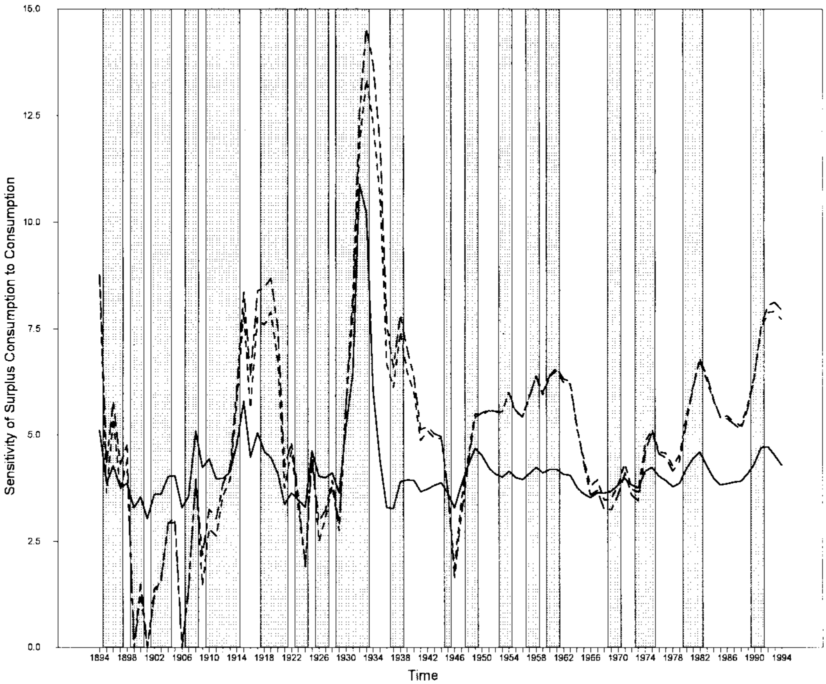

Figure 2
The sensitivity of surplus consumption to consumption: annual data
The solid short, and long dashed lines are the annual values of the sensitivity of surplus consumption to consumption from the 5-year linear habit model, the nonlinear model of Campbell and Cochrane (1999), and a modified model of Campbell and Cochrane (1999), respectively. The sensitivity from each model is calculated from the history of consumption data only. In the nonlinear model of Campbell and Cochrane (1999), consumption growth is i.i.d. In the 5-year linear habit model and the modified model of Campbell and Cochrane (1999), consumption growth follows a homoscedastic AR(1) process. The persistence parameter is $\varphi = 0.99$. The shaded areas indicate recessions.

of the return on the asset times the asset's *reverse consumption beta* from regressing consumption on the return.

I find no evidence that the covariance, the consumption volatility, the consumption beta, or the reverse consumption beta for each asset is related to the information variables at the 10% or higher significance levels (see Appendix B for detail). This is largely consistent with the previous evidence that the covariance of returns with consumption is too smooth to match the time-varying expected returns [e.g., Ferson and Harvey (1993b)]. The results suggest that one should focus on the time-varying price of risk as an explanation of time-varying expected returns.

4. The Methodology and Empirical Results

In this section I use the consumption-based model with habit formation given by Equation (9) to study the relation between expected returns and the surplus consumption ratio. Based on the preliminary results reported earlier, I make the following assumption:

Assumption 1. *The conditional covariance of returns with consumption* $\mathrm{cov}_{t-1}\ (r_{it}, c_t)$ *is positive and constant through time.*

Under Assumption 1, an unrestricted version of the model in Equation (9) is given by the following:

$$\mathrm{E}_{t-1}[r_{it}] - r_{f,t-1} = -(1/2)\sigma^2_{i,t-1} + \alpha_{i,t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda}), \tag{12}$$

where $\alpha_{i,t-1}$ is the Jensen's alpha for asset i and $\beta_i = \gamma \mathrm{cov}_{t-1}(r_{it}, c_t) > 0$ represents the constant regression beta on λ_{t-1}.

The term $\beta_i(\lambda_{t-1} - \bar{\lambda})$ in Equation (12) represents the part of the expected return on each asset that is explained by λ_{t-1} implied by each habit model. The term $\alpha_{i,t-1}$ captures the part of the expected return that is not explained by λ_{t-1}. If the functional form of $\alpha_{i,t-1}$ is assumed to be linear in a vector of information variables, $\boldsymbol{Z}_{t-1}$, the resulting $\alpha_{i,t-1}$ and the explanatory variable, λ_{t-1}, measured from consumption data using one of the habit models, will be correlated.[8] To let $\alpha_{i,t-1}$ capture the unexplained part of the time-varying expected return that is orthogonal to λ_{t-1}, I first regress $\boldsymbol{Z}_{t-1}$ except the constant on λ_{t-1} to obtain the residual vector $\boldsymbol{Z}^o_{t-1}$, and then assume $\alpha_{i,t-1}$ is linear in $\boldsymbol{Z}^o_{t-1}$:

$$\alpha_{i,t-1} = \bar{\alpha}_i \ + \boldsymbol{a}_i \boldsymbol{Z}^o_{t-1}. \tag{13}$$

To gain some insight into the relation between the volatility and λ_{t-1}, I assume that the return volatility is

$$\sigma^2_{i,t-1} = \bar{\sigma}^2_i \ + \ \boldsymbol{d}'_i \boldsymbol{Z}^o_{t-1} + d_{i,\lambda}(\lambda_{t-1} - \bar{\lambda}). \tag{14}$$

In Equation (12), the (variance-adjusted) *total* expected return on asset i is $\alpha_{i,t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda})$, with variance

$$\mathrm{var}(\alpha_{i,t-1} + \beta_i \lambda_{t-1}) = \mathrm{var}(\alpha_{i,t-1}) + \mathrm{var}(\beta_i \lambda_{t-1}), \tag{15}$$

because $\mathrm{cov}(\alpha_{i,t-1}, \lambda_{t-1}) = \boldsymbol{a}'_i \mathrm{cov}(\boldsymbol{Z}^o_{t-1}, \lambda_{t-1}) = 0$. This implies that the fraction of the variation in $[\alpha_{i,t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda})]$ that is explained by λ_{t-1} is

$$\mathrm{VR}_i = \frac{\mathrm{var}(\beta_i \lambda_{t-1})}{\mathrm{var}(\alpha_{i,t-1}) + \mathrm{var}(\beta_i \lambda_{t-1})} = \frac{\mathrm{var}(\beta_i \lambda_{t-1})}{\mathrm{var}(\boldsymbol{a}'_i \boldsymbol{Z}^o_{t-1}) + \mathrm{var}(\beta_i \lambda_{t-1})}. \tag{16}$$

This variance ratio is bounded between zero and one as a result of the orthogonal decomposition of the total expected returns. Using Equation (12) and

[8] For long-horizon habit models, λ_{t-1} is found to be correlated with several information variables, including YSP and DIV.

the auxiliary assumptions in Equations (13) and (14), I estimate this variance ratio VR_i in Equation (16) by using the following disturbance terms:

$$u_{it} = r_{it} - r_{f,t-1} + [\bar{\sigma}_i^2 + \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o + d_\lambda(\lambda_{t-1} - \bar{\lambda})]/2 - [\bar{\alpha}_i + a_i'\boldsymbol{Z}_{t-1}^o + \beta_i(\lambda_{t-1} - \bar{\lambda})], \quad (17)$$

$$v_{it} = u_{it}^2 - \bar{\sigma}_i^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o - d_{i,\lambda}(\lambda_{t-1} - \bar{\lambda}), \quad (18)$$

$$u_{ivt} = [a_i'\boldsymbol{Z}_t^o + \beta_i(\lambda_t - \bar{\lambda})]^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2. \quad (19)$$

Here the first two disturbance terms have means of zero and are orthogonal to $\boldsymbol{Z}_{t-1}^o$ and λ_{t-1}, while the last term has a mean of zero. The system is exactly identified and is estimated by using the generalized method of moments (GMM) of Hansen (1982). Since the last disturbance term is found to be autocorrelated, I use the Newey and West (1987b) procedure to calculate the weighting matrix for the GMM criterion function.

Table 3 reports the results of estimating the system with the monthly data and Table 4 summaries the results obtained from the quarterly and annual data. The column "MCC" refers to the nonlinear, modified CC (1999) model where consumption growth follows an AR(1) process. The other columns report the results of estimating the linear habit model, where habit is assumed to last for 1 quarter, 1 year, 3 years, or 5 years. For each dataset, the results of estimating β_i and VR_i in panel A of Tables 3 and 4 indicate that the performance of the linear habit model for expected returns tends to improve as the duration or persistence of habit formation increases. For 3- and 5-year linear models and the nonlinear model with $\varphi \geq 0.99$, the point estimates of β_i for most portfolios assuming the monthly, quarterly, or annual decision interval are positive and significant at the 5% or 10% level, which is consistent with a positive relation between the expected returns and the sensitivity function, λ_{t-1}, or an inverse relation between the expected returns and the surplus consumption ratio.

A close examination reveals some difference in the explanatory power of the habit models obtained from alternative datasets. Consider the 3- and 5-year linear habit models with $\varphi \geq 0.99$. For the monthly data, habit persistence explains no more than 5% of time variation in expected returns on stocks, but up to 20% of time variation in expected returns on bonds. While the findings for bonds are similar using the monthly and the quarterly data, the explanatory power of the habit models for each stock portfolio is substantially higher using the quarterly and annual data. In particular, for each stock portfolio, the variance ratio is less than 5% with the monthly data, but up to 23% with the quarterly data and 22% with the annual data. The results of estimating the nonlinear model also show increases in the variance ratios for each stock portfolio when the monthly data are replaced with the quarterly or annual data. For example, for the stock portfolio VW, the variance ratio from the quarterly data reaches 22% with a standard error of 12, whereas

Table 3
Estimation of the relation between expected returns and the sensitivity of surplus consumption to consumption: monthly data 1964:1–1995:12

		β_t					VR_t				
φ	Asset	1 quarter	1 year	3 years	5 years	MCC	1 quarter	1 year	3 years	5 years	MCC
		Panel A. Estimation results for β_t and VR_t									
0.75	VW	2.4220	2.9802	3.1014	3.1017	0.3505	0.0024	0.0162	0.0191	0.0191	0.0226
		(6.522)	(2.621)	(2.543)	(2.543)	(0.311)	(0.013)	(0.029)	(0.031)	(0.031)	(0.041)
	EW	2.5034	5.3799	5.5535	5.5539	0.4608	0.0013	0.0271	0.0314	0.0314	0.0197
		(9.213)	(3.693)	(3.612)	(3.613)	(0.407)	(0.010)	(0.037)	(0.040)	(0.040)	(0.035)
	CB	9.0455	3.4500	3.2801	3.2811	0.4573	0.0994	0.0671	0.0663	0.0663	0.1130
		(3.906)**	(2.024)*	(1.957)*	(1.957)*	(0.213)**	(0.081)	(0.077)	(0.077)	(0.077)	(0.102)
	GB	10.815	4.0113	3.7848	3.7858	0.4958	0.1553	0.1008	0.0982	0.0982	0.1495
		(4.366)**	(2.173)*	(2.102)*	(2.102)*	(0.234)**	(0.116)	(0.105)	(0.105)	(0.105)	(0.135)
0.99	VW	2.2669	2.2469	2.5584	3.3642	3.4123	0.0035	0.0256	0.0318	0.0239	0.0648
		(5.012)	(1.507)	(1.494)*	(2.303)	(1.464)**	(0.015)	(0.035)	(0.037)	(0.032)	(0.053)
	EW	2.7070	4.1394	4.4151	5.5653	3.1306	0.0026	0.0445	0.0481	0.0336	0.0276
		(7.131)	(2.088)**	(2.059)**	(3.029)*	(1.933)*	(0.013)	(0.045)	(0.042)	(0.035)	(0.033)
	CB	7.1433	1.1138	2.5358	5.0364	3.6856	0.1034	0.0196	0.0978	0.1664	0.2363
		(3.027)**	(1.136)	(1.219)**	(1.861)**	(1.079)**	(0.082)	(0.040)	(0.088)	(0.107)	(0.114)**
	GB	8.5506	1.3238	2.6299	5.0629	3.9508	0.1617	0.0311	0.1177	0.1881	0.3022
		(3.381)**	(1.209)	(1.345)*	(2.041)**	(1.230)**	(0.117)	(0.057)	(0.113)	(0.134)	(0.153)**
0.9999	VW	2.2738	2.2927	2.4954	3.5161	7.1336[a]	0.0036	0.0280	0.0302	0.0232	0.0690
		(4.970)	(1.455)	(1.480)*	(2.451)	(2.709)**	(0.016)	(0.036)	(0.036)	(0.032)	(0.051)
	EW	2.7358	4.1687	4.3233	5.7532	7.9795[a]	0.0027	0.0475	0.0461	0.0321	0.0436
		(7.076)	(2.016)**	(2.040)**	(3.186)*	(3.551)**	(0.014)	(0.046)	(0.041)	(0.034)	(0.037)
	CB	7.0948	0.9559	2.6034	5.4512	5.5493[a]	0.1036	0.0152	0.1029	0.1738	0.1233
		(3.003)**	(1.112)	(1.226)**	(1.958)**	(2.025)**	(0.082)	(0.036)	(0.090)	(0.108)	(0.079)
	GB	8.4901	1.1518	2.6963	5.4479	6.1984[a]	0.1620	0.0248	0.1235	0.1941	0.1667
		(3.354)**	(1.180)	(1.350)**	(2.150)**	(2.295)**	(0.117)	(0.051)	(0.115)	(0.134)	(0.107)

φ	Asset	1 quarter	1 year	3 years	5 years	MCC
		Panel B. Estimation results for $d_{t\lambda}$				
0.75	VW	1.2276	0.6073	0.5675	0.5674	0.0559
		(0.401)**	(0.131)**	(0.125)**	(0.125)**	(0.015)**
	EW	2.1557	1.1366	1.0296	1.0294	0.0858
		(0.872)**	(0.330)**	(0.321)**	(0.321)**	(0.037)**
	CB	0.6942	0.5083	0.4974	0.4974	0.0420
		(0.187)**	(0.101)**	(0.097)**	(0.098)**	(0.010)**
	GB	0.8186	0.4857	0.4642	0.4642	0.0371
		(0.234)**	(0.124)**	(0.121)**	(0.121)**	(0.013)**
0.99	VW	0.9327	0.2839	0.0976	−0.1271	−0.1770
		(0.306)**	(0.080)**	(0.082)	(0.123)	(0.072)**
	EW	1.6648	0.4901	0.0523	−0.4120	−0.5283
		(0.670)**	(0.187)**	(0.173)	(0.226)*	(0.137)**
	CB	0.5448	0.2664	0.2646	0.3124	0.1212
		(0.146)**	(0.056)**	(0.068)**	(0.102)**	(0.047)**
	GB	0.6318	0.2327	0.2226	0.2534	0.1286
		(0.181)**	(0.070)**	(0.086)**	(0.128)**	(0.061)**
0.9999	VW	0.9248	0.2712	0.0822	−0.1916	−0.9181[a]
		(0.304)**	(0.078)**	(0.081)	(0.130)	(0.148)**
	EW	1.6536	0.4663	0.0217	−0.5266	−1.7301[a]
		(0.665)**	(0.181)**	(0.170)	(0.231)**	(0.320)**
	CB	0.7408	0.2577	0.2609	0.3071	−0.1691[a]
		(0.144)**	(0.054)**	(0.067)**	(0.108)**	(0.081)**
	GB	0.6266	0.2252	0.2201	0.2463	−0.1827[a]
		(0.180)**	(0.067)**	(0.084)**	(0.136)*	(0.102)*

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = r_{it} - r_{f,t-1} + [\bar{\sigma}_i^2 + \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o + d_\lambda(\lambda_{t-1} - \bar{\lambda})]/2 - [\bar{\alpha}_i + a_i{}'\boldsymbol{Z}_{t-1}^o + \beta_i(\lambda_{t-1} - \bar{\lambda})]$	$1, \boldsymbol{Z}_{t-1}^o$ and λ_{t-1}
$v_{it} = u_{it}^2 - \bar{\sigma}_i^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o - d_{i,\lambda}(\lambda_{t-1} - \bar{\lambda})$	$1, \boldsymbol{Z}_{t-1}^o$ and λ_{t-1}
$u_{ivt} = [a_i{}'\boldsymbol{Z}_t^o + \beta_i(\lambda_t - \bar{\lambda})]^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2$	1

$r_i - r_f$ represents the excess return with continuous compounding on asset i. $\lambda(\lambda - \bar{\lambda})$ is the (mean-adjusted) conditional sensitivity of surplus consumption to consumption from the linear habit model ($\alpha = 0.98$), or the modified model of Campbell and Cochrane (1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. $\boldsymbol{Z}^o$ is the vector of information variables, excluding a constant, that are orthogonal to λ. VR_i is the fraction of the variance of the (variance-adjusted) expected return on asset i that is explained by λ. Standard errors are in parentheses.

**,* indicate that the coefficient is significant at 5% and 10%, respectively. Unless noted otherwise, coefficients and standard errors for β_i and $d_{i,\lambda}$ are multiplied by a constant (10^4).

[a] Indicates that coefficients and standard errors are multiplied by 100.

Table 4
Estimation of the relation between expected returns and the sensitivity of surplus consumption to consumption: quarterly data 1952:1–1995:4 and annual data 1894–1995

		β_t					VR_t				
φ	Asset	1 quarter	1 year	3 years	5 years	MCC	1 quarter	1 year	3 years	5 years	MCC
		Panel A. Estimation results for β_t and VR_t									
		Quarterly data									
0.75	VW	30.669	15.486	15.746	15.748	0.8906	0.1235	0.1545	0.1659	0.1659	0.0468
		(12.93)**	(5.726)**	(5.740)**	(5.741)**	(0.713)	(0.102)	(0.115)	(0.121)	(0.121)	(0.075)
	EW	44.706	22.533	22.987	22.990	1.4950	0.1659	0.2065	0.2227	0.2228	0.0824
		(18.36)**	(7.886)**	(7.929)**	(7.930)**	(0.971)	(0.118)	(0.126)	(0.132)*	(0.132)*	(0.098)
	CB	6.5886	0.4385	0.6701	0.6723	0.4215	0.0126	0.0003	0.0007	0.0007	0.0221
		(9.125)	(4.411)	(4.272)	(4.272)	(0.417)	(0.035)	(0.006)	(0.008)	(0.009)	(0.046)
	GB	9.4764	1.6067	1.6896	1.6917	0.5892	0.0291	0.0041	0.0047	0.0048	0.0480
		(9.762)	(4.616)	(4.487)	(4.487)	(0.437)	(0.060)	(0.024)	(0.026)	(0.026)	(0.073)
0.99	VW	30.669	9.6130	11.395	16.155	12.284	0.1235	0.1581	0.1375	0.1166	0.2170
		(12.93)**	(3.422)**	(5.232)**	(6.790)**	(4.045)**	(0.102)	(0.116)	(0.116)	(0.091)	(0.120)*
	EW	44.706	13.723	18.909	24.882	11.593	0.1659	0.2065	0.2338	0.1766	0.1281
		(18.36)**	(4.630)**	(6.487)**	(8.839)**	(5.586)**	(0.118)	(0.126)	(0.124)*	(0.101)*	(0.106)
	CB	6.5886	−1.2511	5.4321	14.043	8.9058	0.0126	0.0056	0.0652	0.1763	0.2353
		(9.125)	(2.656)	(2.717)**	(4.293)**	(2.467)**	(0.035)	(0.023)	(0.069)	(0.106)*	(0.114)**
	GB	9.4764	−0.6743	5.0355	13.706	9.3085	0.0291	0.0019	0.0629	0.1878	0.2818
		(9.762)	(2.716)	(3.331)	(5.371)**	(2.950)**	(0.060)	(0.015)	(0.086)	(0.140)	(0.145)*
0.9999	VW	30.669	9.4453	11.077	16.672	12.232[a]	0.1235	0.1577	0.1291	0.1100	0.2287
		(12.93)**	(3.359)**	(5.189)**	(7.077)**	(4.063)**	(0.102)	(0.116)	(0.111)	(0.087)	(0.137)*
	EW	44.706	13.470	18.584	25.391	11.378[a]	0.1659	0.2046	0.2246	0.1635	0.1317
		(18.36)**	(4.545)**	(6.365)**	(9.213)**	(4.681)**	(0.118)	(0.125)	(0.120)*	(0.097)*	(0.107)
	CB	6.5886	−1.2800	5.8143	15.675	2.3475[a]	0.0126	0.0061	0.0738	0.1937	0.0159
		(9.125)	(2.604)	(2.727)**	(4.544)**	(2.353)	(0.035)	(0.024)	(0.073)	(0.108)*	(0.030)
	GB	9.4764	−0.7172	5.4030	15.317	2.0233[a]	0.0291	0.0022	0.0715	0.2067	0.0125
		(9.762)	(2.662)	(3.353)	(5.715)**	(2.512)	(0.060)	(0.016)	(0.091)	(0.143)	(0.030)

Annual data

0.75	S&P 500	−0.1487	−0.2029	−0.2029	0.0022	0.1073	0.1062	0.1062	0.2517
		(0.176)	(0.241)	(0.241)	(0.001)**	(0.227)	(0.226)	(0.225)	(0.193)
0.99		−0.1487	0.0314	0.0225	0.0103	0.1073	0.1183	0.2151	0.2468
		(0.176)	(0.030)	(0.010)**	(0.006)*	(0.227)	(0.194)	(0.164)	(0.256)
0.9999		−0.1487	0.0286	0.0175	NA	0.1073	0.1201	0.2125	NA
		(0.176)	(0.027)	(0.007)**	NA	(0.227)	(0.191)	(0.160)	NA

Panel B. Estimation results for $d_{i,\lambda}$

Quarterly data

φ	Asset	1 quarter	1 year	3 years	5 years	MCC
0.75	VW	1.6569	0.7129	0.7441	0.7439	0.1738
		(1.252)	(0.616)	(0.619)	(0.619)	(0.082)**
	EW	4.3158	1.7031	1.6099	1.6093	0.3435
		(2.522)*	(1.087)	(1.077)	(1.077)	(0.132)**
	CB	2.7210	1.2144	1.2168	1.2169	0.1398
		(0.636)**	(0.232)**	(0.229)**	(0.229)**	(0.036)**
	GB	2.4493	1.1326	1.1341	1.1342	0.1281
		(0.776)**	(0.295)**	(0.293)**	(0.293)**	(0.041)**
0.99	VW	1.6569	0.4080	0.1978	−1.0272	−0.7766
		(1.252)	(0.411)	(0.437)	(0.607)**	(0.309)**
	EW	4.3158	0.7554	−0.1807	−2.7457	−2.4980
		(2.522)*	(0.631)	(0.985)	(1.123)**	(0.639)**
	CB	2.7210	0.6730	0.7318	0.8185	0.2907
		(0.636)**	(0.136)**	(0.239)**	(0.322)**	(0.192)
	GB	2.4493	0.6554	0.7338	0.8404	0.4408
		(0.776)**	(0.166)**	(0.284)**	(0.417)**	(0.216)**
0.9999	VW	1.6569	0.3992	0.1364	−1.3536	−1.2623[a]
		(1.252)	(0.405)	(0.435)	(0.634)**	(0.518)**
	EW	4.3158	0.7293	−0.2919	−3.3634	−3.0978[a]
		(2.522)*	(0.620)	(0.967)	(1.150)**	(0.783)**
	CB	2.7210	0.6587	0.7075	0.7799	−0.8623[a]
		(0.636)**	(0.133)**	(0.234)**	(0.348)**	(0.268)**
	GB	2.4493	0.6425	0.7149	0.8083	−0.9521[a]
		(0.776)**	(0.163)**	(0.280)**	(0.445)*	(0.307)**

Table 4
(continued)

φ	Asset	1 quarter	1 year	3 years	5 years	MCC
			Panel B. Estimation results for $d_{i,\lambda}$			
			Annual data			
0.75	S&P 500		−0.0317	−0.0439	−0.0439	−0.0466[a]
			(0.081)	(0.111)	(0.111)	(0.024)**
0.99			−0.0317	0.0055	0.0028	0.1408[a]
			(0.081)	(0.014)	(0.004)	(0.152)
0.9999			−0.0317	0.0048	0.0019	NA
			(0.081)	(0.012)	(0.003)	NA

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = r_{it} - r_{f,t-1} + [\bar{\sigma}_i^2 + \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o + d_\lambda(\lambda_{t-1} - \bar{\lambda})]/2 - [\bar{\alpha}_i + a_i'\boldsymbol{Z}_{t-1}^o + \beta_i(\lambda_{t-1} - \bar{\lambda})]$	$1, \boldsymbol{Z}_{t-1}^o$ and λ_{t-1}
$v_{it} = u_{it}^2 - \bar{\sigma}_i^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}^o - d_{i,\lambda}(\lambda_{t-1} - \bar{\lambda})$	$1, \boldsymbol{Z}_{t-1}^o$ and λ_{t-1}
$u_{ivt} = [a_i'\boldsymbol{Z}_t^o + \beta_i(\lambda_t - \bar{\lambda})]^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2$	1

$r_i - r_f$ represents the excess return with continuous compounding on asset i. $\lambda(\lambda - \bar{\lambda})$ is the (mean-adjusted) conditional sensitivity of surplus consumption to consumption from the linear habit model ($\alpha = 0.98$ for quarterly data and $\alpha = 0.84$ for annual data) or the modified model of Campbell and Cochrane (1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. $\boldsymbol{Z}^o$ is the vector of information variables, excluding a constant, that are orthogonal to λ. VR_i is the fraction of the variance of the (variance-adjusted) expected return on asset i that is explained by λ. Standard errors are in parentheses.

**,* indicate that the coefficient is significant at 5% and 10%, respectively. Unless noted otherwise, coefficients and standard errors for β_i and $d_{i,\lambda}$ are multiplied by a constant (10^4).

[a] Indicates that coefficients and standard errors are multiplied by 100.

the variance ratio from the monthly data is only 6.5% with a standard error of 5.3. The variance ratios obtained from the annual data (for the S&P 500 index) are also higher than those from the monthly data (for the stock portfolio VW). In particular, the variance ratio implied by the nonlinear model with $\varphi = 0.99$ is 25%. However, the estimates with the annual data here are not as precise as with the quarterly data. The similarity in the performance based on the quarterly and annual data indicates that the results are robust to time aggregation and seasonal adjustment procedure for consumption data. The better performance of the habit models obtained from the quarterly and annual data than the monthly data may be attributed to the difference in the sample periods used in the analysis, as business-cycle effects are better detected in longer sample periods.

The point estimates of $d_{i,\lambda}$ for the conditional variances of the monthly, quarterly, and annual returns are given in the panel B of Tables 3 and 4. First consider the 5-year linear model for the stock portfolios. With the persistence level $\varphi = 0.75$, the point estimates are positive but only significant at the 5% or 10% level for the monthly data. When φ is increased to 0.99 and higher, the point estimates of $d_{i,\lambda}$ are significantly negative for the equal-weighted stock portfolio using the monthly data and the equal-weighted and the value-weighted stock portfolios using the quarterly data, while the coefficient $d_{i,\lambda}$ is imprecisely estimated in most cases using the annual data. The point estimates for bond portfolios remain positive for all values of φ and in some cases are significantly different from zero. Finally, the results for the nonlinear model are qualitatively similar to the 5-year linear model, except that the coefficient $d_{i,\lambda}$ is negative and significant at the 5% level even for the value-weighted portfolio in the monthly data ($\varphi = 0.99$) and the S&P 500 index in the annual data ($\varphi = 0.75$).

The evidence on the negative relation between the conditional variance of stock returns and the sensitivity function λ_{t-1} implies that the conditional volatility of stock returns is positively related to the surplus consumption ratio, in contradiction to the countercyclical volatility produced by CC (1999) using simulated data. Since expected returns are inversely related to the surplus consumption ratio, expected returns and volatility move with the surplus consumption ratio in opposite directions. Thus the negative relation between expected returns and the volatility in the stock market documented in the literature [e.g., Campbell (1987), Glosten, Jagannathan, and Runkle (1993), and Whitelaw (1994)] can be partly attributed to time-varying surplus consumption. In the next section I show that this can be further explained by time-varying reward:volatility ratios.

Figures 3 and 4 illustrate the results based on the quarterly data for the stock portfolio VW and the bond portfolio CB, respectively. Figure 5 displays the results based on the annual data. The solid lines are the (variance-adjusted) *total* expected returns, $\bar{\alpha}_i + a_i{}'\boldsymbol{Z}^o_{t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda})$, implied by the parameter estimates in Tables 3 and 4. For a given portfolio, these total

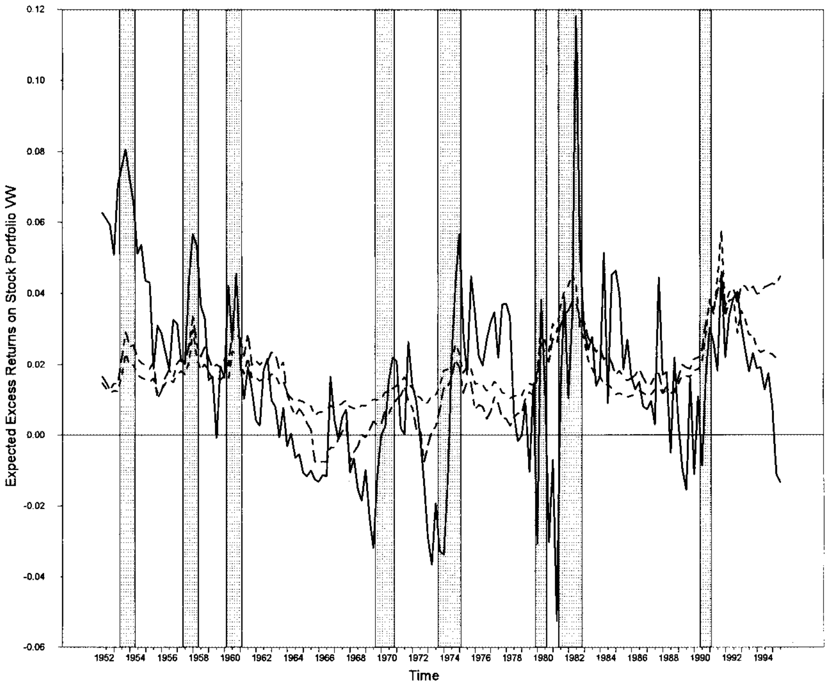

Figure 3
The expected excess return on the value-weighted stock portfolio
The solid line is the total quarterly value of the (variance-adjusted) expected excess return on the value-weighted stock portfolio VW. The short and long dashed lines are the components of the expected excess returns that are explained by the 5-year habit model and the modified model of Campbell and Cochrane (1999). In each model consumption growth follows a homoscedastic AR(1) process. The persistence parameter is $\varphi = 0.99$. The shaded areas indicate recessions.

expected returns are virtually the same for all habit models because the expected returns that are not related to the sensitivity functions λ_{t-1} are captured by the other information variables. The short-and long-dashed lines for each portfolio are components of expected returns, $\bar{\alpha}_i + \beta_i(\lambda_{t-1} - \bar{\lambda})$, that are explained by the 5-year linear model and the nonlinear model, respectively. Overall the linear and nonlinear models produce remarkably similar countercyclical patterns in expected returns except for the last few years of the sample. Consistent with the results about the sensitivity functions reported in Figure 1, Figures 3 and 4 show that the 5-year linear model produces a better fit of the countercyclical pattern in expected returns than the nonlinear model of CC (1999) in the 1990s. However, a large part of the predictable variation in expected returns remains unexplained by the habit models. For example, during the early 1980s, extreme movements in the total expected return for the stock portfolio VW are observed, mostly due to the highly volatile short-term interest rate variables TB1 and XB3 in this period. These extreme movements are not fully explained by the habit models.

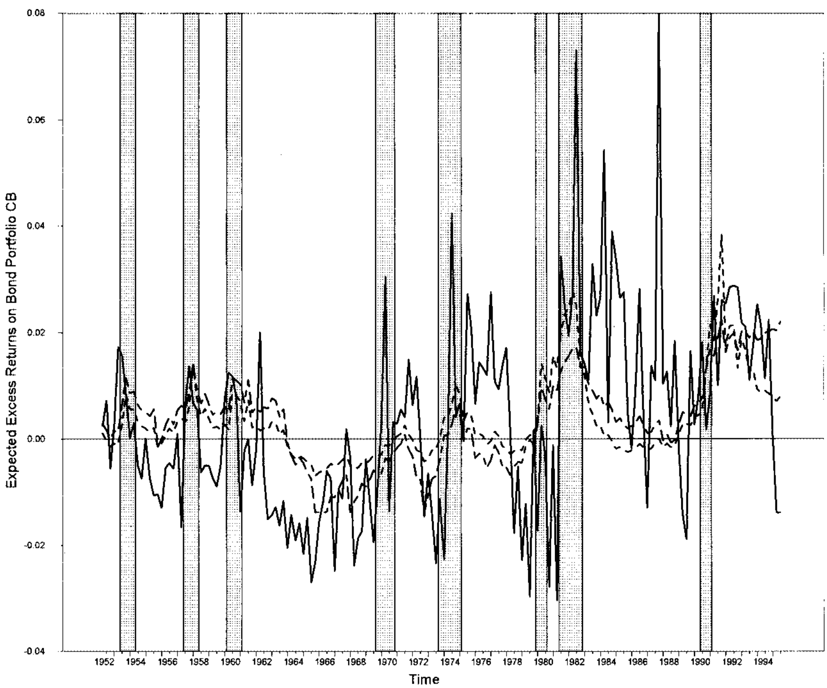

Figure 4
The expected excess return on the corporate bond portfolio
The solid line is the quarterly value of the (variance-adjusted) total expected excess return on the bond portfolio CB. The short and long dashed lines are the components of the expected excess returns that are explained by the 5-year habit model and the modified model of Campbell and Cochrane (1999). In each model consumption growth follows a homoscedastic AR(1) process. The persistence parameter is $\varphi = 0.99$. The shaded areas indicate recessions.

5. Robustness

5.1 Reward:volatility ratios and the surplus consumption ratio

The empirical analysis of the relation between expected returns and the surplus consumption ratio has been based on the hypothesis that the conditional covariance of returns with consumption is constant. While the results in Section 3.2 are largely consistent with this hypothesis, the failure to reject this hypothesis may be attributed to the lack of power or specification errors. Therefore it is important to examine the relation between expected returns and the surplus consumption ratio under an alternative specification. In this section, I replace Assumption 1 with the following assumption:

Assumption 2. *The reverse consumption beta is positive and constant through time,* $\beta^r_{i,t-1} \equiv \beta^r_i$.

Assumption 2 is consistent with the preliminary results reported earlier on the reverse consumption beta and allows the conditional covariance of returns

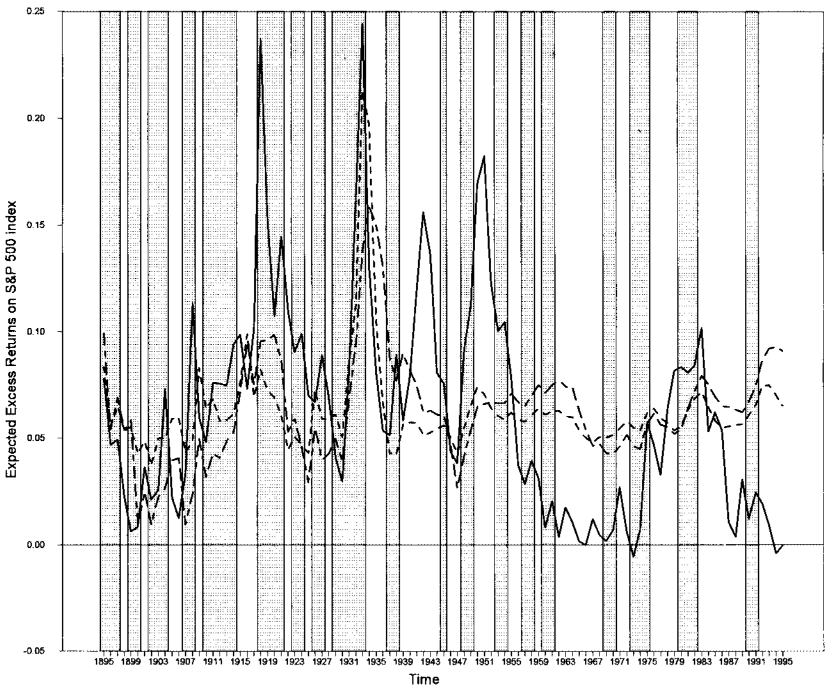

Figure 5
The expected excess return on the S&P 500 index
The solid line is the annual value of the (variance-adjusted) total expected excess return on the S&P 500 index. The short and long dashed lines are the components of the expected excess returns that are explained by the 5-year habit model and the modified model of Campbell and Cochrane (1999). In each model consumption growth follows a homoscedastic AR(1) process. The persistence parameter is $\varphi = 0.99$. The shaded areas indicate recessions.

with consumption to vary with the return volatility. Under this assumption, the covariance-based asset pricing model given by Equation (9) is transformed into the following:

$$\mathrm{E}_{t-1}[r_{it}] - r_{f,t-1} = -(1/2)\sigma^2_{i,t-1} + [\gamma(1+\lambda_{t-1})]\beta^r_i\sigma^2_{i,t-1}. \tag{20}$$

Here the reverse consumption beta, β^r_i, and return volatility, $\sigma^2_{i,t-1}$, are asset specific, but the sensitivity function, λ_{t-1}, is common for all assets. In this way, time variation in expected excess returns is attributable to time-varying volatility of returns and the time-varying sensitivity function. But the time variation in the ratio of the expected excess return on each asset to its conditional variance, or the reward:volatility ratio for each asset depends only on the time-varying sensitivity function.

I construct tests to assess the portion of time variation in the reward: volatility ratio that is explained by the sensitivity function λ_{t-1}. For this purpose, consider an unrestricted version of the model in Equation (20) given by the following:

$$\mathrm{E}_{t-1}[r_{it}] - r_{f,t-1} = -(1/2)\sigma^2_{i,t-1} + \Gamma_{i,t-1}\sigma^2_{i,t-1}. \tag{21}$$

Here $\Gamma_{i,t-1}$ is the unrestricted reward-to-volatility ratio for asset i. Equation (20) implies

$$\Gamma_{i,t-1} = \gamma(1+\lambda_{t-1})\beta^r_i. \tag{22}$$

Consider a hypothetical time-series regression for each asset:

$$\Gamma_{i,t-1} = \overline{\Gamma} + \beta_i(\lambda_{t-1} - \bar{\lambda}) + \varepsilon_{i,t-1}. \tag{23}$$

Here $\beta_i = \gamma\beta^r_i > 0$ is a constant. $\overline{\Gamma} > 0$ and $\bar{\lambda} > 0$ are unconditional means of $\Gamma_{i,t-1}$ and λ_{t-1}, respectively. The error term $\varepsilon_{i,t-1}$ represents the component of $\Gamma_{i,t-1}$ that is unexplained by the habit model. The coefficient of determination, R^2, for the regression is

$$\mathrm{VR}_i \equiv \frac{\beta^2_i\sigma^2_\lambda}{\sigma^2_\Gamma}. \tag{24}$$

The variance ratio VR_i here measures the fraction of time variation in the reward:volatility ratio, $\Gamma_{i,t-1}$, that is explained by λ_{t-1}.

Let $\Gamma_{i,t-1} = \boldsymbol{q}'_i\boldsymbol{Z}_{t-1}$ and $\sigma^2_{i,t-1} = \boldsymbol{d}'_i\boldsymbol{Z}_{t-1}$, where $\boldsymbol{Z}$ is a vector of information variables, including a constant. I define the following disturbance terms to estimate the coefficient β_i and the variance ratio VR_i:

$$u_{it} = r_{it} - r_{f,t-1} + (\boldsymbol{d}'_i\boldsymbol{Z}_{t-1})/2 - (\boldsymbol{q}'_i\boldsymbol{Z}_{t-1})(\boldsymbol{d}'_i\boldsymbol{Z}_{t-1}), \tag{25}$$

$$v_{it} = u^2_{it} - \boldsymbol{d}'_i\boldsymbol{Z}_{t-1}, \tag{26}$$

$$u_{iqt} = [(\boldsymbol{q}'_i\boldsymbol{Z}_t - \bar{q}_i) - \beta_i(\lambda_t - \bar{\lambda})](\lambda_t - \bar{\lambda}), \tag{27}$$

$$u_{ivt} = (\boldsymbol{q}'_i\boldsymbol{Z}_t - \bar{q}_i)^2(\mathrm{VR}_i) - \beta^2_i(\lambda_t - \bar{\lambda})^2. \tag{28}$$

The first two disturbance terms are orthogonal to the vector $\boldsymbol{Z}$ and are used to identify $\boldsymbol{d}$ and $\boldsymbol{q}$. The last two disturbance terms follow from the definitions of β_i and VR_i given by Equations (23) and (24), respectively. Here $\bar{q}_i$ is the unconditional mean of $\boldsymbol{q}'_i\boldsymbol{Z}_{t-1}$. Since all information variables except the constant are mean adjusted, $\bar{q}_i$ should be the first element of $\boldsymbol{q}_i$ and positive. By estimating the exactly identified system given by Equations (25)–(28) jointly using the GMM of Hansen (1982), I obtain consistent estimates of the standard errors of β_i and more importantly, VR_i.

Table 5 reports the results of estimating the system with the monthly data while Table 6 summarizes the results from the quarterly and annual data. The estimated coefficients for the reward:volatility ratios associated with the estimation of the 5-year habit model with $\varphi = 0.99$ are displayed in panel A of Tables 5 and 6. These coefficients and the standard errors are insensitive to the choice of the habit models. The chi-squared statistics based on the Wald test [see Newey and West (1987a)] with five degrees of freedom are for testing that the coefficients for a given portfolio on all information variables except the constant are zero. At the 5% significance level, the results suggest that the average reward:volatility ratio, $\bar{q}_i$, for each stock portfolio is positive and the reward:volatility ratio for each portfolio varies with the information variables.

When the relation between the expected return on the stock market and the volatility of returns is assumed to be fixed, Campbell (1987), Glosten, Jagannathan, and Runkle (1993), and Whitelaw (1994) have found this fixed coefficient to be negative or insignificant. Since the true reward:volatility ratio is time varying, the estimated relations in these earlier studies could be biased due to a missing-variables problem. A similar point is made by Scruggs (1998), who studies the relation between the expected return and volatility of the market using a two-factor approach, similar to Li (1998a).

The estimated coefficients β_i and VR_i are given in panel B of Tables 5 and 6. Similar to the results for the expected returns reported in Tables 3 and 4, the performance of the habit models improves with the duration and the persistence level of habit. Consider the results for the 5-year model with $\varphi = 0.99$. The estimates of β_i from each dataset are positive and significant at the 5% or the 10% level, consistent with the positive relation between the reward:volatility ratio and the sensitivity function, or the inverse relation between the reward-to-volatility ratio and the surplus consumption ratio. Together with the evidence on the negative relation between expected returns and the surplus consumption ratio and the positive relation between the volatility of returns and the surplus consumption ratio for each stock portfolio, the finding here is consistent with the result in Li (1998b) that changing reward to volatility explains more predictable variation in expected returns than the volatility of returns. Decreases in expected returns associated with increases in the volatility of returns near the peaks of the business cycle can be explained by the behavior of risk-averse investors who require less reward to volatility as a result of decreasing risk aversion at these times.

Finally, consider the variance ratios in Tables 5 and 6. While the variance ratios for the bond portfolios are higher than those for the stock portfolios, these ratios are less than 20% for all portfolios based on the linear habit models. The results for the nonlinear model are similar to those for the 5-year linear model, especially when the persistence parameter is $\varphi = 0.99$. Thus a large portion of time variation in the reward:volatility ratios, like in expected returns, is unexplained by the habit models.

5.2 Expected Returns with Simple Compounding

Since the analysis in the earlier sections is based on returns with continuous compounding, expected returns were analyzed along with the conditional variance of returns. When returns with continuous compounding in Equations (17)–(19) are replaced with returns with simple compounding, expected returns can be estimated by omitting the variance term in Equation (17). Consider the disturbance terms:

$$u_{it} = R_{it} - R_{f,t-1} - [\bar{\alpha}_i + a_i{}'\boldsymbol{Z}^o_{t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda})], \tag{29}$$

$$u_{ivt} = [a_i{}'\boldsymbol{Z}^o_t + \beta_i(\lambda_t - \bar{\lambda})]^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2. \tag{30}$$

Here each disturbance term has a mean of zero and the first term is orthogonal to $\boldsymbol{Z}^o_{t-1}$ and λ_{t-1}.

The results of estimating the system using the monthly, quarterly, and annual data for the case of $\varphi = 0.99$ are reported in Table 7. The estimated β_i and VR_i are qualitatively similar to the corresponding results in Tables 3 and 4. For other choices of the parameter φ, the estimation results are also not affected by using returns with simple compounding and omitting the variance term in Equation (17). Thus neither the relation between expected returns and the surplus consumption ratio nor the performance of the habit models is affected by the introduction of the variance of returns in the analysis of expected returns, as in the earlier sections.

It has been argued that when the autocorrelation of S_t is high, the sensitivity of surplus consumption to consumption, λ_{t-1}, should be inversely related to S_{t-1} [see Equation (11)]. This suggests that for habit models with high levels of habit persistence, I can use $1/S_{t-1}$ or its monotonic transformation, s_{t-1}, to replace λ_{t-1} and estimate the relation between expected returns and s_{t-1} directly. The results of estimating the relation using Equations (29) and (30) are reported in Table 8, where λ_{t-1} is replaced with s_{t-1}. The persistence parameter is fixed at $\varphi = 0.99$. For all durations of habit, the estimated values of the coefficient β_i are negative, consistent with the implication of the habit models that a low surplus consumption ratio should forecast high expected returns. For the monthly data, the precision of the estimated β_i here is lower than that in Table 7 for stock portfolios, whereas for the quarterly and annual data, the significance of β_i for each portfolio remains largely unchanged.

When the estimated variance ratios reported in Table 8 are compared with those in Table 7, I find that the explanatory power of the habit models does not change in any substantial way. The variance ratios estimated from the quarterly and annual data are larger than those from the monthly data, like the results in Table 7. For instance, the variance ratios estimated from the 5-year linear model using monthly and quarterly returns on the value-weighted stock portfolio VW are 2.3% and 14.4%, respectively. In annual data, the variance ratio for the S&P 500 index is 27.2%. Once again, the performance of the nonlinear model of CC (1999) is similar to that of the 5-year linear model.

Table 5
Estimation of the relation between the reward:volatility ratios and the sensitivity of surplus consumption to consumption: monthly data 1964:1–1995:12

Asset	Constant	XVW	XB3	YSP	DIV	TB1	Nonintercept $\chi^2(5)$
	Information variables						
	Panel A. Coefficient estimates for reward to volatility, $\boldsymbol{q}_i$, from the 5-year habit model with $\varphi = 0.99$						
VW	4.9457	1.7643	4.3233	−0.0442	7.2618	−7.4776	98.526
	(1.253)**	(0.844)**	(1.134)**	(1.275)	(1.865)**	(1.677)**	[0.0000]
EW	4.8594	2.6269	3.3981	0.0800	6.6154	−6.3283	120.975
	(0.939)**	(0.696)**	(1.092)**	(1.004)	(1.670)**	(1.422)**	[0.0000]
CB	1.8208	−4.2830	0.6528	9.4991	−0.3232	2.0411	43.039
	(2.906)	(1.403)**	(1.225)	(2.248)**	(2.237)	(2.205)	[0.0000]
GB	0.9415	−4.4886**	1.1423	7.1858	−0.9678	2.5927	30.516
	(2.141)	(1.620)	(1.135)	(1.875)**	(2.084)	(2.206)	[0.0000]

φ	Asset	β_t: 1 quarter	1 year	3 years	5 years	MCC	R^2 (VR_t): 3 months	1 year	3 years	5 years	MCC
		Panel B. Estimation results for β_i and $R^2(\mathrm{VR}_i)$									
0.75	VW	−0.0696	0.0916	0.0988	0.0989	0.0070	0.0008	0.0045	0.0057	0.0057	0.0024
		(0.089)	(0.062)	(0.061)	(0.061)	(0.007)	(0.002)	(0.006)	(0.007)	(0.007)	(0.004)
	EW	−0.0940	0.0790	0.0877	0.0877	0.0060	0.0018	0.0041	0.0054	0.0054	0.0023
		(0.087)	(0.057)	(0.056)	(0.056)	(0.006)	(0.003)	(0.006)	(0.007)	(0.007)	(0.005)
	CB	0.1680	0.1508	0.1737	0.1739	0.0154	0.0035	0.0092	0.0132	0.0131	0.0088
		(0.156)	(0.102)	(0.105)	(0.105)*	(0.010)	(0.006)	(0.012)	(0.015)	(0.014)	(0.011)
	GB	0.2291	0.1679	0.1816	0.1817	0.0162	0.0098	0.0171	0.0217	0.0217	0.0147
		(0.125)*	(0.084)**	(0.085)**	(0.085)**	(0.008)	(0.010)	(0.016)	(0.019)	(0.019)	(0.014)

0.99	VW	−0.0532	0.0843	0.0953	0.1637	0.0522	0.0007	0.0098	0.0124	0.0162	0.0042
		(0.079)	(0.039)**	(0.050)*	(0.085)**	(0.069)	(0.002)	(0.008)	(0.013)	(0.017)	(0.011)
	EW	−0.0760	0.0793	0.0945	0.1590	0.0532	0.0017	0.0104	0.0147	0.0184	0.0052
		(0.077)	(0.035)**	(0.041)**	(0.068)**	(0.059)	(0.003)	(0.009)	(0.013)	(0.016)	(0.012)
	CB	0.1462	0.0995	0.2950	0.6311	0.4566	0.0038	0.0102	0.0886	0.1800	0.2417
		(0.137)	(0.067)	(0.087)**	(0.149)**	(0.112)**	(0.007)	(0.013)	(0.037)**	(0.047)**	(0.067)**
	GB	0.2026	0.1005	0.2417	0.4961	0.3497	0.0110	0.0157	0.0896	0.1673	0.2151
		(0.109)*	(0.055)*	(0.076)**	(0.129)**	(0.099)**	(0.011)	(0.016)	(0.046)**	(0.065)**	(0.091)**
0.9999	VW	−0.0526	0.0835	0.0953	0.1759	−0.0128	0.0007	0.0099	0.0124	0.0168	0.0000
		(0.079)	(0.038)**	(0.051)*	(0.091)*	(14.19)	(0.002)	(0.008)	(0.013)	(0.017)	(8.804)
	EW	−0.0753	0.0786	0.0945	0.1704	−1.4180	0.0016	0.0106	0.0146	0.0189	0.0000
		(0.077)	(0.034)**	(0.042)**	(0.073)**	(12.94)	(0.003)	(0.009)	(0.013)	(0.016)	(8.860)
	CB	0.1454	0.0982	0.3036	0.6931	34.425	0.0038	0.0102	0.0937	0.1940	0.0323
		(0.136)	(0.066)	(0.088)**	(0.160)**	(20.55)*	(0.007)	(0.013)	(0.038)**	(0.048)**	(17.363)
	GB	0.2017	0.0988	0.2480	0.5413	23.477	0.0111	0.0156	0.0941	0.1780	0.0230
		(0.109)*	(0.054)*	(0.077)**	(0.138)**	(15.73)	(0.011)	(0.016)	(0.047)**	(0.067)**	(13.747)

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = r_{it} - r_{f,t-1} + (\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})/2 - (\boldsymbol{q}_i'\boldsymbol{Z}_{t-1})(\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})$	$\boldsymbol{Z}_{t-1}$
$v_{it} = u_{it}^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}$	$\boldsymbol{Z}_{t-1}$
$u_{iqt} = [(\boldsymbol{q}_i'\boldsymbol{Z}_t - \bar{q}_i) - \beta_i(\lambda_t - \bar{\lambda})](\lambda_t - \bar{\lambda})$	1
$u_{ivt} = (\boldsymbol{q}_i'\boldsymbol{Z}_t - \bar{q}_i)^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2$	1

$r_i - r_f$ represents the excess return with continuous compounding on asset i. $\boldsymbol{d}_i{}'\boldsymbol{Z}$ is the conditional variance of the excess return on asset i. $\boldsymbol{q}_i'\boldsymbol{Z}$ $(\boldsymbol{q}_i'\boldsymbol{Z} - \bar{q}_i)$ is the (mean-adjusted) reward:volatility ratio for asset i. $\lambda(\lambda - \bar{\lambda})$ is the (mean-adjusted) conditional sensitivity of surplus consumption to consumption from the linear habit model ($\alpha = 0.98$), or the modified model of Campbell and Cochrane (1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. β_i and $R^2(\mathrm{VR}_i)$ are the slope coefficient and coefficient of determination from regressing $\boldsymbol{q}_i'\boldsymbol{Z}$ on λ. Standard errors are in parentheses.

**,* indicate that the coefficient is significant at 5% and 10%, respectively.

χ^2 (5) statistic (with p-value in brackets) is for the Wald test that all coefficients of $\boldsymbol{q}_i$ except the intercept are zero.

Table 6
Estimation of the relation between the reward:volatility ratios and the sensitivity of surplus consumption to consumption: quarterly data 1952:1–1995:12 and annual data 1894–1995

Asset	Constant	XVW	XB3	YSP	DIV	TB1	Nonintercept $\chi^2(5)$
	Information variables						
	Panel A. Coefficient estimates for reward to volatility, $\boldsymbol{q}_i$, from the 5-year habit model with $\varphi = 0.99$						
	Quarterly data						
VW	4.3861	1.6866	1.5315	1.5728	4.9638	−4.2758	65.445
	(0.913)**	(0.820)**	(0.604)**	(0.621)**	(1.035)**	(1.052)**	[0.0000]
EW	3.6853	1.5297	1.1822	1.3045	4.0958	−3.0822	45.812
	(0.711)**	(0.636)**	(0.502)**	(0.489)**	(0.934)**	(0.913)**	[0.0000]
CB	2.5930	−3.4265	2.6538	6.3125	0.7163	0.0271	32.143
	(3.402)	(1.333)**	(0.830)**	(1.295)**	(1.564)	(1.382)	[0.0000]
GB	0.1803	−4.3798	1.8417	5.8481	0.7044	0.9746	39.013
	(2.185)	(1.155)**	(0.873)**	(1.034)**	(1.261)	(1.370)	[0.0000]
	Annual data						
S&P 500	1.9883				1.5143		
	(0.702)**				(0.591)**		

φ	Asset	β_t: 1 quarter	1 year	3 years	5 years	MCC	R^2 (VR$_t$): 1 quarter	1 year	3 years	5 years	MCC
		Panel B. Estimation results for β_i and $R^2(\text{VR}_i)$									
		Quarterly data									
0.75	VW	0.0250	0.0628	0.0689	0.0689	−0.0033	0.0002	0.0057	0.0071	0.0071	0.0013
		(0.063)	(0.034)*	(0.034)**	(0.034)**	(0.004)	(0.012)	(0.006)	(0.007)	(0.007)	(0.004)
	EW	0.0339	0.0602	0.0656	0.0656	−0.0015	0.0007	0.0081	0.0100	0.0100	0.0004
		(0.048)	(0.025)**	(0.026)**	(0.026)**	(0.003)	(0.019)*	(0.006)	(0.007)	(0.007)	(0.002)
	CB	0.1412	0.0573	0.0647	0.0647	0.0078	0.0045	0.0029	0.0038	0.0038	0.0044
		(0.149)	(0.080)	(0.081)	(0.081)	(0.011)	(0.008)	(0.007)	(0.008)	(0.008)	(0.011)
	GB	0.1966	0.0782	0.0828	0.0828	0.0127	0.0090	0.0055	0.0064	0.0064	0.0122
		(0.118)*	(0.061)	(0.061)	(0.061)	(0.008)	(0.009)	(0.008)	(0.009)	(0.009)	(0.013)

0.99	VW	0.0250	0.0657	0.0823	0.1715	0.1144	0.0002	0.0155	0.0145	0.0256	0.0374
		(0.063)	(0.023)**	(0.043)*	(0.074)**	(0.041)**	(0.012)	(0.009)*	(0.015)	(0.022)	(0.028)
	EW	0.0339	0.0600	0.0793	0.1547	0.0959	0.0007	0.0203	0.0210	0.0327	0.0412
		(0.048)	(0.018)**	(0.032)**	(0.054)**	(0.032)**	(0.019)*	(0.010)**	(0.016)	(0.025)	(0.032)
	CB	0.1412	0.0237	0.1810	0.4453	0.2891	0.0045	0.0012	0.0427	0.1053	0.1455
		(0.149)	(0.048)	(0.074)**	(0.129)**	(0.081)**	(0.008)	(0.005)	(0.025)*	(0.033)**	(0.041)**
	GB	0.1966	0.0298	0.1732	0.4134	0.2480	0.0090	0.0020	0.0404	0.0938	0.1106
		(0.118)*	(0.037)	(0.054)**	(0.091)**	(0.062)**	(0.009)	(0.005)	(0.021)*	(0.031)**	(0.041)**
0.9999	VW	0.0250	0.0655	0.0817	0.1887	20.964	0.0002	0.0159	0.0141	0.0274	0.1375
		(0.063)	(0.023)**	(0.043)*	(0.080)**	(5.533)**	(0.012)	(0.009)*	(0.015)	(0.024)	(0.057)**
	EW	0.0339	0.0597	0.0789	0.1689	14.801	0.0007	0.0207	0.0206	0.0343	0.1073
		(0.048)	(0.018)**	(0.032)**	(0.059)**	(4.643)**	(0.019)*	(0.010)**	(0.016)	(0.027)	(0.052)**
	CB	0.1412	0.0229	0.1900	0.5008	−12.408	0.0045	0.0012	0.0464	0.1175	0.0293
		(0.149)	(0.047)	(0.075)**	(0.138)**	(11.12)	(0.008)	(0.005)	(0.025)*	(0.033)**	(0.049)
	GB	0.1966	0.0287	0.1815	0.4627	−18.549	0.0090	0.0019	0.0438	0.1036	0.0677
		(0.118)*	(0.036)	(0.054)**	(0.098)**	(8.847)**	(0.009)	(0.005)	(0.022)**	(0.032)**	(0.060)
						Annual data					
0.75	S&P 500		−2.9942	−4.0763	−4.0764	0.0237		0.0466	0.0460	0.0460	0.0340
			(1.327)**	(1.808)**	(1.808)**	(0.013)*		(0.026)*	(0.026)*	(0.026)*	(0.028)
0.99			−2.9942	0.7816	0.4112	0.1359		0.0466	0.0778	0.0825	0.0509
			(1.327)**	(0.333)**	(0.161)**	(0.068)**		(0.026)*	(0.036)**	(0.030)**	(0.045)
0.9999			−2.9942	0.7092	0.3108	NA		0.0466	0.0786	0.0757	NA
			(1.327)**	(0.300)**	(0.120)**	NA		(0.026)*	(0.036)**	(0.025)**	NA

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = r_{it} - r_{f,t-1} + (\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})/2 - (\boldsymbol{q}_i'\boldsymbol{Z}_{t-1})(\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})$	$\boldsymbol{Z}_{t-1}$
$v_{it} = u_{it}^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}$	$\boldsymbol{Z}_{t-1}$
$u_{iqt} = [(\boldsymbol{q}_i'\boldsymbol{Z}_t - \bar{q}_i) - \beta_i(\lambda_t - \bar{\lambda})](\lambda_t - \bar{\lambda})$	1
$u_{ivt} = (\boldsymbol{q}_i'\boldsymbol{Z}_t - \bar{q}_i)^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2$	1

$r_i - r_f$ represents the excess return with continuous compounding on asset i. $\boldsymbol{d}_i'\boldsymbol{Z}$ is the conditional variance of the excess return on asset i. $\boldsymbol{q}_i'\boldsymbol{Z}$ $(\boldsymbol{q}_i'\boldsymbol{Z} - \bar{q}_i)$ is the (mean-adjusted) reward-to-volatility ratio for asset i. $\lambda(\lambda - \bar{\lambda})$ is the (mean-adjusted) conditional sensitivity of surplus consumption to consumption from the linear habit model ($\alpha = 0.98$ for quarterly data and $\alpha = 0.84$ for annual data), or the modified model of Campbell and Cochrane (MCC, 1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. β_i and $R^2(\mathrm{VR}_i)$ are the slope coefficient and coefficient of determination from regressing $\boldsymbol{q}_i'\boldsymbol{Z}$ on λ. Standard errors are in parentheses.

**,* indicate that the coefficient is significant at 5% and 10%, respectively.

$\chi^2(5)$) statistic (with p-value in brackets) is for the Wald test that all coefficients of $\boldsymbol{q}_i$ except the intercept are zero.

Table 7
Estimation of the relation between expected returns with simple compounding and the sensitivity of surplus consumption to consumption for the case $\phi = 0.99$: monthly data 1964:1–1995:12, quarterly data 1952:1–1995:4, and annual data 1894–1995

	β_t					VR_t				
Asset	1 quarter	1 year	3 years	5 years	MCC	1 quarter	1 year	3 years	5 years	MCC
					Monthly data					
VW	2.4048	2.3707	2.6871	3.4826	3.4333	0.0036	0.0256	0.0329	0.0244	0.0633
	(5.183)	(1.610)	(1.525)*	(2.321)	(1.479)**	(0.015)	(0.035)	(0.037)	(0.032)	(0.052)
EW	2.8434	4.3849	4.6145	5.7166	3.1314	0.0026	0.0450	0.0496	0.0340	0.0269
	(7.414)	(2.242)*	(2.119)**	(3.065)*	(1.953)*	(0.014)	(0.046)	(0.043)	(0.035)	(0.032)
CB	7.4180	1.1974	2.6101	5.1306	3.7125	0.1033	0.0206	0.0981	0.1664	0.2351
	(3.152)**	(1.201)	(1.263)**	(1.904)**	(1.090)**	(0.082)	(0.041)	(0.089)	(0.108)	(0.114)**
GB	8.8643	1.4308	2.7064	5.1563	3.9585	0.1694	0.0332	0.1188	0.1891	0.2995
	(3.517)**	(1.279)	(1.392)*	(2.086)**	(1.242)**	(0.118)	(0.059)	(0.114)	(0.135)	(0.154)**
					Quarterly data					
VW	32.388	10.206	11.967	17.034	13.199	0.1255	0.1625	0.1390	0.1187	0.2361
	(13.70)**	(3.612)**	(5.362)**	(6.931)**	(4.147)**	(0.103)	(0.118)	(0.113)	(0.089)	(0.125)*
EW	48.155**	14.8331	20.406	26.897	12.475	0.1702	0.2125	0.2415	0.1834	0.1373
	(9.61)	(4.930)**	(6.831)**	(9.170)**	(5.730)**	(0.119)	(0.127)*	(0.121)**	(0.097)*	(0.109)
CB	6.8143	−1.1758	5.6462	14.535	8.8889	0.0128	0.0048	0.0673	0.1804	0.2268
	(9.342)	(2.652)	(2.785)**	(4.372)**	(2.500)**	(0.036)	(0.021)	(0.070)	(0.107)*	(0.112)**
GB	9.6832	−0.6120	5.2510	14.182	9.2516	0.0290	0.0015	0.0653	0.1918	0.2692
	(10.04)	(2.724)	(3.407)	(5.475)**	(2.963)**	(0.061)	(0.013)	(0.087)	(0.141)	(0.143)*
					Annual data					
S&P 500		−0.1589	0.0352	0.0258	0.0114		0.0985	0.1190	0.2295	0.2370
		(0.193)	(0.036)	(0.012)**	(0.007)		(0.214)	(0.207)	(0.176)	(0.263)

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = R_{it} - R_{f,t-1} - [\bar{\alpha}_i + a_i{}'\mathbf{Z}^o_{t-1} + \beta_i(\lambda_{t-1} - \bar{\lambda})]$	$1, \mathbf{Z}^o_{t-1}$ and λ_{t-1}
$u_{ivt} = [a_i{}'\mathbf{Z}^o_t + \beta_i(\lambda_t - \bar{\lambda})]^2(\mathrm{VR}_i) - \beta_i^2(\lambda_t - \bar{\lambda})^2$	1

$R_i - R_f$ represents the excess return with simple compounding on asset i. $\lambda(\lambda - \bar{\lambda})$ is the (mean-adjusted) conditional sensitivity of surplus consumption to consumption from the linear habit model ($\alpha = 0.98$ for monthly and quarterly data and $\alpha = 0.84$ for annual data), or the modified model of Campbell and Cochrane (1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. $\mathbf{Z}^o$ is the vector of information variables, excluding a constant, that are orthogonal to λ. VR_i is the fraction of the variance of the expected return on asset i that is explained by λ. Standard errors are in parentheses.

**,* indicate that the coefficient is significant at 5% and 10%, respectively. Coefficients and standard errors for β_i from the monthly and quarterly data are multiplied by a constant (10^4).

Table 8
Estimation of the relation between expected returns with simple compounding and the log surplus consumption ratio for the case $\phi = 0.99$: monthly data 1964:1–1995:12, quarterly data 1952:1–1995:4 and annual data 1894–1995

	β_t					VR_t				
Asset	1 quarter	1 year	3 years	5 years	MCC	1 quarter	1 year	3 years	5 years	MCC
					Monthly data					
VW	−0.0004	−0.0054	−0.0066	−0.0063	−0.0040	0.0000	0.0129	0.0304	0.0230	0.0230
	(0.009)	(0.006)	(0.004)	(0.004)	(0.003)	(0.001)	(0.028)	(0.038)	(0.033)	(0.029)
EW	−0.0013	−0.0102	−0.0105	−0.0096	−0.0050	0.0001	0.0233	0.0392	0.0282	0.0184
	(0.013)	(0.008)	(0.006)*	(0.006)	(0.003)	(0.003)	(0.036)	(0.040)	(0.034)	(0.024)
CB	−0.0129	−0.0051	−0.0069	−0.0091	−0.0053	0.0882	0.0358	0.1055	0.1523	0.1260
	(0.006)**	(0.004)	(0.003)**	(0.003)**	(0.002)**	(0.074)	(0.057)	(0.092)	(0.103)	(0.085)
GB	−0.0140	−0.0059	−0.0071	−0.0091	−0.0053	0.1160	0.0541	0.1250	0.1710	0.1439
	(0.006)**	(0.004)	(0.004)**	(0.004)**	(0.002)**	(0.098)	(0.079)	(0.118)	(0.130)	(0.114)
					Quarterly data					
VW	−0.0473	−0.0395	−0.0345	−0.0343	−0.0347	0.1365	0.1818	0.1754	0.1442	0.1806
	(0.018)**	(0.016)**	(0.013)**	(0.014)**	(0.011)**	(0.103)	(0.146)	(0.122)	(0.106)	(0.098)*
EW	−0.0703	−0.0567	−0.0503	−0.0469	−0.0353	0.1827	0.2299	0.2283	0.1674	0.1212
	(0.026)**	(0.022)**	(0.019)**	(0.019)**	(0.014)**	(0.117)	(0.151)	(0.129)*	(0.112)	(0.086)
CB	−0.0059	−0.0069	−0.0189	−0.0267	−0.0252	0.0050	0.0129	0.1145	0.1837	0.2026
	(0.014)	(0.008)	(0.007)**	(0.008)**	(0.008)**	(0.023)	(0.033)	(0.085)	(0.103)*	(0.109)*
GB	−0.0096	−0.0093	−0.0180	−0.0260	−0.0264	0.0147	0.0257	0.1166	0.1944	0.2443
	(0.015)	(0.009)	(0.008)**	(0.010)**	(0.009)**	(0.045)	(0.051)	(0.107)	(0.135)	(0.149)*
					Annual data					
S&P 500		−0.0894	−0.1142	−0.1046	−0.0868		0.0794	0.2301	0.2717	0.2962
		(0.137)	(0.068)	(0.047)**	(0.048)		(0.222)	(0.208)	(0.204)	(0.274)

The following system is estimated jointly:

Disturbance term	Orthogonal to
$u_{it} = R_{it} - R_{f,t-1} - [\bar{\alpha}_i + a_i{}'\mathbf{Z}^o_{t-1} + \beta_i(s_{t-1} - \bar{s})]$	$1, \mathbf{Z}^o_{t-1}$ and s_{t-1}
$u_{ivt} = [a_i{}'\mathbf{Z}^o_t + \beta_i(s_t - \bar{s})]^2(\mathrm{VR}_i) - \beta_i^2(s_t - \bar{s})^2$	1

$R_i - R_f$ represents the excess return with simple compounding on asset i. $s(s - \bar{s})$ is the (mean-adjusted) log surplus consumption ratio from the linear habit model ($\alpha = 0.98$ for monthly and quarterly data and $\alpha = 0.84$ for annual data), or the modified model of Campbell and Cochrane (1999). In each model consumption growth is assumed to follow a homoscedastic AR(1) process. $\mathbf{Z}^o$ is the vector of information variables, excluding a constant, that are orthogonal to s. VR_i is the fraction of the variance of the expected return on asset i that is explained by s. Standard errors are in parentheses.
**,* indicate that the coefficient is significant at 5% and 10%, respectively.

For instance, the variance ratios for the portfolio VW or the S&P 500 index from the nonlinear model are 2.3% using the monthly data, 18.1% using the quarterly data, and 29.6% using the annual data.

5.3 Changes in regimes

Ferson and Merrick (1987) report evidence on instability in relations between asset returns and consumption in the post-October 1979 period with a change in targets employed by the Federal Reserve in the implementation of monetary policy. Evans and Lewis (1994, 1995) show that discrete process shifts associated with changes in regimes induce the "peso problem," namely, correlations between forecast errors and conditioning information in studying the behavior of interest rates. For the models considered here, instability in the relations between expected returns, the reward:volatility ratios, and the sensitivity functions may weaken the explanatory power of the habit models. As an experiment, I include D, and (D)(TB1) as additional information variables, where D is the dummy variable indicating the post-October 1979 regime. When the systems in Tables 3–8 are estimated in this way, I find that the explanatory power of the habit models does not change in any substantial way.

6. Conclusions

This article uses the consumption-based asset pricing model with habit formation to study the time variation in expected returns on stocks and bonds. I find that habit models generally imply an inverse relation between expected returns and surplus consumption. I empirically examine the statistical significance of the relation for the linear habit model with alternative levels of habit persistence and different durations of habit, and the nonlinear, infinite-horizon habit model of CC (1999). I also estimate the portion of time variation in expected returns on stocks and bonds that is associated with movements in surplus consumption implied by each habit model.

Empirical results indicate that the performance of the linear habit model improves with the duration and persistence of habit formation. When habit is assumed to slowly adjust to past 5-year's consumption, the inverse relation between expected returns on stocks and bonds and surplus consumption is often statistically significant. The evidence also indicates that for common stocks, the volatility of returns is positively related to surplus consumption and the reward:volatility ratio is negatively related to surplus consumption. Therefore the countercyclical variation in the price of risk and the negative relation between expected returns and the volatility in the stock market documented in the literature can be explained in part by the time-varying surplus consumption implied by the habit models. However, less than 30% of the predictable variation of expected returns or the price of risk, using standard lagged information variables, is attributed to surplus consumption. Given the predictive power of the information variables for the monthly, quarterly, and annual returns studied in this article, the fraction of the stock return variance that can be explained by surplus consumption is economically small. With a high level of habit persistence, the performance of the infinite-horizon non-linear habit model of CC (1999) is similar to that of the 5-year linear habit model.

Appendix A: Calculation of the Sensitivity Functions

Consumption growth follows a conditionally normal and homoscedastic AR(1) process:

$$c_t - c_t = \mu_{c,t-1} + u_{ct} = (1-\varphi_c)\bar{\mu}_c + \varphi_c(c_{t-1} - c_{t-2}) + u_{ct}, u_{ct} \sim N(0, \sigma^2). \tag{A1}$$

Using the definition of S_t given by Equation (5), the sensitivity function given by Equation (11) for the linear habit specification in Equation (10) is

$$\begin{aligned}\lambda_{t-1} &= \mathrm{E}_{t-1}\left[\frac{1}{S_t}\right] - 1 \\ &= \mathrm{E}_{t-1}[1 - (X_{t-1}/C_{t-1})e^{-(c_t - c_{t-1})}]^{-1} - 1 \\ &= \int_{-\infty}^{\infty}\left[1 - \alpha\left(\frac{1-\varphi^m}{1-\varphi^{Jm}}\right)\sum_{j=1}^{J}\varphi^{(j-1)m}(C_{t-j}/C_{t-1})e^{-(\mu_{c,t-1}+\sigma y)}\right]^{-1} p(y)dy - 1, \end{aligned} \tag{A2}$$

where $\mu_{c,t-1}$ and σ are given by Equation (A1) and $p(y)$ is the density function for a standard normal distribution. The sensitivity function is evaluated by feeding the history of actual consumption into Equation (A2).

In the CC (1999) model, consumption growth is i.i.d. ($\varphi_c = 0$) and the log surplus consumption ratio follows a conditionally normal and heteroscedastic AR(1) process:

$$s_t = (1-\varphi^m)\bar{s} + \varphi^m s_{t-1} + \lambda_{t-1}u_{ct}, \tag{A3}$$

where the sensitivity function λ_{t-1} is

$$\lambda_{t-1} = (1/\overline{S})\sqrt{1 - 2(s_{t-1} - \bar{s})} - 1 \tag{A4}$$

if the right-hand side of Equation (A4) is positive, and zero otherwise. The steady state is $\overline{S} = \sigma[\gamma/(1-\varphi^m)]^{1/2}$. In a modified model, I assume that consumption growth follows Equation (A1). To be consistent with the linear habit model, the autocorrelation coefficient of the surplus consumption ratio is written as φ^m that measures the persistence of habit.

Compared with the sensitivity function of Equation (A2) implied by the linear habit model, one advantage of the CC (1999) approach is that the sensitivity function of Equation (A4) is an explicit function of s_t and therefore can be calculated without evaluating a conditional expectation. One potential difficulty of implementing the CC (1999) approach is that with large movements in s_t, the sensitivity function of Equation (A4) can reach zero and stay at this level for a prolonged period of time. Further, unlike the finite-horizon linear model, which is well defined

Table A1
Tests of alternative specifications of conditions covariances of returns with consumption growth

	Hypothesis				
Asset	Reverse consumption beta $e_t'Z$ is constant	Return volatility $d_t'Z$ is constant	Covariance $h_t'Z$ is constant	Consumption beta $b_t'Z$ is constant	Consumption volatility $d_c'Z$ is constant
	Monthly data (χ^2 statistic)				
VW	5.164	20.128	3.658	4.229	6.849
	[0.396]	[0.001]	[0.600]	[0.517]	[0.232]
EW	1.100	11.456	4.176	4.016	
	[0.954]	[0.043]	[0.524]	[0.547]	
CB	1.545	83.465	0.501	0.592	
	[0.908]	[0.000]	[0.992]	[0.988]	
GB	4.010	61.464	0.309	0.490	
	[0.548]	[0.000]	[0.998]	[0.993]	
All	11.421	128.94	12.688	12.509	
	[0.935]	[0.000]	[0.890]	[0.898]	
	Quarterly data (χ^2 statistic)				
VW	5.526	3.890	2.884	2.212	5.741
	[0.355]	[0.565]	[0.718]	[0.819]	[0.332]
EW	7.318	6.582	5.408	3.582	
	[0.198]	[0.254]	[0.368]	[0.611]	
CB	3.672	48.764	8.485	7.120	
	[0.598]	[0.000]	[0.131]	[0.212]	
GB	4.684	35.675	6.386	6.250	
	[0.456]	[0.000]	[0.270]	[0.283]	
All	13.892	71.106	20.919	12.038	
	[0.836]	[0.000]	[0.401]	[0.915]	
	Annual data (t statistic)				
S&P 500	−0.436	0.015	−0.230	−0.508	1.4437
	[0.663]	[0.988]	[0.818]	[0.612]	[0.149]

Each of the following systems of disturbance terms is estimated jointly:

System A	System B	System C
$u_{it} = r_{it} - r_{f,t-1} - \boldsymbol{a}_i'\boldsymbol{Z}_{t-1}$	$u_{ct} = c_t - c_{t-1} - \boldsymbol{a}_c'\boldsymbol{Z}_{t-1}$	$u_{ct} = c_t - c_{t-1} - \boldsymbol{a}_c'\boldsymbol{Z}_{t-1}$
$v_{it} = u_{it}^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}$	$v_{it} = u_{ct}(r_{it} - r_{f,t-1}) - \boldsymbol{h}_i'\boldsymbol{Z}_{t-1}$	$v_{ct} = u_{ct}^2 - \boldsymbol{d}_c'\boldsymbol{Z}_{t-1}$
$w_{it} = (\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})(\boldsymbol{e}_i'\boldsymbol{Z}_{t-1}) - u_{it}(c_t - c_{t-1})$		$w_{it} = (\boldsymbol{d}_c'\boldsymbol{Z}_{t-1})(\boldsymbol{b}_i'\boldsymbol{Z}_{t-1}) - u_{ct}(r_{it} - r_{f,t-1})$

Each of the disturbance terms is orthogonal to the vector of information variables, $\boldsymbol{Z}$. $r_i - r_f$ represents the excess return with continuous compounding on asset i. $c_t - c_{t-1}$ is the change in the log of per capita, seasonally adjusted real consumption of nondurables plus services. $\boldsymbol{a}_i'\boldsymbol{Z}$ and $\boldsymbol{a}_c'\boldsymbol{Z}$ are conditional means of the excess return on asset i and consumption growth, respectively. $\boldsymbol{h}_i'\boldsymbol{Z}$ is the conditional covariance of the excess return on asset i with consumption growth. $\boldsymbol{d}_i'\boldsymbol{Z}$ and $\boldsymbol{d}_c'\boldsymbol{Z}$ are conditional variances of the excess return on asset i and consumption growth, respectively. $\boldsymbol{e}_i'\boldsymbol{Z}$ is the reverse consumption beta of asset i. $\boldsymbol{b}_i'\boldsymbol{Z}$ is the consumption beta of asset i. $\chi^2(5)$ statistic (with p-value in brackets) is for the Wald test that all coefficients except the intercept are zero.

even for $\varphi = 1$, in the CC (1999) model, one must impose the restriction $0 < \varphi^m < 1 - \gamma\sigma^2$ to insure that $\overline{S} < 1$ and avoid the unit root problem.

Appendix B: Covariance of Returns with Consumption

The reverse consumption beta is $\beta_{i,t-1}^r = \text{cov}_{t-1}(r_{it}, c_t)/\sigma_{i,t-1}^2$, where $\sigma_{i,t-1}^2$ is the conditional variance of the return on asset i. Let $\boldsymbol{Z}$ denote the vector of information variables including a constant. Following much of the literature, conditional moments of returns including mean, variance, and beta are assumed to be linear in $\boldsymbol{Z}$. Let the conditional expected excess return and volatility of asset i be $\boldsymbol{a}_i'\boldsymbol{Z}$ and $\sigma_{i,t-1}^2 = \boldsymbol{d}_i'\boldsymbol{Z}$, respectively, and the conditional reverse consumption beta be $\beta_{i,t-1}^r = \boldsymbol{e}_i{}'\boldsymbol{Z}$. To examine whether β_i^r and σ_i^2 are time varying, I employ the following disturbance terms:

$$u_{it} = r_{it} - r_{f,t-1} - \boldsymbol{a}_i'\boldsymbol{Z}_{t-1}, \tag{B1}$$

$$v_{it} = u_{it}^2 - \boldsymbol{d}_i'\boldsymbol{Z}_{t-1}, \tag{B2}$$

$$w_{it} = (\boldsymbol{d}_i'\boldsymbol{Z}_{t-1})(\boldsymbol{e}_i'\boldsymbol{Z}_{t-1}) - u_{it}(c_t - c_{t-1}), \tag{B3}$$

for $i = 1, \ldots, n$. Each of the disturbance terms is orthogonal to $\boldsymbol{Z}$. I estimate this exactly identified system using the GMM of Hansen (1982).

In the second approach, I assume that the conditional covariance of the excess return on each asset with consumption growth is linear in information variables: $\text{cov}_{t-1}(r_{it}, c_t) = \boldsymbol{h}_i'\boldsymbol{Z}_{t-1}$, where $\boldsymbol{h}_i$ is a coefficient vector. The third approach uses a multiplicative decomposition of the conditional covariance with consumption in the form: $\text{cov}_{t-1}(r_{it}, c_t) = \beta_{i,t-1}\sigma_{c,t-1}^2$, where $\beta_{i,t-1} = \boldsymbol{b}_i{}'\boldsymbol{Z}_{t-1}$ is the conditional consumption beta of the excess return on asset i and $\sigma_{c,t-1}^2 = \boldsymbol{d}_c'\boldsymbol{Z}_{t-1}$ is the conditional volatility of consumption growth.

The results of estimating the three alternative specifications indicate that there is no evidence that the conditional covariances, the consumption betas, or the reverse consumption betas are time varying (see Table A1). The results are qualitatively similar under alternative specifications where quadratic terms of the information variables are included in the conditional expected returns or where the standard deviations of returns are linear in the information variables, as in Kandel and Stambaugh (1990) and Whitelaw (1994). The results on the consumption volatility are in contradiction to what Kandel and Stambaugh (1990) find using quarterly consumption data over a longer time period extending back to 1929.

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