An Exploration of Asset Returns in a Production Economy with Relative Habits

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Abstract

This paper explores asset returns in a production economy with habit forming households. I show that a model with capital adjustment costs and relative habits is consistent with salient financial facts, such as the equity premium, the market price of risk, and the riskfree interest rate. These predictions are not at odds with good business cycle predictions. In the model economy investment is strongly procyclical and more volatile than output, which in turn is more volatile than consumption. Moreover, consumption growth is positively autocorrelated and negatively (positively) correlated with future (past) stock returns.

Keywords: Equity premium, Business cycles, Habit persistence.

JEL classification: G12, E22, C63

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1 Introduction

Habit forming preferences have been notoriously successful in solving the equity premium puzzle. One of their most popular representations is due to Abel (1990, 1999), who shows that an asset pricing model with relative habits can account for financial regularities that can not be explained by standard models. However, this finding is confined to a fruit-tree framework in which equilibrium consumption follows a stochastic process. To date, we still do not know how Abel's habits fare when households are allowed to take consumption decisions. This paper takes a first step towards filling this gap, and asks whether a model with relative habits and consumption choice can be consistent with the empirical equity premium and business cycle facts simultaneously.

After Mehra and Prescott's (1985) statement of the equity premium puzzle, researchers have attempted to come up with a solution by allowing for habit forming preferences. Two leading candidates are *relative habits* -agents derive utility from the ratio between current consumption and their habit stock- and *survival habits* -agents derive utility from the gap between current consumption and their habit stock. In an endowment economy framework, Abel (1990, 1999) uses the former and Constantinides (1990), Boldrin, Christiano and Fischer (1997), and Campbell and Cochrane (1999) use the later to explain the historical premium on stocks, among other financial facts. Recently, Budría and Díaz (2005) have compared the financial predictions of these two utility functions.

The endowment economy framework nevertheless has its limitations, and recently some authors have extended the analysis to production economies. This new scenario challenges models of habit formation by offering the possibility of studying business cycle and financial phenomena simultaneously.

Boldrin, Christiano and Fischer (1995, 2001), Christiano and Fisher (1998) and Jermann (1998) develop versions of the real business cycle model (RBC model, henceforth) that can generate a sizable premium when short term rigidities are introduced in the capital market. These studies draw on a survival representation of habits. In this paper, I depart from this view and assume that habits are relative.

Referring to his model of asset pricing, Abel (1999, p. 27) argues that "the next step is to extend the model to allow the economy to transfer goods across time by capital investment". In this paper, I take that step and develop a model with a nontrivial production sector and consumption choice. Households in the artificial economy are very reluctant to changes in consumption levels, but, unlike in endowment economies, they can take consumption decisions to insure against consumption risk. In order to mitigate this smoothing channel, I introduce capital adjustment costs. New capital is accumulated according to a concave technology so that changing the capital stock rapidly is more costly than changing it slowly. After a positive shock, firms react allocating less resources to investment or, to put it different, very risk averse individuals end up following volatile consumption paths despite the habit formation process. Thus, in equilibrium, households face high consumption risk, and require a substantial premium on stocks to be compensated by the risk borne.

Relative habits have been used to address a variety of economic problems[1]. However, in spite of its popularity, the macroeconomic predictions of this utility function are still unknown. To fill this gap, I report business

[1] Drawing on this specification Carroll, Overland and Weil (2000) construct a growth model that accounts for the observed positive correlation between savings and growth, Fuhrer (2000) shows that a monetary policy model can capture the gradual hump-shaped response of real spending and inflation to various shocks, Díaz, Pijoan, and Ríos-Rull (2003) ask whether Aiyagari's model of precautionary savings can account for the empirical wealth distribution when habits are incorporated, and Ravn, Schmitt-Grohé and Uribe (2004) explore the demand function faced by habit forming individuals.

cycle statistics and show that when combined with capital adjustment costs, relative habits are consistent with salient business cycle features, such as the positive autocorrelation of consumption growth, the positive (negative) correlation between consumption growth and past (future) stock returns, the pro-cyclicality of consumption and investment, as well as the ordering of volatilities: investment is more volatile than output, which in turn is more volatile than consumption.

The rest of the paper is organized as follows. Section 2 describes the model economy and defines its equilibrium. Section 3 discusses the rationale behind the choice of functional forms and parameters. Section 4 reports the main findings upon financial and macroeconomic variables. It also presents a sensitivity analysis in which the effects of changes in the importance of habits and capital adjustment costs on asset returns are evaluated. Finally, Section 5 presents the concluding remarks.

2 The model

The model presented is a modification of the one sector stochastic growth model. The economy is populated by a representative firm and an arbitrarily large number of identical households, each endowed with a fixed amount of labor which is supplied to the firm. The firm produces a single consumption/investment good according to a constant returns to scale production function and finances its investment through retained earnings. Two assets in this economy are traded in complete financial markets: a perfectly divisible equity share of the firm and a one-period riskless bond. The equity is a claim to a infinite stream of firm's dividends. The bond is a right to perceive one unit of consumption one period ahead.

2.1 Households

Households' tastes over streams of consumption are given at time t by

$$V_t = E_t \sum_{j=0}^{\infty} \beta^j U(C_{t+j,} H_{t+j}) \tag{1}$$

where β is the subjective discount factor, C_t is the consumption rate, and H_t is the habit stock. Current habits are determined by yesterday's consumption,

$$H_t = C_{t-1} \tag{2}$$

Labor time is exogenous and normalized to unity, $L_t = 1$. At each period, the budget constraint is

$$W_t L_t + S_t(P_t^e + D_t) + B_t = C_t + S_{t+1} P_t^e + B_{t+1} P_t^b \tag{3}$$

where L_t is labor, W_t is the wage rate, S_t and B_t are the quantities of equities and bonds the investor holds from period $t-1$ to period t, and P_t^e and P_t^b denote the price of the risky asset and the price of the riskless bond, respectively. The dividend on equity is D_t. The bond pays one unit of the consumption good at time $t+1$ and then expires.

Households maximize (1) subject to (2) and (3).

2.2 The Firm

The representative firm produces according to a constant returns to scale production function, with labor and capital as inputs

$$Y_t = Z_t F(K_t, L_t) \tag{4}$$

where Z_t is a technology shock. At each period, the firm has to decide on the amount of investment and how much labor to hire. The objective of the firm manager is to maximize the discounted present value of a infinite sequence of cash flows to the owners,

$$Max_{\{K_{t+j}, L_{t+j}\}_{j=0}^{\infty}} \sum_{j=0}^{\infty} \beta^j M_{t+j}(Z_{t+j}F(K_{t+j}, L_{t+j}) - W_{t+j}L_{t+j} - I_{t+j}) \tag{5}$$

where M_{t+j} is the shareholders' marginal valuation in terms of today's consumption of one additional unit of consumption at time $t+j$. More formally, $M_{t+j} = \frac{V_{C_{t+j}}}{V_{C_t}}$, where V_{C_t} is the derivative of (1) with respect to C_t.

The firm accumulates capital according to the following equation

$$K_{t+1} = (1-\delta)K_t + \psi(I_t/K_t)K_t \tag{6}$$

where δ is the depreciation rate and $\psi(.)$ is a positive, concave function. This function implies that in order to increase the capital stock rapidly, large amounts of investment are needed.

Dividends to shareholders are defined as the net cash flow –the residual of output value after labor wages have been paid and investment has been financed– of the firm at every period,

$$D_t = Y_t - W_t L_t - I_t \tag{7}$$

2.3 Equilibrium

Let $X_t = (K_t, Z_t, H_t)$ be the vector of state variables. An equilibrium is a sequence of households plans $\{C_t(X_t), S_t(X_t), B_t(X_t)\}_{t=1}^{\infty}$, a sequence of firm aggregates $\{Y_t(X_t), I_t(X_t), D_t(X_t)\}_{t=1}^{\infty}$ and a sequence of prices, $\{W_t(X_t)$, $P_t^e(X_t)$, $P_t^b(X_t)\}_{t=1}^{\infty}$ such that: (i) Aggregate consumption and investment equals output, $C_t(X_t)+I_t(X_t) = Y_t(X_t)$, the aggregate holdings of the equity is a fixed amount normalized to one, $S_t(X_t) = 1$, and the riskless asset is in zero net supply, $B_t(X_t) = 0$; (ii) For all t, factor inputs are determined by the firm's first order conditions, $W_t = Y_{L_t}(X_t)$ and $E_t[M_{t+1}(Y_{K_{t+1}}(X_{t+1}) - I_{K_{t+1}}(X_{t+1})] = I_{K_{t+1}}(X_t)$; and (iii) Asset prices are determined by the first order conditions of households, $P_t^e = E_t[M_{t+1}(P_{t+1}^e+D_{t+1})]$ and $P_t^b = E_t(M_{t+1})$.

Aggregate quantities and asset prices are computed from the solution to the related social planner's problem. The rate of return on equity and the riskfree asset are, respectively,

$$R_{t+1}^e = \frac{P_{t+1}^e + D_{t+1}}{P_t^e} - 1 \qquad \text{and} \qquad R_t^f = \frac{1}{P_t^b} - 1 \tag{8}$$

The premium on equity is then

$$EP_t = R_{t+1}^e - R_t^f \tag{9}$$

3 Calibration

I calibrate the model on a quarterly basis. First, I choose explicit functional forms for the utility function, the production function, the technological process, and the capital accumulation equation. Then, I assign values to the parameters involved so that the model reproduces some features of US macroeconomic and financial data.

3.1 Functional forms

3.1.1 Preferences

The representative household has relative habits. In particular,

$$U(C_t, H_t) = \frac{(C_t/H_t^{\gamma})^{1-\tau}}{1-\tau} \qquad \gamma \in (0,1) \tag{10}$$

According to this specification, the enjoyment of consumption depends on the proportion of current consumption relative to the habit stock[2]. Increasing today's purchases has two effects. On the one hand, it increases instantaneous utility. On the other hand, it reduces the enjoyment of future consumption through the induced increase in the habit stock. I assume that households are aware of this second effect, i.e., habits are internal[3].

3.1.2 Production function

Output in the economy is given by a Cobb-Douglas production function,

$$Y_t = Z_t K_t^{\alpha} L_t^{1-\alpha} \tag{11}$$

At the steady state, Z_t grows at a rate g. The state of technology evolves

[2]See Carroll (2001) for technical details characterizing the optimal solution of the consumer's problem with this utility function.

[3]Some studies assume that habits are *external*. This corresponds to a "keeping up with the Joneses" utility function in which the reference consumption level depends on the economy-wide consumption. In this case, the habit stock is viewed by the household as evolving exogenously. Although the financial implication of internal and external habits are similar, they are associated to different levels of risk aversion. In particular, Boldrin, Christiano and Fischer (1997) have shown that the coefficient of risk aversion in wealth is counterfactualy high with "keeping up with the Joneses" utility functions, while it is reasonably low for internal specifications.

according to

$$z_{t+1} = \overline{z} + \rho z_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{12}$$

for $z_t = \log(Z_t)$.

3.1.3 Capital accumulation technology

Drawing on previous work, I choose the following functional form for the cost of adjustment function

$$\psi(I_t/K_t) = \frac{a}{1 - 1/\xi}(I_t/K_t)^{1-\frac{1}{\xi}} + b \tag{13}$$

The above capital equation can be related to the q-theory. Tobin's q, defined as the derivative of tomorrow's capital stock with respect to investment, is

$$q_t = \psi'(I_t/K_t) = a(I_t/K_t)^{-\frac{1}{\xi}} \tag{14}$$

When $\xi = \infty$, the marginal rate of transformation between consumption and capital is constant and equal to one, that is, there are not capital adjustment costs. When $\xi < \infty$, q_t is decreasing in investment and fluctuates endogenously over the cycle. To make it clear, Figure 1 illustrates the relationship between ξ and the concavity of the cost of adjustment function.

It can be shown that the parameter ξ captures the elasticity of investment with respect to Tobin's q[4]. In the next section, I set ξ according to previous estimates. Finally, the parameters a and b determine the steady state values of q_t and the investment-capital ratio.

[4] Investment can be written as $I = (qb)^\xi K$. Hence, $\frac{\Delta I}{\Delta q} = \xi(qb)^{\xi-1}bK$. Then, using the definition of elasticity, it follows that $\frac{q}{I}\frac{\Delta I}{\Delta q} = \xi$.

3.2 Parameters

3.2.1 Standard RBC parameters

The model is calibrated to replicate a set of long-run averages computed from US data. I target the investment-capital ratio, the capital share, the riskfree rate, the average consumption growth, and the autocorrelation and standard deviation of Solow's residuals. These conditions give $\delta = 0.025$, $\alpha = 0.4$, $\beta = 0.99$, $g = 0.005$, $\rho = 0.95$, and $\sigma_\varepsilon = 0.01$. Finally, the preference parameter τ is set to 5.

3.2.2 Tobin's q

The existence of costs for installing new capital is well documented in the literature. Christiano and Fischer (1998) review several estimations of the elasticity of investment with respect to Tobin's q, and report values that range from 0.4 to 1.14. In this paper, however, I choose a somewhat lower value, $\xi = 0.25$. This choice is motivated by the fact that previous works in the field by Jermann (1998), Hornstein and Uhlig (2000) and Boldrin, Christiano and Fischer (2001) use a similar elasticity and, therefore, my choice allows for comparison. Section 4.5 presents a sensitivity analysis which indicates that the results presented here can also be obtained with slightly higher elasticities.

Finally, the parameters a and b are selected to match the steady state properties of a model without capital adjustment costs[5].

[5] These steady state consitions are (i) $I/K = \delta$, and (ii) $q = 1$. The steady state investment is $I = [\frac{(\delta-b)(1-1/\xi)}{a}]^{\frac{1}{1-1/\xi}} K$. Thus, imposing (i), gives $b = \frac{1}{1-\xi}\delta$. Using (ii), $q = a(\delta)^{-\frac{1}{\xi}} = 1$, which gives $a = \delta^{\frac{1}{\xi}}$.

3.2.3 Habits

The inclusion of habits in the utility function appears to be consistent with previous econometric analyses[6]. Once the standard RBC parameters and the cost of adjustment function have been calibrated, I select the size of habits to replicate the empirical equity premium. I take as a target a 6.63% annual premium, which taking an arithmetic average gives a 1.66% quarterly premium. This condition gives $\gamma = 0.80$. This choice is in line with previous parametrizations[7].

4 Findings

This section presents a set of financial and macroeconomic observations for the artificial economy, and compares them to those of US postwar data. To get further insights, the results of a model without habits and/or without capital adjustment costs are also presented. To compute quantities and asset prices, I calculate nonlinear functions of the state variables using the nonlinear approach described in Judd (1992)[8].

[6]See, for example, Dunn and Singleton (1986), Eichenbaum, Hansen, and Singleton (1988), Ferson and Constantinides (1991), Detemple and Zapatero (1991), Heaton (1995), Banerjee and Batini (2003), and Tallarini and Zhang (2004).

[7]For instance, Fuhrer (2000) reports that the best achievements of his model occur when $\gamma = 0.8$. Díaz, Pijoan, and Ríos-Rull (2003) use $\gamma = 0.75$ in their benchmark calibration. In Carroll, Overland and Weil (2000) γ ranges from 0.25 to 0.75. Finally, Abel (1990) accounts well for the equity premium with $\gamma = 1.06$.

[8]I use a projection method based on a three dimensional, complete Chebyshev polynomial basis up to the third order. A more detailed description of how it is implemented is available from the author upon request.

4.1 The equity premium and the Sharpe ratio

Table 1 reports a set of financial statistics for different models. I start by focussing on the equity premium.

A model without habits and without capital adjustment costs ('Standard') predicts an almost zero premium, thus giving rise to the equity premium puzzle. As opposite, the benchmark economy ('Benchmark') matches the empirical 1.66% premium on equity. To understand the channels of this success, consider the following formula[9],

$$E_t(1 + EP_{t+1}) = -\frac{Cov_t(M_{t+1}, 1 + R^e_{t+1})}{E_t(M_{t+1})} \tag{15}$$

The premium on any asset depends on how its returns commove with the marginal valuation of consumption. If the asset pays little in a recession -i.e., it fails to deliver wealth precisely when wealth is more valuable to investors-, agents require a higher interest rate on it to compensate for the risk borne. This suggests that to induce large premia, a model should display (i) large upturns of the marginal utility of consumption at recessions, and (ii) procyclical and volatile asset returns. Clearly, this is not the case of the standard model.

According to the above formula, a switch from power utility to habit persistence has two primary effects on the equity premium. First, it widens the spread across states of nature of the one-period-ahead marginal utility of consumption. For a given process of the return on equity, this raises its mean excess return. This effect is accounted for by the first term in the covariance formula and, following Boldrin, Christiano and Fischer (1997), we will call it the *curvature channel*. The second term of the formula captures the *capital*

[9] See Campbell and Cochrane (1995) for further details.

gains channel: it measures the increase in the equity premium induced by the change of the structure in equity returns when we switch from power utility to habit forming preferences and hold the sequence of marginal rates of substitution constant.

Consider a model without capital adjustment costs. In this case, switching from power utility to habit forming preferences ('Habit') has a negligible impact on the risk premium. Under habit formation, sudden peaks in consumption are very harmful for future utility and, consequently, households adjust their savings decisions to avoid consumption risk. This smoothing channel minimizes the impact of the curvature channel, and the resulting equity premium is close to zero.

When we introduce capital adjustment costs in a model with standard preferences ('CAC'), the predicted premium rises to 0.19%, a value that is still too far from its empirical counterpart. With frictions in the capital market, adjusting the capital stock slowly costs fewer resources than doing so rapidly. Therefore, firms choose smooth investment paths, which translates into high consumption volatility. Then, it may seem surprising the failure of this model to generate a premium. However, it should not be so under the light of the covariance formula. Recall that it is the combination of the capital gains channel with the curvature channel that boosts the risk premium. Even though consumption is fairly more volatile under capital adjustment costs, the lack of curvature in the utility function removes a large fraction of stocks risk.

Now consider the benchmark economy. With frictions in the capital market consumption is very volatile, in spite of the attitude of households towards risk. This has two effects on the equilibrium risk premium. On the one hand, the marginal valuation of consumption becomes less predictable and more volatile, which ceteris paribus increases the risk premium through the curvature channel. On the other hand, households with habits have strong incentives to allocate resources in financial markets after a positive innovation. This drives stock prices up at the expansions and makes returns highly procyclical. As a consequence, the risk premium increases through the capital gains channel. Overall, the model's ability to generate a sizable premium comes from its ability to combine the curvature and the capital gains channel.

We can obtain further insights on the determinants of equity premia by analyzing Table 2. It contains information on the cyclical behavior of the two components of stock returns: prices and dividends. The first thing to note is that in all models returns are basically driven by variations in prices. This reflects that relative to prices, dividends are too small to significantly affect returns[10]. In the benchmark economy, changes in stock prices generate large variations in returns, thus making stocks a bad hedge against risk. In contrast, stocks are not sufficiently risky in the other models. In the 'Habit' and 'Standard' models the volatility of stock prices is too low. In the 'CAC' model, prices are volatile and dividends are clearly procyclical[11]. In this case, however, the lack of curvature in the utility function removes the riskiness of stocks.

The Sharpe ratio –defined as the ratio of the mean and standard deviation of the excess return on stocks– is an additional measure to test the consistency of financial models[12]. In the data, the standard deviation of stock returns

[10]Among the four models, the lowest steady state price-dividend ratio corresponds to the standard model. Even in that case, this ratio is as high as 98.9.

[11]Note how dividends are procyclical in the 'CAC' model. Log-dividends are proportional to the difference between log-output and log-investment. Thus, their dynamic behavior is determined by two opposite forces: the elasticity of output and the elasticity of investment with respect to shocks. In the 'CAC' model, unlike in the other models, the former is greater than the later.

[12]Cochrane (1997, p. 6) argues that the Sharpe ratio "is a better measure of the fundamental characteristic of stocks than the mean excess return itself, since it is invariant

has been 7.7%, which gives a 0.22 Sharpe ratio. According to Table 1, the 'Standard', 'Habit' and 'CAC' models fail in generating a sufficiently high Sharpe ratio. In contrast, the benchmark economy hits upon the empirical value. To some extent, this comes as a surprise. The model economy was not tailored to match the risk-return trade-off in financial markets, but the equity premium. Interestingly, I find that by matching the equity premium, the model economy also matches the market price of risk or, at least, comes close to its empirical estimates[13].

4.2 The riskfree rate

Here, I focus on the ability of the model to match the first and second moments of the real interest rate. Following Mehra and Prescott's (1985) equity premium puzzle, Weil (1989) stated the riskfree rate puzzle: models with high consumption risk aversion face serious difficulties in reconciling historical consumption growth rates with (low) riskfree rates. However, as illustrated by Kocherlakota (1996), habit forming preferences can overcome the riskfree rate puzzle. At the core of this success is the fact that habits increase the household's demand for savings relative to the reference specification, thus decreasing the equilibrium interest rate.

In line with this evidence, I find that the benchmark economy can match the historical riskfree rate. Unfortunately, intertemporal variations in this rate are much larger in the artificial economy than in the data. As Table 1 shows, the predicted 3.70% standard deviation is too high as compared to the empirical 0.89%. As opposite, the standard model underpredicts variations of the riskfree rate by almost one order of magnitude. The intuition under-

to leveraging".

[13]Estimations of the Sharpe ratio may differ, depending on the sample period and the characterization of the true market portfolio. Differences nevertheless are small. See Lettau and Uhlig (2002) for a set of alternative estimates.

lying these results is simple. In the standard case, the curvature of utility is low. Therefore, fluctuations in consumption levels do not translate into large fluctuations in the marginal valuation of consumption. This keeps the return on the riskless asset practically unchanged. In contrast, the curvature of utility is high in the benchmark economy and, thus, changes in consumption levels translate into large fluctuations in the riskfree rate.

The volatility of the riskfree rate is a long-standing puzzle for models with habit formation. Campbell and Cochrane (1999) and Abel (1999) have shown that a more complex representation of habits can contribute to solve this anomaly. Unfortunately, their achievements are based on a process for consumption that is exogenous and, therefore, can not be easily transferred to RBC models[14]. Note that in the RBC framework, the riskfree rate is determined by the consumption choices of households, which in turn depend on the habit process. This contrasts to endowment economies, in which the consumption process is invariant to the formulation of habits. In this paper I explore whether relative habits can generate a consumption path that avoids large fluctuations in the marginal valuation of consumption. Somewhat disappointing, I find that fluctuations in the riskfree rate are too large in the model economy.

4.3 Business cycle statistics

Given the relative success of the model economy on financial market predictions, it is worth investigating its macroeconomic implications. To that purpose, Table 3 reports a set of popular business cycle statistics.

Again, we can obtain useful insights by analyzing different scenarios. Con-

[14] As an additional problem, the Campbell-Cochrane specification has anomalous implications that need to be solved. See Ljungqvist and Uhlig (2003).

sider a model without capital adjustment costs. In this case, switching from standard preferences to habit forming preferences reduces the volatility of consumption from 0.34 to 0.24. This change reflects the nature of habit forming households: they optimally choose smoother consumption plans to reduce the negative impact that current purchases have on the enjoyment of future consumption. Note that with habits,

$$U(C_t, H_t) = \frac{(\frac{C_t}{C_{t-1}} C_{t-1}^{1-\gamma})^{1-\sigma}}{1-\sigma} \tag{16}$$

This expression makes it clear that habit forming households are reluctant to fluctuations not only in consumption levels, but also in consumption growth rates. Figure 2 reports the impulse of consumption to a positive, one-standard deviation shock to technology. While in the standard case consumption responds immediately after a shock, it peaks after some periods in the habit case. This clearly reflects the willingness of consumers to adjust their habit stock gradually over time[15].

Consider now the 'CAC' model. As Figure 2 shows, with a concave capital accumulation equation firms choose flatter investment plans, and consumption absorbs most of the change in output caused by a shock to technology. As a consequence, the model's performance on the relative volatilities of ag-

[15] Lettau and Uhlig (2000) argue that when taken alone, consumption habits give rise to a consumption puzzle, insofar as the standard deviation of consumption falls to counterfactually low levels. However, they focus only on survival habits. My findings suggest that relative habits are only partially exposed to this problem. An important difference between the consumption process implied by survival habits and relative habits is that, as compared to the standard case, survival habits predict a lower volatility for both consumption growth and consumption levels, while relative habits predict a lower volatility for consumption growth but a higher volatility for consumption levels. The explanation is as follows. With survival habits, consumption is rather insensitive to technology shocks. In contrast, the peak response of consumption is large under relative habits and, consequently, deviations from steady state levels are large too. I find that this effect increases the volatility of consumption *levels* from 0.34 in the standard case to 0.39 in the habit case. At the same time, the consumption response is gradual, which reduces the volatility of consumption *growth* from 0.34 in the standard case to 0.24 in the habit model.

gregate variables is poor. It overstates the volatility of consumption -which is more volatile than output- and understates the volatility of investment -which is less volatile than output.

Finally, consider the benchmark case. The model economy can replicate salient business cycle features, such as the pro-cyclicality of consumption and investment as well as the ordering of volatilities: investment is more volatile than output, which in turn is more volatile than consumption. The reason for these findings has to do with the interaction between risk aversion and rigidities in the capital market. On the one hand, habit households use savings as a buffer against consumption risk, which translates into large fluctuations in the investment rate. On the other hand, the firm's decision is to avoid large fluctuations in the investment rate, due to the capital adjustment costs. Thus, part of the change in output is absorbed by consumers, who end up following volatile consumption paths despite their attitude towards risk. These two effects can be seen in Figure 2.

As an additional finding, the model economy generates positive autocorrelation in consumption growth. The mechanism underlying this result is simple. Households are very averse to short term fluctuations in consumption and, therefore, today's purchases are influenced by yesterday's consumption. This dependence increases the autocorrelation of consumption growth from 0.02 in the standard model to 0.39, a value that comes close to the 0.31 found in the data. Unfortunately, the model economy lacks a mechanisms to account for the persistence of output.

The match between the model economy and the observed data is good but clearly not perfect. Due to the capital adjustment costs, investment is almost 1.8 times less volatile in the model than in the data, while consumption is too volatile. It should be noted, however, that the consumption data comes from US consumption of services and nondurables, as usual. If we consider instead personal expenditure or durables, the observed volatility rises to 0.97 and 3.73, respectively[16]. Thus, if we interpret the consumption good of the model as a combination of different types of consumption, then the model's prediction comes closer to the data. As a second shortcoming, investment and consumption are too procyclical. Still, the benchmark economy does better than the standard model.

4.4 The correlation between consumption growth and stock returns

In the data, consumption growth is positively correlated with past stock returns and negatively correlated with future returns. As Table 4 shows, the benchmark economy is consistent with this evidence. In contrast, the alternative models are not. The ability of the model economy to generate this pattern comes from the willingness of habit forming households to allocate resources in financial markets after a positive shock. This drives stock prices up, which ceteris paribus decreases future stock returns. Moreover, in the subsequent periods consumption rises gradually and households' demand for asset falls. This drives prices down, and returns on equity drop. Indeed, this effect is particularly strong and, as a consequence, the correlations between consumption growth and future returns are more decisively negative in the benchmark economy than in the data.

The contemporaneous correlation between returns and consumption growth is relatively high in the model economy. This suggests that to some extent households fear stocks because they pay bad when consumption is already low. Unfortunately, this explanation is much less evident in the data, insofar

[16] The numbers are calculated from NIPA data for the period 1959:1-2004:4.

as indeed consumption and returns are poorly correlated. Notwithstanding this, the predicted 0.63 correlation constitutes a small improvement over endowment economies, where the joint determination of consumption and dividends generates a correlation close to unity.

4.5 Two comparative statics exercises

In this section I investigate separately the quantitative impact of habits and capital adjustment costs on the risk premium. Table 5 reports the results for different values of γ. As agents become more risk averse, they need to be compensated with a higher premium in order to hold stocks. Thus for example, rising γ from 0.80 to 0.83 rises the equity premium from 1.66% to 2.47% and the Sharpe ratio from 0.22 to 0.26, while decreasing γ from 0.80 to 0.76 reduces the premium by 0.76%. As a related effect, the interest rate falls and becomes more volatile as γ increases. Note that the precautionary savings motive is more important for more risk averse individuals and, consequently, the equilibrium interest rate must fall in order to discourage savings. Moreover, higher risk aversion translates into large swings in the marginal rate of substitution, which increases the volatility of the interest rate.

In Table 6, I report the estimates for different values of ξ. As expected, decreasing ξ has a positive impact on the risk premium and the Sharpe ratio. As the ξ falls, the accumulation equation becomes more concave. Therefore, firms optimally choose smoother investment paths and agents end up facing higher consumption risk. Stocks must then carry a higher premium to compensate investors for the risk borne. A related result is that lower values of ξ are associated to lower and more volatile interest rates.

Overall, the results in Tables 5 and 6 indicate that habits and capital adjustment costs must be simultaneously high to generate a premium. The sensitivity analysis also suggests that, to some extent, these two mechanisms are interchangeable, and that similar results can be obtained with alternative parametrizations[17].

5 Summary and conclusions

In this paper, I explored asset returns in a production economy with habit forming households and capital adjustment costs. I found that the model economy can account for salient financial facts and business cycle phenomena simultaneously.

I used a formulation of habits that is novel among RBC models. I found that relative habits can account for the empirical equity premium, the Sharpe ratio, and the riskfree rate in a context of consumption choice. The challenge came from the fact that previous work by Abel (1990, 1999) was confined to a fruit-tree framework in which equilibrium consumption and dividends were exogenous stochastic processes.

While there is consensus on the existence of time-nonseparabilities, a quantitative evaluation of the welfare costs of business cycles under this type of utility functions does not appear to have been published. In the model presented here, households do not care much about steady state levels of consumption but rather about changes in consumption between periods. Therefore, small fluctuations may have a strong impact on welfare. This may explain why agents in real economies fear recessions so much. It also suggests that the welfare costs of business cycles might be larger than previously thought.

[17] For instance, I found that the following values for (γ, ξ) can also generate a reasonable premium: $(0.82, 0.33)$, $(0.78, 0.20)$, and $(0.77, 0.17)$, while the remaining statistics of the model remain practically unchanged.

As a shortcoming, the model overpredicts the volatility of the riskfree rate. This is a typical puzzle in models with habit formation. I intended to address it by exploiting a relative formulation of habits. Unfortunately, I found that relative habits can not prevent the marginal rate of substitution from fluctuating too much. Therefore, I conclude that a functional form that overcomes the riskfree rate volatility puzzle in an endogenous consumption framework is still in the waits.

As a second shortcoming, the model assumes that hours worked are fixed. In spite of this simplification, the model can generate endogenous business cycles along which the interconnection between asset returns and macroeconomic fluctuations can be studied. Whether the results presented here are robust to the introduction of endogenous labor is a challenge for future research. Previous evidence suggests that allowing for labor decisions damages the financial predictions of these types of models. The reason is that agents can use labor movements to insure against consumption fluctuations. However, it is not clear how relevant this problem is. There are two reasons for optimism. First, the model economy can be extended to reconcile labor decisions with asset returns. Allowing for "capitalists" and "workers" along the lines of Danthine, Donaldson, and Mehra (1992) is a candidate solution. Second, there are results in the literature that show that the endogeneity of labor is a tractable problem. Recently, Uhlig (2004) has shown that imposing an exogenous law of motion on wages can contribute to explain macroeconomic and financial facts simultaneously.

Assessing whether the previous shortcomings are fundamental problems of the model economy or whether minor modifications can overcome them is a task for future work.

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7 Tables and Figures

TABLE 1. FINANCIAL STATISTICS

	EP	SR	R^f	σ_{R^f}
Data	1.66	0.22	0.25	0.89
Standard	0.00	0.01	3.78	0.11
Habit	0.00	0.03	2.11	0.09
CAC	0.19	0.05	3.66	0.64
Benchmark	1.66	0.22	0.25	3.70

Notes to Table 1: (i) Abbreviated names are: EP, equity premium; SR, Sharpe ratio; R^f, riskfree rate; (ii) σ_x denotes the standard deviation of variable x; (iii) Returns are at quarterly frequency and in percent terms; (iv) The US numbers are estimates for the sample period 1947:1-1995:4; (v) The simulated data corresponds to arithmetic averages of 50 replications of sample size 200.

TABLE 2. MOMENTS OF STOCK PRICES AND DIVIDENDS

	EP	σ_{R^e}	σ_{P^e}	σ_D	$\rho(Y, R^e)$	$\rho(Y, P^e)$	$\rho(Y, D)$
Standard	0.00	0.11	0.17	3.28	-0.18	-0.01	-0.99
Habit	0.00	0.12	0.18	4.95	0.44	0.48	-0.96
CAC	0.19	4.01	3.98	1.07	0.99	0.99	0.99
Benchmark	1.66	7.70	7.66	2.35	0.90	0.90	-0.44

Notes to Table 2: (i) Abbreviated names are: EP, equity premium; R^e, equity return; P^e, equity price; D, dividends; Y, output; (ii) σ_x denotes the standard deviation of variable x, and $\rho(x, k)$ denotes the correlation between variable x and variable k; (iii) Returns are at quarterly frequency and in percent terms. Prices and dividends are filtered with the first-difference filter; (iv) The simulated data corresponds to arithmetic averages of 50 replications of sample size 200.

TABLE 3. RBC STATISTICS

	σ_C/σ_Y	σ_I/σ_Y	$\rho(Y,C)$	$\rho(Y,I)$	$\rho(C)$	$\rho(Y)$
Data	0.55	2.64	0.49	0.71	0.31	0.26
Standard	0.34	2.68	0.99	0.99	0.02	-0.02
Habit	0.24	3.02	0.69	0.99	0.70	-0.01
CAC	1.01	0.98	0.99	0.99	0.02	-0.02
Benchmark	0.76	1.91	0.91	0.92	0.39	-0.01

Notes to Table 3: (i) Abbreviated names are: Y, output; C, consumption; I, investment; (ii) σ_x denotes the standard deviation of variable x, $\rho(x,k)$ denotes the correlation between variable x and variable k, and $\rho(x)$ is the autocorrelation of variable x; (iii) The US numbers are calculated from the NIPA and cover the sample period 1959:1-2004:4, GDP for output, Consumption of nondurables and services for consumption, and Fixed investment for investment. Variables have been filtered with the first-difference filter; (iv) The simulated data corresponds to arithmetic averages of 50 replications of sample size 200.

TABLE 4. CROSS-CORRELATIONS, CONSUMPTION AND RETURNS

	$\rho(\Delta C_t, R^e_{t+j})$				
Lag (j)	-2	-1	0	+1	+2
Data	0.15	0.19	0.12	-0.10	-0.05
Standard	0.07	0.07	-0.09	0.39	0.36
Habit	0.35	0.52	0.77	0.61	0.55
CAC	-0.02	-0.02	0.99	-0.03	-0.03
Benchmark	0.11	0.26	0.63	-0.46	-0.20

Notes to Table 4: (i) $\rho(\Delta C_t, R^e_{t+j})$ denotes the correlation between consumption growth at time t and stock returns at time $t+j$; (ii) The Data row covers the sample period 1947:1-1995:4 and is taken from Campbell and Cochrane (1999); (iii) The reported statistics are based on raw, unfiltered data; (iii) The simulated data corresponds to arithmetic averages of 50 replications of sample size 200.

TABLE 5. FINANCIAL VARIABLES AND THE SIZE OF HABITS

$\xi = 0.25$				
	EP	SR	R^f	σ_{R^f}
$\gamma = 0.83$	2.47	0.26	-0.43	4.26
$\gamma = 0.82$	2.20	0.26	-0.17	4.01
$\gamma = 0.81$	1.92	0.24	0.05	3.84
$\gamma = 0.80$	1.66	0.22	0.25	3.34
$\gamma = 0.79$	1.43	0.20	0.43	3.58
$\gamma = 0.78$	1.23	0.17	0.58	3.49
$\gamma = 0.77$	1.06	0.15	0.72	3.41
$\gamma = 0.76$	0.90	0.13	0.85	3.32
$\gamma = 0$	0.19	0.05	3.66	0.64

Notes to Table 5: See notes (i)-(iii) and (v) to Table 1.

TABLE 6. FINANCIAL VARIABLES AND CAPITAL ADJUSTMENT COSTS

$\gamma = 0.80$				
	EP	SR	R^f	σ_{R^f}
$\xi = 0.20$	2.64	0.24	0.06	4.54
$\xi = 0.25$	1.66	0.22	0.25	3.34
$\xi = 0.33$	1.18	0.21	0.51	2.91
$\xi = 0.50$	0.66	0.16	0.89	2.06
$\xi = \infty$	0.00	0.03	2.11	0.09

Notes to Table 6: See notes (i)-(iii) and (v) to Table 1.

FIGURE 1. THE COST OF ADJUSTMENT FUNCTION

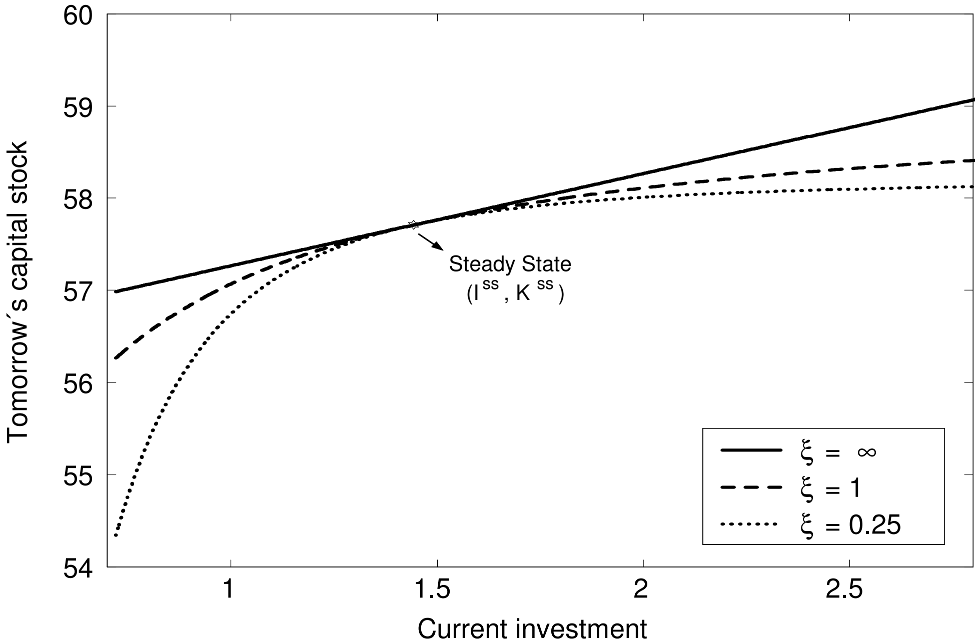

FIGURE 2. IMPULSE RESPONSES, CONSUMPTION AND INVESTMENT