Term Premium and Equity Premium in Economies with Habit Formation*

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Abstract

In this paper we calculate closed form solutions for asset prices under habit forming preferences. We decompose the equity premium into a risk and a term premium and express these components, together with the second moment of asset returns, as functions of the RRA and the IES coefficients. We show that the term premium and the volatility of the risk-free interest rate are mainly driven by the inverse of the IES, while the risk premium depends to a larger extent on RRA. We show analytically that habits cannot completely disentangle the measure of risk aversion from the IES and that, in order to match the observed equity premium, a very low value of the IES (very close to zero) is needed. For a reasonable calibration of the consumption process, this results in a term premium that is 7 times that observed in the data and a volatility of the risk-free rate that is one order of magnitude above its empirical value. We conclude that at the core of the term premium and the risk-free rate volatility puzzle is the fact that the main effect of habits is on valuation of consumption across dates (IES) and not across states of nature (RRA).

Keywords: Term premium, equity premium, habit formation, Intertemporal elasticity of substitution.
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1 Introduction

Recent literature in asset pricing has emphasized that many long-standing puzzles can be solved by assuming the presence of low frequency components in aggregate consumption coupled with Kreps and Porteus (1978) and Epstein and Zin's (1989) preferences which exhibit concern for those low-frequency components. A key element of Epstein and Zin's (1989) preferences is that they allow an independent parameterization for the coefficient of risk aversion and the elasticity of intertemporal substitution. Bansal and Yaron (2004) and Hansen, Heaton, and Li (2008) show that assuming high intertemporal elasticity of substitution (IES hereafter) and a high level of the risk aversion coefficient (RRA hereafter), plus a predictable component in the process of consumption growth (termed long run risk), Epstein and Zin's (1989) preferences can deliver the observed equity premium, as well as the return of the risk free asset.[1]

The success of these preferences in addressing the equity premium puzzle leads us to study the properties of their chief competitor, that is, habit formation, along these dimensions.[2] In this paper we show that habit formation can match the observed equity premium only if we assume very low values of the IES, very close to zero. This is so because habits cannot completely disentangle the measure of risk aversion from the measure of the IES: under habit forming preferences, high risk aversion always implies very low IES, and vice versa. We show analytically that there is a direct relationship between the IES and the size of the term premium. For a reasonable calibration of the aggregate consumption process we find that habit forming preferences always imply a value of the IES below 0.1, and a term premium more than 7 times the empirical value. That is, habit forming preferences mainly affect how people value fluctuations of consumption across dates—measured by the IES—more than how people value consumption across states of nature—measured by the RRA.

We proceed in this paper as follows: First of all, we develop theoretical measures for the IES and the RRA coefficient. As is known in the literature, we show that habits cannot completely

[1] The literature that uses Epstein-Zin preferences has grown during recent years: See, for instance, Bansal, Dittmar, and Lundblad (2005), Bansal, Khatchatrian, and Yaron (2005) about asset pricing, Colacito and Croce (2005) on the level and volatility of foreign exchange rates, and Croce (2006) on the welfare cost of business cycles.

[2] Habit forming preferences have been successfully tested in a variety of areas ranging from the consumption puzzles, as in Sommer (2007), the effects of the monetary policy (see Fuhrer 2000, Amato and Laubach 2004), behavior of the aggregate saving rate in a growth economy, (see Carroll, Overland, and Weil 2000) to movements of the current account (see Gruber 2004). In all these studies, habit formation helps to bring the response of aggregate consumption closer to its observed behavior, mainly because habit formation makes consumption responses to any innovation more sluggish.

disentangle the RRA from the IES. Although the RRA coefficient is no longer the inverse of the IES, they are inversely related, as in standard preferences. Moreover, it is always the case that the RRA coefficient is lower than the inverse of the IES. Next, we follow the procedure described by Abel (1999, 2006), and Hansen, Heaton, Lee, and Roussanov (2007) and construct a log-normal approximation of asset returns in an exchange economy. An advantage of our approach is that our analytical approximations can be expressed in terms of the RRA and IES coefficients, for any given level of autocorrelation in the assumed consumption process, as opposed to Abel (1999, 2006), and Hansen, Heaton, Lee, and Roussanov (2007), who focus on exchange economies where the consumption growth process is i.i.d. Thus, we are able to decompose the equity premium in two components, a term premium and a risk premium, and express them as functions of the IES and the RRA. The second advantage is that our measures are sufficiently general to accommodate the two dominant ways in which habit formation has been modeled in the literature: as a ratio or as a difference. Finally, we conduct various quantitative exercises using the expressions for equity, term and risk premium found previously. We find that whenever we match the level of the equity premium observed in the data, the model delivers a term premium which is too high, about 80 percent of the equity premium, and a value for the IES below 0.1. Moreover, the RRA coefficient is always lower than the inverse of the IES, which implies that households subject to habit formation are always more averse to fluctuations of consumption across dates than across states of nature. This is due to the fact that habit formation induces a stronger complementarity of consumption across dates than it does across states of nature. We also find that higher habits lower the IES at a much higher rate than they raise the RRA, which implies that higher habits increase the term premium at a higher rate than the risk premium.

The rest of the paper is organized as follows: in section 2 we develop our theoretical measures for risk aversion and the intertemporal elasticity of substitution. Section 3 uses the log-normal approximation to obtain closed form solutions for the expected return of assets of various maturities. In section 4 we calibrate our model economy and assess the ability of the habit formation model to account for the observed equity and term premium jointly. Section 5 concludes.

2 Value of consumption at different dates and states of nature

In this section we develop theoretical measures for the Intertemporal Elasticity of Substitution, which reflects the valuation of consumption across dates, and the coefficient of Relative Risk Aversion, which reflects how an individual values consumption across states of nature. In order to obtain intuition about how these measures are determined under habit forming preferences, we present their definitions in a very simple economy.

2.1 A simple economy

Consider a discrete-time economy with a continuum of identical infinitely-lived consumers. Assume further that the interest rate is given and there are perfect credit markets. In this economy the problem solved by a household is

$$
\begin{aligned}
V\left(w_t, h_t\right) = \quad & \max_{\{c_{t+i}\}_{i=0}^{\infty}} \sum_{i=0}^{\infty} \beta^i u\left(c_{t+i}, h_{t+i}\right) \\
\text{s. t.} \quad & c_{t+i} + s_{t+i+1} = (1+r)^i w_t + (1+r) s_{t+i}, \text{ for all } i, \\
& h_{t+1} = f\left(c_t, h_t\right), \text{ for all } t \geq 1,
\end{aligned}
\tag{2.1}
$$

where w_t denotes a household's net worth at the beginning of period t, h_t is the habit stock and s_t represents the beginning of period t holdings of a security that pays interest rate r. The solution to this problem is a sequence of functions of the state (w_t, h_t) that we denote as $\{g_{t+i}\left(w_t, h_t\right)\}_{i=0}^{\infty}$. We introduce additional notation and call

$$
U_t = \sum_{i=0}^{\infty} \beta^i u\left(c_{t+i}, h_{t+i}\right). \tag{2.2}
$$

That is, U_t denotes the intertemporal level of utility starting at time t for a given sequence of consumption.

To obtain closed-form expressions of the IES and the RRA coefficients, we need to specify the type of preferences we are focusing on. There are two competing ways in which habits have been introduced in the literature. On the one hand, there is a *relative consumption* branch. Past consumption piles up into a habit stock that enters utility dividing today's consumption, capturing the notion that, under habit formation, it is not the absolute level but consumption relative to the stock that matters. This notion has been used, for instance, by Abel (1990), Carroll, Overland, and Weil (2000) or Fuhrer (2000). On the other hand, there is a *survival consumption* branch. Past consumption piles up into a habit stock that determines a minimal consumption for today, below which utility is not defined. This way of modeling habits was pioneered by Ryder, Jr., and Heal (1973), and followed, for instance, by Constantinides (1990), Heaton (1995), Boldrin, Christiano, and Fisher (1997) or Dynan (2000). Therefore, the two different approaches differ in two dimensions. First, the *relative consumption* consumer cares about the relative difference between consumption and habit stock, whereas the *survival consumption* consumer cares about the absolute difference. Second, for *survival habits* preferences, consuming below the minimal level given by the habit stock is not defined (death), whereas it is well defined for its *relative habit* counterpart. The functional forms used for relative and survival habits are, respectively,

$$u(c_t, h_t) = \frac{[c_t\, h_t^{-\gamma}]^{1-\tau}}{1-\tau}, \tag{2.3}$$

$$u(c_t, h_t) = \frac{[c_t - \gamma\, h_t]^{1-\tau}}{1-\tau}. \tag{2.4}$$

The parameter γ measures the intensity of habits. If $\gamma = 1$, households only care about the consumption to habits ratio, in the case of relative habits, and about the difference in the case of survival habits. The literature assumes that the stock of habits evolves according to the law $h_{t+1} = (1-\lambda)\, h_t + \lambda\, c_t$. Here, to make our point, it will suffice to assume that $h_t = c_{t-1}$; in other words, the habit stock has no persistence, $\lambda = 1$.

2.2 The Intertemporal Elasticity of Substitution

The measure that captures how an individual values consumption at different dates is the inverse of the IES. Here we provide a closed form solution for this measure, and study how it is affected by the presence of habits. In Appendix A we show that, at the steady state, the inverse of the IES is the Arrow-Pratt coefficient,

$$IES_t = \left(-\frac{\Lambda_{t+1,\,t+1}}{\Lambda_{t+1}}\, c_{t+1}\right)^{-1}. \tag{2.5}$$

where Λ_t is the first partial derivative of (2.2) with respect to c_t, taking into account the impact of the change in c_t in all future values of the habit stock h_t. Similarly, $\Lambda_{t,\,t+i}$ is the first partial derivative of Λ_t with respect to c_{t+i}. In a steady state allocation, the consumption path satisfies $\ln(c_{t+1}/c_t) = \overline{x}$, for all t, where $\overline{x}$ denotes the steady state growth rate. Under relative habits the expression shown in (2.5) becomes

$$IES_r = \frac{1-\gamma\,\phi_r}{(\tau-1)\,(1+\gamma^2\phi_r)+(1-\gamma\,\phi_r)}, \quad \phi_r = \beta\, e^{\overline{x}(1-\gamma)(1-\tau)}, \tag{2.6}$$

where ϕ_r can be thought of as the effective discount factor. For survival habits, expression (2.5) can be written as

$$IES_s = \frac{1}{\tau}\,\frac{(1-\varphi)\,(1-\varphi\,\phi_s)}{(1-\varphi)\,(1-\varphi\,\phi_s)+\varphi\,(1+\phi_s)}, \quad \varphi = \gamma\, e^{-\overline{x}}, \quad \phi_s = \beta\, e^{\overline{x}(1-\tau)}. \tag{2.7}$$

The parameter φ can be interpreted as the effective habits parameter in the detrended version of the economy, whereas ϕ_s is the effective discount factor.

To see how the intensity of habits affects the curvature of the utility function we have plotted expressions (2.6) and (2.7) in Figures 1 and 2, respectively, for several values of the habits intensity parameter, γ. In the first panel of the first row of each figure, we have plotted the IES for values of the risk aversion parameter τ greater than one, and the first panel of the second row shows the IES for values of τ less than one. Let us inspect Figure 1 first. As we can see, relative habits exhibit a lower IES than do standard preferences as long as $\tau > 1$. Moreover, in that case, the IES falls with the level of habits intensity, γ. This is so because relative habits induce a higher complementarity between consumption across dates for $\tau > 1$. This higher complementarity implies that a given increase in the consumption growth rate brings about a larger fall in the valuation of future consumption (given by the inverse of IES). The relationship is reversed for values of τ less than one. In such a case, the IES is always greater for habit preferences than for standard preferences, and increasing with the habits intensity parameter γ; that is, households with habit forming preferences are more willing to take changes in the growth rate of consumption than are households with standard preferences. This is not the case for survival habits, as we can see in Figure 2, since the IES is always lower for survival habits than for standard preferences, regardless of the value of τ. That is, survival habits always induce a higher complementarity of consumption across dates than do standard preferences, whereas that is not the case for relative habits.

2.3 Risk aversion

To understand how preferences towards consumption at different states of nature are affected by the presence of habits, we need a measure of risk aversion. We follow Boldrin, Christiano, and Fisher (1997) and define risk aversion in consumption as

$$RRA_t = -\frac{u_{cc_t} + \beta V_{h_{t+1},h_{t+1}} \left(\frac{\partial h_{t+1}}{\partial c_t}\right)^2}{u_{c_t} + \beta V_{h_{t+1}} \frac{\partial h_{t+1}}{\partial c_t}} \, c_t, \tag{2.8}$$

where $V_{h_{t+1}}$ denotes the partial derivative of $V\left(w_{t+1}, h_{t+1}\right)$ with respect to the stock of habits and $V_{h_{t+1},h_{t+1}}$ is its second derivative. The function $V\left(w_{t+1}, h_{t+1}\right)$ solves the problem shown in (2.1) at period $t+1$. The expressions u_{c_t} and u_{cc_t} denote, respectively, the first and second derivative of the instantaneous utility function with respect to consumption, that is, without taking into account the effect of the change in current consumption on future habits. Summarizing, the RRA coefficient measures how much an individual is willing to pay to avoid a fair gamble in current consumption, holding next period's wealth constant. It is shown in Appendix A that we can express the coefficient of risk aversion in consumption as

$$RRA_t = -\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t - \frac{\Lambda_{t,\,t+1}}{\Lambda_t} e_{t+1}\, c_{t+1}, \tag{2.9}$$

where e_{t+1} denotes the elasticity of the consumption function $g_{t+1}\left(w_{t+1}, h_{t+1}\right)$ with respect to h_{t+1}. Let us assume the economy is at the steady state and that elasticity e_{t+1} is around one. Then, risk aversion in consumption is the sum of two terms: the inverse of the IES plus a term that comprises changes in future utility due to changes solely in the stock of habits,

$$RRA \simeq -\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t - \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}. \tag{2.10}$$

In a steady state allocation the expression shown above becomes

$$RRA_r = \frac{1}{IES_r} - \frac{\gamma\,\phi_r\,(\tau - 1)}{1 - \gamma\,\phi_r} \tag{2.11}$$

for relative habits. The expression of the RRA coefficient for survival habits is

$$RRA_s = \frac{1}{IES_s} - \tau\,\frac{\varphi\,\phi_s}{(1-\varphi)\,(1-\varphi\,\phi_s)}. \tag{2.12}$$

Figures 1 and 2 show the RRA coefficient as a function of the habits parameter for different values of τ. As we can see, the IES and the RRA are always inversely related. It is true, as argued by Constantinides (1990), that the RRA coefficient is not the inverse of the IES under habit forming preferences, but the inverse relationship stands. That is, as in the standard preferences case, it is not possible to have, at the same time, a high value for the IES and a high value for the RRA coefficient. Moreover, Constantinides (1990) shows that under survival habits the RRA coefficient is always lower than the inverse of the IES. We find the same result, as we can see from inspecting expression (2.12), regardless of the value of the risk aversion parameter τ. This is so because, when deciding whether to take a gamble in current consumption, the household takes into account the impact of the gamble on the future habit level, which affects the marginal utility of future consumption, compensating the effect of the gamble on current marginal utility.

For relative habits, however, the relationship between the IES and the RRA coefficient varies. As we can see in expression (2.11), for the RRA coefficient to be less than the inverse of the IES we need τ to be greater than one. If $\tau < 1$, the RRA coefficient is lower than under standard preferences and decreasing with γ.

3 Asset pricing

In this section we set our benchmark economy and obtain closed form solutions for the returns of risk free and risky assets, as well as for the equity, risk and term premium.

3.1 An exchange economy

The utility function of the representative household is

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, h_t\right). \tag{3.1}$$

The stock of habits at time t is just the level of consumption at period $t-1$, $h_t = c_{t-1}$. The instantaneous utility function is the one specified in expressions (2.3) and (2.4). There is a production unit that produces commodity c_t. The growth rate in c_t is denoted as $x_{t+1} = \ln\left(c_{t+1}/c_t\right)$ and it follows an AR(1) process,

$$x_{t+1} = (1-\rho)\overline{x} + \rho\, x_t + \varepsilon_{t+1}, \quad \rho \in (-1,1). \tag{3.2}$$

The random component ε_{t+1} is normal and i.i.d. with zero mean and variance σ_ε^2. The parameter ρ denotes the autocorrelation coefficient. We denote by σ^2 the variance of consumption growth, which is equal to $\frac{\sigma_\varepsilon^2}{1-\rho^2}$.

To avoid the need for separate derivations for the equilibrium prices of, for instance, riskless bills and stocks, we follow Abel (1999, 2006) and we calculate the equilibrium price of a canonical asset that is general enough to include these assets as special cases. Our canonical asset will be a discount security. In period t, a n-period discount security is a claim to a single payoff that takes place n periods ahead, $y_{t+n}(\nu)$. The growth rate underlying the payoffs of any security follows the process

$$z_{t+1}(\nu) = (1-\rho)\overline{x} + \rho\, z_t(\nu) + \nu\, \varepsilon_{t+1}, \quad \rho \in (-1,1), \quad \nu \geq 0. \tag{3.3}$$

where $z_{t+1} = \ln(y_{t+1}/y_t)$ and ν is a volatility parameter. Notice that the above equation can be used to characterize a variety of assets. If $\nu = 1$, the security is simply a claim to consumption. If $\nu = 0$, the canonical asset is a fixed-income security, with a deterministic payoff and if $\nu > 1$ we are representing levered equity, as in Abel (1999, 2006), Bansal and Yaron (2004), and Lettau, Ludvigson, and Wachter (2008). Thus, by choosing n and ν, we can simultaneously price different securities, including short-period bonds, characterized by $n = 1$ and $\nu = 0$, whose return represents the economy risk-free interest rate. Long term bonds are characterized by $n > 20$ quarters and $\nu = 0$, whereas stocks are characterized by $n = \infty$ and $\nu > 1$.

3.2 The expected return of the canonical asset

We denote by $p_t(n,\nu)$ the price at period t of a discount security that pays off the dividend $y_{t+n}(\nu)$ at period $t+n$ and expires afterwards. The pricing condition for the n-period discount security is:

$$p_t(n,\nu) = E_t\left[\frac{\Lambda_{t+n}}{\Lambda_t}\, y_{t+n}(\nu)\right],\ n = 1,\ldots,N. \tag{3.4}$$

Using the convention

$$p_t(0,\nu) = y_t(\nu), \tag{3.5}$$

we can write the gross return of the security between time t and time $t+1$, n periods before its expiration as

$$R_{t+1}(n,\nu) = \frac{p_{t+1}(n-1,\nu)}{p_t(n,\nu)}. \tag{3.6}$$

In order to obtain closed-form solutions for equilibrium returns, we will use a log-normal approximation to the above expression. The method is similar to the procedure described by Abel (1999, 2006), and Hansen, Heaton, Lee, and Roussanov (2007), and is shown in Appendix B.

In Appendix C we show that the expected return on a one period security is approximated by the expression

$$\ln E[R_{t+1}(1,\nu)] = -\ln\left(\phi\, e^{-\overline{x}}\right) - \Psi_1 \frac{\sigma^2}{2} + \Psi_2\, \nu\, \sigma^2, \tag{3.7}$$

where

$$\Psi_1 = \frac{1 + \left(\frac{\phi^2-1}{\phi}\right)(1 - IES \cdot RRA)^2 - 2\,\rho\,(1 - IES\cdot RRA)}{IES^2}, \tag{3.8}$$

$$\Psi_2 = \frac{1 - \rho\left(\frac{1+\phi}{\phi}\right)(1 - IES\cdot RRA)}{IES}. \tag{3.9}$$

Recall that parameter ϕ is the effective discount factor, equal to $\beta\, e^{\overline{x}(1-\gamma)(1-\tau)}$ for relative habits, as shown in (2.6), and equal to $\beta\, e^{\overline{x}(1-\tau)}$ for survival habits, as shown in (2.7). Expression (3.7) shows that the return to a one-period asset is the sum of three terms.[3] The first term measures the effect of impatience and growth on the return of the asset. The second term, $\Psi_1 \frac{\sigma^2}{2}$, arises because, in a world of uncertainty, agents would like to hedge against future unfavorable consumption realizations by building "buffer stocks" of the consumption good. Hence, in equilibrium, the interest rate must be negatively correlated with the volatility of consumption, σ^2. We can call this effect the idiosyncratic uncertainty effect. The third term, $\Psi_2\, \nu\, \sigma^2$, is always positive and measures the effect of aggregate

[3]We follow Mehra and Prescott (2003) in this discussion.

uncertainty on the return of the asset. Notice that Ψ_1 and Ψ_2 depend on the difference between the inverse of the IES and the RRA coefficient. That is, both the idiosyncratic uncertainty effect as well as the aggregate uncertainty effect depend on how the individual values consumption across dates and across states of nature.

Next, we turn to long term assets. Let us denote as $E\left[R_{t+1}(\infty,\nu)\right]$ the expected return of a discount security when its maturity period is arbitrarily large, $E\left[R_{t+1}(\infty,\nu)\right] \equiv \lim_{n\to\infty} E\left[R_{t+1}(n,\nu)\right]$. We can characterize its first moment in the following way:

$$\ln\, E[R_{t+1}(\infty,\nu)] = -\ln\left(\phi\, e^{-\overline{x}}\right) - \Upsilon_1 \frac{\sigma^2}{2} + \Upsilon_2\, \nu\, \sigma^2, \tag{3.10}$$

where

$$\Upsilon_1 = \frac{\frac{4\rho}{(1-\rho)\phi^2}\left(1-(1+\phi)IES\cdot RRA\right)^2 - \left(\frac{1-2\rho}{\phi^2} - \frac{2+\phi}{\phi}\right)\left(1-IES\cdot RRA\right)^2}{IES^2} + \frac{1-\frac{2(1+\phi)}{\phi}\left(1-IES\cdot RRA\right)}{IES^2}, \tag{3.11}$$

$$\Upsilon_2 = \frac{\frac{2\rho}{(1-\rho)\phi}\left(1-(1+\phi)IES\cdot RRA\right) + \frac{\rho}{\phi}\left(1-IES\cdot RRA\right) + IES\cdot RRA}{IES}. \tag{3.12}$$

(See Appendix C). As with one period securities, the first term measures the impatience and growth effect, the second one, $\Upsilon_1\, \sigma^2/2$, comprises the effect due to idiosyncratic uncertainty of consumption, and the third term, $\Upsilon_2\, \nu\, \sigma^2$, is due to aggregate uncertainty.

3.3 Equity Premium, risk premium and term premium

As is usual in the literature, we define the equity premium as the excess return on equity over a one period risk free asset. In terms of our notation:

$$EP(\nu) = \ln\, E[R_{t+1}(\infty,\nu)] - \ln\, E[R_{t+1}(1,0)]. \tag{3.13}$$

We decompose the equity premium as the sum of two components: one entirely due to risk, the risk premium, whereas the other is due to the differences in asset maturity and is labeled with the term premium. More specifically, we define the risk premium as the excess return of a long term risky asset over a long term risk free asset,

$$RP(\nu) = \ln\, E[R_{t+1}(\infty, \nu)] - \ln\, E[R_{t+1}(\infty, 0)]. \tag{3.14}$$

while the term premium is defined as the excess return of a long term risk free asset over its one period counterpart

$$TP(0) = \ln\, E[R_{t+1}(\infty, 0)] - \ln\, E[R_{t+1}(1, 0)]. \tag{3.15}$$

Using (3.7) and (3.10) we get

$$RP(\nu) = \Upsilon_2\, \nu\, \sigma^2. \tag{3.16}$$

$$TP(0) = (\Psi_1 - \Upsilon_1)\, \frac{\sigma^2}{2}. \tag{3.17}$$

Therefore, the equity premium can be written as

$$EP(\nu) = (\Psi_1 - \Upsilon_1)\, \frac{\sigma^2}{2} + \Upsilon_2\, \nu\, \sigma^2. \tag{3.18}$$

The above formulas illustrate how the equity and the term premium are governed by the RRA and the IES coefficients. To make the relation more transparent, we can consider an i.i.d consumption process and an effective discount factor equal to one, $\phi = 1$. In that case

$$RP(\nu) = RRA\ \nu\, \sigma^2 \tag{3.19}$$

$$TP(0) = \Big((1/IES)^2 - RRA^2\Big)\ \sigma^2 \tag{3.20}$$

These closed form solutions provide useful hints for understanding the key channels by which habit forming preferences generate equity and term premia. They show that for given consumption and dividend processes, the risk premium depends *linearly* on RRA,while the term premium depends *exponentially* on the difference between the inverse of IES and RRA. Therefore, two ingredients are needed in order to generate a sizeable equity premium and a low term premium simultaneously: i) high RRA and ii) an inverse of the IES close enough to the RRA coefficient. However, as we show in the paper, habits lower the IES at a much higher rate than they raise the RRA, which generates an equity premium that is mostly a term premium. This statement will be made precise in section 4.

3.4 Second moments

In Appendix C we show that, following our log-linear approach, we can write the variance of the one period risk free asset as

$$Var[R_{t+1}(1,0)] = \Psi_3 \sigma^2, \tag{3.21}$$

where

$$\Psi_3 = \frac{1}{\phi^2} \frac{(1 - IES \cdot RRA)^2}{IES^2}, \tag{3.22}$$

That is, the volatility of the riskfree rate is mainly driven by the IES, as was the case of the term premium. The volatility of the return on long period assets is

$$Var[R_{t+1}(\infty,\nu)] = \left[2\Psi_3(1 + \Psi_3^{-1/2}) + \Psi_4\right] \nu\sigma^2, \tag{3.23}$$

where

$$\Psi_4 = \nu - \frac{2\rho\,(1 - IES \cdot RRA)}{\phi\, IES}. \tag{3.24}$$

4 A quantitative exercise

In this section we turn to calibrate our model economy to asses quantitatively the size of the risk, the term and the equity premium as well as the volatility of the risk-free rate.

4.1 The benchmark calibration

Our model period is a quarter. We follow Boldrin, Christiano, and Fisher (1997), who use quarterly consumption data from 1959 to 1989 and obtain an average consumption growth rate equal to 0.44

percent. We also take from them the volatility of consumption growth, 0.0052. This implies setting $\overline{x} = 0.0044$, and $\sigma_\varepsilon = 0.0052$ for the consumption growth process. As for the autocorrelation factor, ρ, Boldrin, Christiano, and Fisher (1997) set $\rho = 0.34$, whereas Campbell and Cochrane (1999) use an i.i.d process. We have chosen an intermediate value, $\rho = 0.15$. In our model, ν is the proportion between the standard deviation of dividend growth and consumption growth. Depending on the data source, the sample period, the time aggregation, and the definition of dividends, estimates of ν range from about 3 to 11. Abel (1999) uses $\nu = 2.74$. In Campbell and Cochrane (1999), the quarterly standard deviation of dividend growth is 5.6 percent, which implies that dividends are 11 times more volatile than consumption. With these numbers in mind, we have chosen an intermediate value of $\nu = 7$.

Estimates of the quarterly equity premium range from 1.61 in Campbell and Cochrane (1999) to 2.00, as in Lettau 2003. We target a value of 1.80. The composition of the equity premium is sensitive to the sample period considered. Lettau (2003) uses the postwar sample period and finds that only 11 percent of the equity premium can be accounted for by a term premium. It differs from that reported in Jermann (1998) and Abel (1999). They consider the 1923-1996 sample period, and report that one fourth of the total premium is a term premium. Since Lettau (2003) focusses on postwar data, here we assume that the term premium comprises 11 percent of the equity premium.

Next, we need to calibrate the preference parameters. We choose the discount factor so that $\beta = 0.99$. We want to calibrate the rest of the preference parameters so that the equity premium in our model economy matches its value in the data. For relative habits we have set the risk aversion parameter, τ_r, equal to 1.5. The value of the habits parameter needed to match the equity premium is $\gamma_r = 0.975$. For survival habits we set the value of the risk aversion parameter so that the effective discount factor is the same under both habit specifications. This implies setting $\tau_s = \tau_r + \gamma_r (1 - \tau_r)$. The implied value is $\tau_s = 1.012$. The value of γ_s needed to deliver an equity premium equal to 1.8 percent is 0.772.

Table 1 shows the results concerning equity premium, term premium and asset volatilities. Notice that the first row of Table 1 is just labeled 'Habits', without specifying the type of habits. This is so because there is a one-to-one mapping between both habit specifications as long as the risk aversion parameter in the relative habits specification is greater than one. That is, in a such a case, both habit specifications deliver exactly the same IES and RRA coefficient. Consequently, they deliver the same equity premium, term premium and values of asset volatilities. In the second row, we report the predictions of the model without habits. Notice that, as is known in the literature, habits can replicate the empirical equity premium but, in turn, imply a too high volatility of the risk free asset. Moreover, the resulting term premium (1.467) is more than 7 times the empirical value (0.198). This is directly related to the fact that the IES is very low, 0.035, and that the RRA coefficient is about the half of the inverse of the IES. In other words, habit formation induces a higher complementarity of consumption across dates than do standard preferences. This implies that households prefer short term risk free assets to their long term counterparts. Hence, a high premium is needed to hold the latter. Moreover, since $RRA < 1/IES$, households fear more variations of consumption across dates than across states of nature. This is why, when matching the observed equity premium, the fraction due to a term premium is much larger than the fraction due to a risk premium. To clarify the results further we conduct alternative calibrations to determine the key factors affecting the term premium.

4.2 Varying the degree of risk aversion

Here we want to check whether our results are sensitive to the assumed value of the risk aversion parameter τ. Thus, we change our benchmark calibration in the following way: We take a value for τ_r greater than one in the relative habits specification, and choose γ_r so that the delivered equity premium is 1.80 percent. Next, we choose the risk aversion parameter for the survival habits specification, τ_s, so that the effective discount factor is the same under both habit specifications and calibrate γ_s to match the equity premium in the data. Both habit specifications deliver the same term premium, IES, and RRA coefficient. For any value of τ less than one, the relative habits specification cannot deliver an equity premium close to what we see in the data, as can be inferred from inspecting Figure 1. This is why we only report results for survival habits for $\tau < 1$. The results are shown in Table 2. The first thing to notice is that the IES is always around 0.035 in order to match the equity premium. As is apparent, given the consumption autocorrelation process, a higher τ needs a lower value of the habits parameter γ in order to maintain the equity premium at its empirical value. In the last column we report the percentage of the equity premium that is a term premium. The results are illustrative. Much of the equity premium (about 81 percent) is a term premium, regardless of the value of τ.

4.3 Consumption growth autocorrelation and the size of the term premium

In this section we turn to study how the persistence of the consumption growth process affects the size of the term premium. We recalibrate our model economy for values of the persistence parameter ρ going from -0.6 to 0.6. First of all, we keep our benchmark calibration and show the implied equity and term premia, as a fraction of the equity premium, for different values of the persistence parameter ρ. This is shown in the last two columns of Table 3 labeled EP^* and $(TP/EP)^*(\%)$. Notice that the equity premium decreases with ρ. The term premium decreases in absolute value and as a fraction of the equity premium. This is so because, as Otrok, Ravikumar, and Whiteman (2002) argue, habit formation implies that households fear more fluctuations of consumption at high frequencies than at low frequencies. Consequently, they would like to save in the form of short term assets and borrow in long term assets. Thus, the term premium must be very high to make them willing to hold the latter. By increasing ρ the consumption process becomes more persistent and fluctuations take place, on average, at lower frequencies, frequencies at which the habit stock moves along with consumption. Hence, households are more willing to hold long term assets the larger ρ is, and the term premium, as a fraction of the equity premium, decreases.

As a robustness check, we change the preferences parameters so that both habits specifications deliver the observed equity premium in the data and the same effective discount factor for any value of ρ. The preferences parameters, the implied IES and RRA coefficient, as well as the equity and term premia are shown in the first six columns of Table 3. Notice that the same pattern emerges: the term premium, as a fraction of the equity premium, decreases with ρ and it ranges from 64 to almost 92 percent.

4.4 The effect of leverage

Jermann (1998) suggests that introducing leverage may decrease the importance of the term premium. Table 4 shows that the existence of leverage reduces the fraction of the equity premium accounted for by the term premium. We have recalibrated the habits model for every level of leverage so that the equity premium is 1.80. The most remarkable finding is that for reasonable values of leverage the model cannot match the data. As we can see, we need a value of $\nu = 100$, which implies that stocks are 100 times more volatile than consumption, in order for the term premium to be around 11 percent of the equity premium.

4.5 The IES and the term premium

The previous sections show that habit formation is able to reproduce the observed equity premium only by delivering a term premium and a volatility of the risk-free rate much higher than what is observed in the data. We have argued that this is so because habit forming preferences imply a very low IES and a RRA coefficient lower than the inverse of the IES; in other words, habits induce a much higher complementarity of consumption across dates than across states of nature. In the previous exercises we have seen that the IES needed to match the observed equity premium is about 0.035. In this section we conduct a different exercise: we set a combination of preference parameters so that the model economy matches the observed level of term premium, 0.198 percent. Table 5 is constructed as Table 2, but matching the term premium instead. In the last column, we report the equity premium implied by the model. Notice that a higher τ raises the equity premium, but its level is always below 0.38 percent, whereas in the data it is 1.80 percent. Also, notice, that a higher τ implies a higher RRA and a lower IES. Consequently, to keep the term premium constant, the value of γ needs to be lowered. Table 6 shows the implied equity premium when the preference parameters are chosen to match the term premium for various levels of the persistence parameter ρ. As larger persistence, other things being equal, lowers the term and the equity premium, the value of γ needs to be augmented to keep the term premium constant. Given that premium, we find that the equity premium increases with ρ. However, the variation is too small, and the predicted value is always below 0.42 percent.

Summarizing, habit forming preferences cannot deliver the observed equity premium except for very low values of the IES, about 0.035. The magnitude of the IES is a key empirical issue. Hansen and Singleton (1982) and Attanasio and Weber (1989) estimate the IES to be well in excess of 1. More recently, Vissing-Jørgensen and Attanasio (2003) also estimate the IES over one—they show that their estimates are close to that used in Bansal and Yaron (2004), 1.5. However, Hall (1988) and Campbell (1999) estimate the IES to be well below one.[4] Thus, the implied value of the IES with habit forming preferences is consistent with Hall (1988) and Campbell's (1999) estimates but produce a term premium much larger than what is observed in the data. If we calibrate habit preferences so that they deliver a term premium that matches the data, the equity premium delivered is less than one fourth of what is observed. This is so because habit formation

[4] In a recent paper, Guvenen (2006) argues that if the IES rises with wealth and there is limited stock market participation the properties of asset prices are governed by the IES of wealthy households, those with high IES, whereas aggregate consumption reflects the low IES of the majority not so wealthy consumers.

induces a much larger complementarity of consumption across dates than across states of nature. Moreover, under habit forming preferences, it is not possible to raise the level of risk aversion without lowering the IES at a much higher rate.

5 Final comments

In this paper we provided closed-form solutions for the first and second moments of asset prices in an exchange economy with habit forming preferences. The formulas were general enough to comprise a variety of securities and the two dominant ways in which habit formation has been modeled in the literature, as a ratio or as a difference. We showed that the main effect of habits is on valuation of consumption across dates (IES), not across states of nature (RRA). We showed that a calibrated exchange representative model economy can reproduce the empirical equity premium. Nevertheless, the model predicts a size of the term premium that is 7 times larger than that observed in the data, and a volatility of the risk-free rate that is almost one order of magnitude above the empirical value. We conclude that at the core of this puzzle is the inability of habit forming preferences to entirely decouple risk aversion from the intertemporal elasticity of substitution.

References

Abel, A. (1990). Assets prices under habit formation and catching up with the Joneses. *American Economic Review 89*(2), 38–42.

Abel, A. (1999). Risk premia and term premia in general equilibrium. *Journal of Monetary Economics 43*, 3–33.

Abel, A. B. (2006). Equity premia with benchmark levels of consumption: Closed-form results. NBER Working Papers 12290, National Bureau of Economic Research, Inc.

Amato, J. D. and T. Laubach (2004). Implications of habit formation for optimal monetary policy. *Journal of Monetary Economics 51*(2), 305–325.

Attanasio, O. P. and G. Weber (1989). Intertemporal substitution, risk aversion and the euler equation for consumption. *Economic Journal 99*(395), 59–73.

Bansal, R., R. F. Dittmar, and C. T. Lundblad (2005). Consumption, dividends, and the cross section of equity returns. *Journal of Finance 60*(4), 1639–1672.

Bansal, R., V. Khatchatrian, and A. Yaron (2005). Interpretable asset markets? *European Economic Review 49*(3), 531–560.

Bansal, R. and A. Yaron (2004). Risks for the long run: A potential resolution of asset pricing puzzles. *Journal of Finance 59*(4), 1481–1509.

Boldrin, M., L. Christiano, and J. Fisher (1997). Habit persistence and asset returns in an exhange economy. *Macroeconomic Dynamics 1*(2), 312–332.

Campbell, J. and J. Cochrane (1999). By force of habit: A consumption-based explanation of aggregate shock market behavior. *Journal of Political Economy 107*(2), 205–251.

Campbell, J. Y. (1999, 06). Asset prices, consumption, and the business cycle. In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume 1 of *Handbook of Macroeconomics*, Chapter 19, pp. 1231–1303. Elsevier.

Carroll, C., J. Overland, and D. Weil (2000). Saving and growth with habit formation. *American Economic Review 90*(3), 341–355.

Colacito, R. and M. Croce (2005). Risks for the long run and the real exchange rate. 2005 Meeting Papers 794, Society for Economic Dynamics.

Constantinides, G. (1990). Habit formation: A resolution of the equity premium puzzle. *Journal of Political Economy 98*(3), 519–543.

Croce, M. M. (2006). Welfare costs, long run consumption risk, and a production economy. 2006 Meeting Papers 582, Society for Economic Dynamics.

Díaz, A., J. Pijoan-Mas, and J.-V. Ríos-Rull (2003). Precautionary savings and wealth distribution under habit formation. *Journal of Monetary Economics 50*(6), 1257.

Dynan, K. E. (2000). Habit formation in consumer preferences: Evidence form panel data. *American Economic Review 90*(3), 391–406.

Epstein, L. G. and S. E. Zin (1989). Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework. *Econometrica 57*(4), 937–69.

Fuhrer, J. C. (2000). Habit formation in consumption and its implications formonetary policy models. *American Economic Review 90*(3), 367–90.

Gruber, J. W. (2004). A present value test of habits and the current account. *Journal of Monetary Economics 51*(7), 1495–1507.

Guvenen, F. (2006). Reconciling conflicting evidence on the elasticity of intertemporal substitution: A macroeconomic perspective. *Journal of Monetary Economics 53*(7), 1451–1472.

Hall, R. E. (1988). Intertemporal substitution in consumption. *Journal of Political Economy 96*(2), 339–57.

Hansen, L. P., J. Heaton, J. Lee, and N. Roussanov (2007). Intertemporal substitution and risk aversion. In J. Heckman and E. Leamer (Eds.), *Handbook of Econometrics*, Volume 6 of *Handbook of Econometrics*, Chapter 61. Elsevier.

Hansen, L. P., J. C. Heaton, and N. Li (2008). Consumption strikes back? Measuring long-run risk. *Journal of Political Economy 116*(2), 260–302.

Hansen, L. P. and K. J. Singleton (1982). Generalized instrumental variables estimation of nonlinear rational expectations models. *Econometrica 50*(5), 1269–1286.

Heaton, J. (1995). An empirical investigation of asset pricing with temporally dependent preference specification. *Econometrica 63*(3), 681–717.

Jermann, U. (1998). Asset pricing in production economies. *Journal of Monetary Economics 41*, 257–275.

Kreps, D. M. and E. L. Porteus (1978). Temporal resolution of uncertainty and dynamic choice theory. *Econometrica 46*(1), 185–200.

Lettau, M. (2003). Inspecting the mechanism: The determination of asset prices in the RBC model. *Economic Journal 113*, 550–575.

Lettau, M., S. C. Ludvigson, and J. A. Wachter (2008). The declining equity premium: What role does macroeconomic risk play? *Review of Financial Studies 21*(4), 1653–1687.

Mehra, R. and E. C. Prescott (2003). The equity premium in retrospect. NBER Working Paper 9525.

Otrok, C., B. Ravikumar, and C. Whiteman (2002). Habit formation: A resolution of the equity premium puzzle? *Journal of Monetary Economics 49*, 1261–1288.

Ryder, H. E. Jr., and G. M. Heal (1973). Optimal growth with intertemporally dependent preferences. *Review of Economic Studies 40*(1), 1–31.

Sommer, M. (2007). Habit formation and aggregate consumption dynamics. *Advances in Macroeconomics, B.E. Journals 7*(1), Article 21.

Vissing-Jørgensen, A. and O. P. Attanasio (2003). Stock-market participation, intertemporal substitution, and risk-aversion. *American Economic Review 93*(2), 383–391.

Appendices

A Measures of risk aversion

Proposition 1. *The Intertemporal Elasticity of Substitution at the steady state is given by the inverse of the Arrow-Pratt coefficient,*

$$\frac{1}{IES_t} = -\frac{\Lambda_{t+1,\,t+1}}{\Lambda_{t+1}}\, c_{t+1}. \tag{A.1}$$

Proof. We define the intertemporal elasticity of substitution, IES as the percentage change in consumption from time t to time $t+1$ induced by a 1% change in the interest rate at time t, other things being equal. Conversely, the inverse of the IES is the elasticity of the marginal rate of substitution, denoted as MRS_t, with respect to the consumption growth rate. Thus, if we define $X_{t+1} = c_{t+1}/c_t$, we can write,

$$\frac{1}{IES_t} = -\frac{d \ln MRS_t}{d\, X_{t+1}}\, X_{t+1}. \tag{A.2}$$

Let us write c_{t+1} as $X_{t+1}\, c_t$, and c_{t+2} as $X_{t+2}\, X_{t+1}\, c_t$ in Λ_t and Λ_{t+1}. We take the ln of the MRS_t and we make a first order linear approximation around the steady state,

$$\begin{aligned} \ln(MRS_t) = \quad & \ln\left(\Lambda_{t+1}\right) - \ln\left(\Lambda_t\right) \simeq \\ & \ln\left(\Lambda^{ss}_{t+1}\right) - \ln\left(\Lambda^{ss}_t\right) + \frac{\Lambda^{ss}_{t+1,\,t}}{\Lambda^{ss}_{t+1}}(c_t - c^{ss}_t) + \frac{\Lambda^{ss}_{t+1,\,t+1}}{\Lambda^{ss}_{t+1}}\,(X_{t+1}\, c_t - c^{ss}_t) + \\ & + \frac{\Lambda^{ss}_{t+1,\,t+2}}{\Lambda^{ss}_{t+1}}\,(X_{t+2}\, X_{t+1}\, c_t - c^{ss}_t) - \frac{\Lambda^{ss}_{t,\,t+1}}{\Lambda^{ss}_t}\,(X_{t+1}\, c_t - c^{ss}_t) - \frac{\Lambda^{ss}_{t,\,t}}{\Lambda^{ss}_t}(c_t - c^{ss}_t). \end{aligned} \tag{A.3}$$

Differentiating $\ln(MRS_t)$ with respect to X_{t+1} we obtain

$$\frac{d \ln MRS_t}{d\, X_{t+1}} = \frac{\Lambda^{ss}_{t+1,\,t+1}}{\Lambda^{ss}_{t+1}}\, c_t + \frac{\Lambda^{ss}_{t+1,\,t+2}}{\Lambda^{ss}_{t+1}}\, X_{t+2}\, c_t - \frac{\Lambda^{ss}_{t,\,t+1}}{\Lambda^{ss}_t}\, c_{t+1}. \tag{A.4}$$

At the steady state we know that $\left(\Lambda^{ss}_{t+1,\,t+2}/\Lambda^{ss}_{t+1}\right) c^{ss}_{t+2} = \left(\Lambda^{ss}_{t,\,t+1}/\Lambda^{ss}_t\right) c^{ss}_{t+1}$. Thus,

$$\frac{d \ln MRS_t}{d\, X_{t+1}}\, X_{t+1} = \frac{\Lambda^{ss}_{t+1,t+1}}{\Lambda^{ss}_{t+1}}\, c_{t+1}, \tag{A.5}$$

which, by definition, is the Arrow-Pratt coefficient. □

Proposition 2. *Risk aversion in consumption is*

$$RRA = -\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t - \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, e_{t+1}\, c_{t+1}, \tag{A.6}$$

Proof. This proof draws heavily from Díaz, Pijoan-Mas, and Ríos-Rull (2003). It can be shown that

$$u_{c_t} + \beta V_{h_{t+1}} \frac{\partial h_{t+1}}{\partial c_t} = \Lambda_t + \beta \frac{d\, h_{t+1}}{d\, c_t} \Lambda_{t+1} \left[\sum_{i=0}^{\infty} \beta^i \frac{\Lambda_{t+1+i}}{\Lambda_{t+1}} \frac{\partial\, g_{t+1+i}\,(w_{t+1}, h_{t+1})}{\partial\, h_{t+1}} \right]. \tag{A.7}$$

Recall that $h_{t+1} = c_t$ and that $[\beta\,(1+r)]^i\, \Lambda_{t+1+i} = \Lambda_{t+1}$, we obtain

$$u_{c_t} + \beta V_{h_{t+1}} \frac{\partial h_{t+1}}{\partial c_t} = \Lambda_t + \beta\, \Lambda_{t+1} \left[\sum_{i=0}^{\infty} \frac{1}{(1+r)^i} \frac{\partial\, g_{t+1+i}\,(w_{t+1}, h_{t+1})}{\partial\, h_{t+1}} \right]. \tag{A.8}$$

The expression inside the brackets is the derivative of the household's budget constraint with respect to h_{t+1} and is equal to zero, hence

$$u_{c_t} + \beta V_{h_{t+1}} \frac{\partial h_{t+1}}{\partial c_t} = \Lambda_t. \tag{A.9}$$

Differentiating again,

$$u_{cc_t} + \beta V_{h_{t+1},h_{t+1}} \left(\frac{\partial h_{t+1}}{\partial c_t} \right)^2 = \Lambda_{t,\,t} + \sum_{i=1}^{\infty} \Lambda_{t,\,t+i} \frac{\partial\, g_{t+i}\,(w_{t+1}, h_{t+1})}{\partial\, h_{t+1}}. \tag{A.10}$$

Notice that $\Lambda_{t,\,t+i} = 0$ for all $i > 2$. Then, dividing equation (A.10) by (A.9) we obtain

$$- \frac{u_{cc_t} + \beta V_{h_{t+1},h_{t+1}} \left(\frac{\partial h_{t+1}}{\partial c_t} \right)^2}{u_{c_t} + \beta V_{h_{t+1}} \frac{\partial h_{t+1}}{\partial c_t}}\, c_t = - \frac{\Lambda_{t\,t}}{\Lambda_t}\, c_t - \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, e_{t+i} c_{t+i}, \tag{A.11}$$

where

$$e_{t+i} = \frac{\partial\, g_{t+i}\,(w_{t+1}, h_{t+1})}{\partial\, h_{t+1}} \frac{h_{t+1}}{c_{t+i}}. \tag{A.12}$$

and the result follows. □

B The log-normal approximation

The expression for the prices shown in (3.4) can be written as follows

$$p_t(n, \nu) = y_t(\nu)\, E_t \left[\frac{\Lambda_{t+n}}{\Lambda_t} \prod_{j=1}^{n} Z_{t+j}(\nu) \right], \tag{B.1}$$

where

$$Z_{t+j}(\nu) = \frac{y_{t+j}(\nu)}{y_{t+j-1}(\nu)}. \tag{B.2}$$

Let us assume that the economy is at the steady state at time $t-1$. Then we can express consumption in terms of deviations with respect its steady state level as

$$c_{t+j} = \exp\left(\widetilde{x}_{t+j} + \ldots.. + \widetilde{x}_{t-1}\right) c^{ss}_{t+j}. \tag{B.3}$$

Applying a Taylor expansion of degree one to $\frac{\Lambda_{t+n-i}}{\Lambda_t}$ around the steady state we find

$$\ln\left(\frac{\Lambda_{t+n}}{\Lambda_t}\right) \simeq \ln\left(\frac{\Lambda^{ss}_{t+n}}{\Lambda^{ss}_t}\right) + \sum_{j=-1}^{1} \frac{\Lambda^{ss}_{t+n,\,t+n+j}}{\Lambda^{ss}_{t+n}} c^{ss}_{t+n+j} \left(\exp\left(\sum_{l=-1}^{n+j} \widetilde{x}_{t+l}\right) - 1\right) - \sum_{j=-1}^{1} \frac{\Lambda^{ss}_{t,\,t+j}}{\Lambda^{ss}_t} c^{ss}_{t+j} \left(\exp\left(\sum_{l=-1}^{j} \widetilde{x}_{t+l}\right) - 1\right) \tag{B.4}$$

Since $\exp(a) - 1 \approx a$ we have,

$$\ln\left(\frac{\Lambda_{t+n}}{\Lambda_t}\right) \simeq \ln\left(\frac{\Lambda^{ss}_{t+n}}{\Lambda^{ss}_t}\right) + \sum_{j=-1}^{1} \frac{\Lambda^{ss}_{t+n,\,t+n+j}}{\Lambda^{ss}_{t+n-i}} c^{ss}_{t+n+j} \left(\sum_{l=-1}^{n+j} \widetilde{x}_{t+l}\right) - \sum_{j=-1}^{1} \frac{\Lambda^{ss}_{t,\,t+j}}{\Lambda^{ss}_t} c^{ss}_{t+j} \left(\sum_{l=-1}^{j} \widetilde{x}_{t+l}\right). \tag{B.5}$$

Taking into account that

$$\frac{\Lambda^{ss}_{t+n,\,t+n+j}}{\Lambda^{ss}_{t+n}} c^{ss}_{t+n+j} = \sum_{j=-1}^{1} \frac{\Lambda^{ss}_{t,\,t+j}}{\Lambda^{ss}_t} c^{ss}_{t+j} \tag{B.6}$$

and that

$$\frac{\Lambda^{ss}_{t,\,t-1}}{\Lambda^{ss}_t} c^{ss}_{t-1} = \frac{1}{\phi} \frac{\Lambda^{ss}_{t,\,t+1}}{\Lambda^{ss}_t} c^{ss}_{t+1}, \tag{B.7}$$

where ϕ is the effective discount factor, which is equal to $\beta\, e^{\overline{x}\,(1-\gamma)(1-\tau)}$ for relative habits and $\beta\, e^{\overline{x}\,(1-\tau)}$ for survival habits we find

$$\ln\left(\frac{\Lambda_{t+n}}{\Lambda_t}\right) \simeq \ln\left(\frac{\Lambda^{ss}_{t+n}}{\Lambda^{ss}_t}\right) + \frac{\Lambda^{ss}_{t,\,t}}{\Lambda^{ss}_t} c^{ss}_t \left(\sum_{l=-1}^{n} \widetilde{x}_{t+l} - \sum_{l=-1}^{0} \widetilde{x}_{t+l}\right) + \frac{\Lambda^{ss}_{t,\,t+1}}{\Lambda^{ss}_t} c^{ss}_{t+1} \left[\left(\sum_{l=-1}^{n+1} \widetilde{x}_{t+l} - \sum_{l=-1}^{1} \widetilde{x}_{t+l}\right) + \frac{1}{\phi}\left(\sum_{l=-1}^{n-1} \widetilde{x}_{t+l} - \widetilde{x}_{t-1}\right)\right]. \tag{B.8}$$

Thus, the asset pricing equation can be written as

$$p_t(n,\nu) \simeq y_t(\nu)\, E_t\Bigg[\exp\left(\ln\left(\frac{\Lambda^{ss}_{t+n}}{\Lambda^{ss}_t}\right) + \frac{\Lambda^{ss}_{t,\,t}}{\Lambda^{ss}_t}\, c^{ss}_t \sum_{l=1}^{n} \widetilde{x}_{t+l} + \frac{\Lambda^{ss}_{t,\,t+1}}{\Lambda^{ss}_t}\, c^{ss}_{t+1}\left(\sum_{l=2}^{n+1}\widetilde{x}_{t+l} + \frac{1}{\phi}\sum_{l=0}^{n-1}\widetilde{x}_{t+l}\right) + \sum_{l=1}^{n} z_{t+l}(\nu)\right)\Bigg] \tag{B.9}$$

where $z_{t+j}(\nu) = \ln(Z_{t+j}(\nu))$.

C The price and the rate of return of the canonical asset

Proposition 3. *The covariance of consumption growth and dividends growth satisfies cov* $(x_{t+j}, z_t) = \rho^{|j|}\nu\,\sigma$.

Proof. To obtain the covariance formula, write the $AR(1)$ processes in its $MA(\infty)$ version:

$$x_{t+1} = \frac{\overline{x}}{1-\rho} + \sum_{i=0}^{\infty}\rho^i\varepsilon_{t+1-i} + \rho^{t+1}x_0, \tag{C.1}$$

and

$$z_{t+1}(\nu) = \frac{\overline{x}}{1-\rho} + \nu\sum_{i=0}^{\infty}\rho^i\varepsilon_{t+1-i} + \rho^{t+1}z_0(\nu), \tag{C.2}$$

where the last term in both equations can be neglected for a sufficiently large t. Then

$$E[x_{t+j}\, z_t] = \frac{\overline{x}^2}{(1-\rho)^2} + \rho^{|j|}\nu\sum_{i=0}^{\infty}\rho^{2i}E[\varepsilon^2_{t-i}] \tag{C.3}$$

$$= \frac{\overline{x}^2}{(1-\rho)^2} + \rho^{|j|}\,\nu\,\frac{\sigma^2_\varepsilon}{1-\rho^2}. \tag{C.4}$$

Finally, taking into account that $cov(x_{t+j}, z_t) = E[x_{t+j}\, z_t] - E[x_{t+j}]\, E[z_t]$ with $E[x_{t+j}] = \frac{\overline{x}}{1-\rho}$, $E[z_t] = \frac{\overline{x}}{1-\rho}$, and $\widetilde{x}_t = x_t - \overline{x}$, we get

$$Cov(x_{t+j}, z_t) = Cov(\widetilde{x}_{t+j}, z_t) = \rho^{|j|}\nu\frac{\sigma^2_\varepsilon}{1-\rho^2} = \rho^{|j|}\nu\sigma^2. \tag{C.5}$$

□

Proposition 4. *The price of a discount security can be written as*

$$p_t(1,\nu) \simeq y_t(\nu)\,\exp\left[\ln\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)\right]\exp\left[\frac{1}{\phi}\frac{\Lambda_{t,\,t+1}}{\Lambda_t}\,c_{t+1}\,\widetilde{x}_t\right]\, E_t\left[\exp\left(q_t(1,\nu)\right)\right], \tag{C.6}$$

where

$$q_t(1,\nu) = \frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t\, \widetilde{x}_{t+1} + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, \widetilde{x}_{t+2} + z_{t+1}(\nu), \tag{C.7}$$

$$p_t(2,\nu) \simeq y_t(\nu)\, \exp\left[\ln\left(\frac{\Lambda_{t+2}}{\Lambda_t}\right)\right] \exp\left[\frac{1}{\phi}\, \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, \widetilde{x}_t\right]\, E_t\left[\exp\left\{q_t(2,\nu)\right\}\right], \tag{C.8}$$

$$q_t(2,\nu) = \left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \frac{1}{\phi}\, \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right) \widetilde{x}_{t+1} + \left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right) \widetilde{x}_{t+2} + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, \widetilde{x}_{t+3} + z_{t+1}(\nu) + z_{t+2}(\nu). \tag{C.9}$$

For any $n \geq 3$*,*

$$p_t(n,\nu) \simeq y_t(\nu)\, \exp\left[\ln\left(\frac{\Lambda_{t+n-i}}{\Lambda_t}\right)\right] \exp\left[\frac{1}{\phi}\, \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, \widetilde{x}_t\right]\, E_t\left[\exp\left\{q_t(n,\nu)\right\}\right], \tag{C.10}$$

where

$$q_t(n,\nu) = \left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \frac{1}{\phi}\, \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right) \widetilde{x}_{t+1} + \left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\left(1 + \frac{1}{\phi}\right)\right) \left(\sum_{l=2}^{n-i-1} x_{t+l}\right) + \left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right) x_{t+n-i} + \frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, x_{t+n-i+1} + \sum_{l=1}^{n-i} z_{t+l}(\nu). \tag{C.11}$$

Proof. It follows from the log-linear approximation described in Appendix B. □

One period assets

Using Proposition 4 we can write the return of a one period asset as

$$R_{t+1}(1,\nu) = \frac{y_{t+1}(\nu)}{p_t(1,\nu)} = \frac{\exp\left[z_{t+1}(\nu) - \frac{1}{\phi}\,\frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\, \widetilde{x}_t\right]}{E_t\left[\exp(q_t(1,\nu))\right] \exp\left(\ln\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)\right)} \tag{C.12}$$

where, using Proposition 3,

$$E_t[\exp(q_t(1,\nu))] = \exp\left[\overline{x} + \left(\left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t\right)^2 + \left(\frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right)^2 + \nu\left(\nu + 2\,\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t\right) + 2\,\rho\left(\frac{\Lambda_{t,\,t+1}}{\Lambda_t}\, c_{t+1}\right)\left(\frac{\Lambda_{t,\,t}}{\Lambda_t}\, c_t + \nu\right)\right)\frac{\sigma^2}{2}\right] \tag{C.13}$$

Taking the unconditional expectation,

$$E\left[R_{t+1}(1,\nu)\right] \simeq \exp\left\{-\ln\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right) - \left(\left(\frac{\Lambda_{t,t}}{\Lambda_t}\,c_t\right)^2 + \left(\frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)^2\left(\frac{\phi^2-1}{\phi^2}\right)\right)\frac{\sigma^2}{2}\right\} \times$$
$$\exp\left\{-\left[\nu\left(\frac{\Lambda_{t,t}}{\Lambda_t}\,c_t\right) + \rho\left(\frac{\Lambda_{t,t}}{\Lambda_t}\,c_t\right)\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right) + \nu\rho\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}, c_{t+1}\left(\frac{\phi+1}{\phi}\right)\right)\right]\sigma^2\right\}. \tag{C.14}$$

Finally, rearranging terms, and using (2.5) and (2.10), expression (3.7) follows. To calculate the second moment, note that $Var\left[R_{t+1}(1,\nu)\right] = E\left[R_{t+1}(1,\nu)^2\right] - E\left[R_{t+1}(1,\nu)\right]^2$. Some algebra gives

$$Var[R_{t+1}(1,\nu)] \simeq \left[\left(\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)^2 + \nu\left(\nu - 2\rho\left(\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)\right)\right]\sigma^2. \tag{C.15}$$

Finally, using (2.5) and (2.10), expression (3.21) follows.

n-period assets

Using the definition (3.6), and (C.10) we have

$$R_{t+1}(n,\nu) = \exp\left[-\ln\left(\frac{\Lambda_{t+n}}{\Lambda_t}\right) + z_{t+1}(\nu) + \frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}(x_{t+1}-x_t)\right]\frac{E_{t+1}[\exp(q_{t+1}(n-1,\nu))]}{E_t[\exp(q_t(n,\nu))]} \tag{C.16}$$

It can be checked that for $n \geq 3$,

$$E_t\left[\exp(q_t(n,\nu))\right] = \frac{\exp(b)}{\exp(a)^{n-2}}\,\Gamma(n,\nu) \tag{C.17}$$

where, using Proposition 3,

$$b = 2\overline{x} + \left[\left(\tfrac{\Lambda_{t,t}}{\Lambda_t}\,c_t + \tfrac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)^2 + \left(\tfrac{\Lambda_{t,t}}{\Lambda_t}\,c_t + \tfrac{1}{\phi}\tfrac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)^2\right]\tfrac{\sigma^2}{2} + \left[\left(\tfrac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\right)^2 + 2\nu\left(\nu + 2\tfrac{\Lambda_{t,t}}{\Lambda_t}\,c_t + \tfrac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\left(1+\tfrac{1}{\phi}\right)\right)\right]\tfrac{\sigma^2}{2} \tag{C.18}$$

$$a = -\left[\left(\frac{\Lambda_{t,t}}{\Lambda_t}\,c_t + \frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\left(1+\frac{1}{\phi}\right)\right)^2 + \nu\left[\nu + 2\left(\frac{\Lambda_{t,t}}{\Lambda_t}\,c_t + \frac{\Lambda_{t,t+1}}{\Lambda_t}\,c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\right]\right]\frac{\sigma^2}{2} \tag{C.19}$$

and $\Gamma(n,\nu)$ is a complicated function of cross-correlation terms,

$$\Gamma(n,\nu)=\exp\left\{\left[\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\sum_{i=1}^{n-2}\rho^i+\right.\right.$$
$$\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\rho^{n-1}+2\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)^2\sum_{j=0}^{n-3}\sum_{i=1}^{n-j-2}\rho^i+$$
$$\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\rho^n+\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\sum_{i=1}^{n-2}\rho^i$$
$$\left.\left.\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\rho\sum_{i=1}^{n-2}\rho^i+\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\rho\right]\sigma^2\right\}\times$$
$$\exp\left\{\left[\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\sum_{i=1}^{n-1}\rho^i+2\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\sum_{j=0}^{n-3}\sum_{i=1}^{n-j-2}\rho^i\right.\right.$$
$$\left.\left.\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\sum_{i=1}^{n-1}\rho^i+\left(\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\right)\sum_{i=1}^{n}\rho^i\right]\nu\,\sigma^2\right\}. \tag{C.20}$$

We define,

$$\Omega(\infty,\nu)=\lim_{n\to\infty}\frac{\Gamma(n-1,\nu)}{\Gamma(n,\nu)} \tag{C.21}$$

and, after some algebra, we obtain

$$\Omega(\infty,\nu)=\exp\left[-2\frac{\rho}{1-\rho}\left(\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)\right)\left[\frac{\Lambda_{t,t}}{\Lambda_t}c_t+\frac{\Lambda_{t,t+1}}{\Lambda_t}c_{t+1}\left(1+\frac{1}{\phi}\right)-\nu\right]\sigma^2\right] \tag{C.22}$$

Then, taking the limit when $n\to\infty$,

$$\lim_{n\to\infty}\frac{E_{t+1}[\exp\{q_{t+1}(n-1,\nu)\}]}{E_t[\exp\{q_t(n,\nu)\}]}=\exp(a)\,\Omega(\infty,\nu), \tag{C.23}$$

we can write the interest rate on a infinite period security as,

$$R_{t+1}(\infty,\nu)=\exp\left[-\ln\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)+z_{t+1}(\nu)+\frac{1}{\phi}\frac{\Lambda_{t,t+1}}{\Lambda_t}(\widetilde{x}_{t+1}-\widetilde{x}_t)\right]\exp(a)\,\Omega(\infty,\nu). \tag{C.24}$$

Taking the unconditional expectation, and using (2.9) and (2.5) we can write,

$$\begin{aligned}&E\left[\exp\left[z_{t+1}(\nu)+\tfrac{1}{\phi}\tfrac{\Lambda_{t,t+1}}{\Lambda_t}(\widetilde{x}_{t+1}-\widetilde{x}_t)\right]\right]\simeq\\&\exp\left[\overline{x}+\left[\tfrac{\nu^2}{2}+\tfrac{1}{\phi^2}\left(1/IES-RRA\right)^2+\tfrac{\nu}{\phi}(1/IES-RRA)-\right.\right.\\&\left.\left.\tfrac{\rho}{\phi}\left(1/IES-RRA\right)\left(\tfrac{1}{\phi}\left(1/IES-RRA\right)+\nu\right)\right]\sigma^2\right],\end{aligned} \tag{C.25}$$

$$E\left[\exp(a)\right] \simeq \exp\Bigg[-\overline{x} - \Bigg[\left((1/IES - RRA)\left(1+\frac{1}{\phi}\right) - 1/IES \right)^2 + \nu\left(\nu + 2\left((1/IES - RRA)\left(1+\frac{1}{\phi}\right) - 1/IES\right)\right)\Bigg]\frac{\sigma^2}{2}\Bigg]. \quad \text{(C.26)}$$

The formula for $E[R_{t+1}(\infty,\nu)]$ follows after rearranging terms. To obtain the second moment, note that $Var\left[R_{t+1}(\infty,\nu)\right] = E\left[R_{t+1}(\infty,\nu)^2\right] - E\left[R_{t+1}(\infty,\nu)\right]^2$. After some algebra, we get

$$Var[R_{t+1}(\infty,\nu)] \simeq \left[2\left(\frac{1}{\phi}\frac{\Lambda_{t,\,t+1}}{\Lambda_t}c_{t+1}\right)^2 + \nu\left(\nu + \frac{2(1-\rho)}{\phi}\frac{\Lambda_{t,\,t+1}}{\Lambda_t}c_{t+1}\right)\right]\sigma^2. \quad \text{(C.27)}$$

Using (2.9) and (2.5) again, the formula for $Var[R_{t+1}(\infty,\nu)]$ follows.

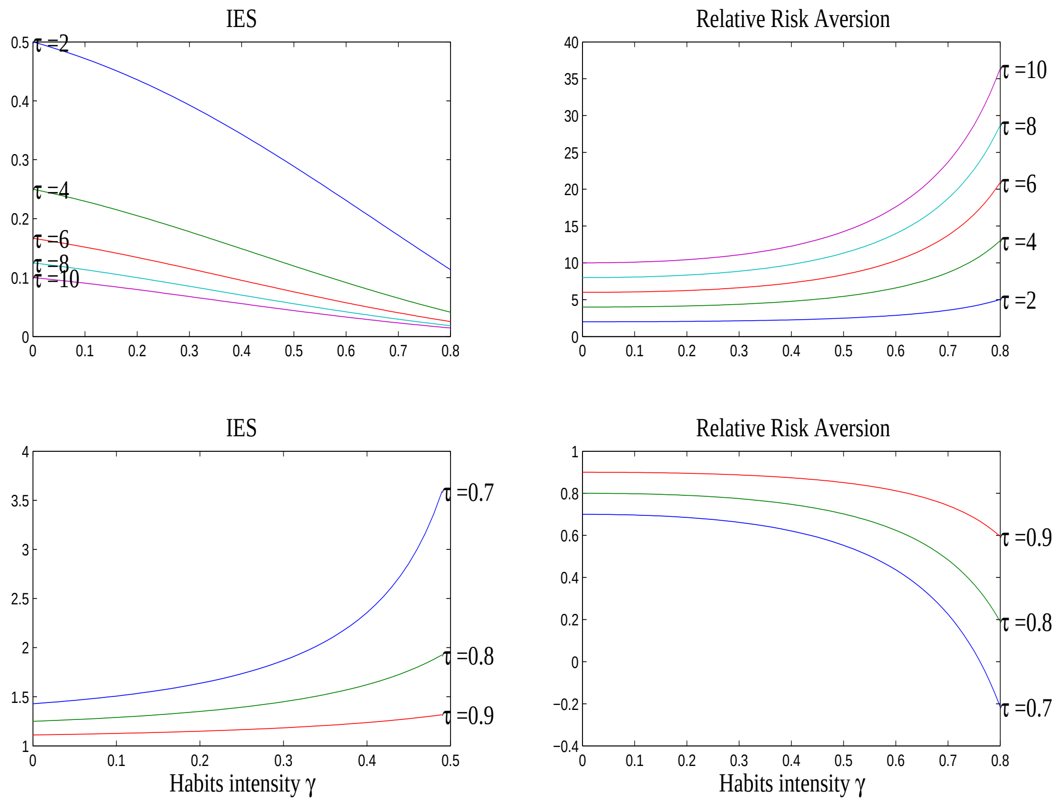

Figure 1: Intertemporal Elasticity of Substitution and Relative Risk Aversion for relative habits. We have assumed $\sigma = 0.0053$, $\beta = 0.99$, $\overline{x} = 0.0044$, and $\nu = 7$.

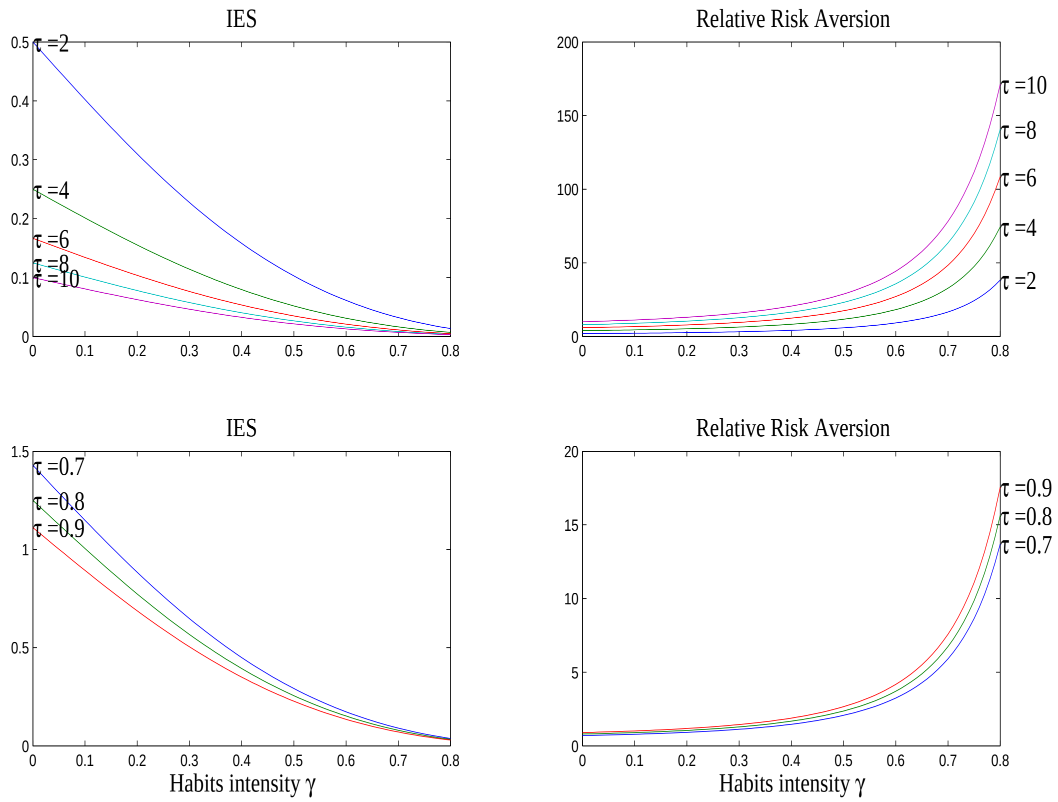

Figure 2: Intertemporal Elasticity of Substitution and Relative Risk Aversion for survival habits. We have assumed $\sigma = 0.0053$, $\beta = 0.99$, $\overline{x} = 0.0044$, and $\nu = 7$.

Table 1: The benchmark calibration

	IES	RRA	EP	TP	RP	σ_{re_n}	σ_{rf_n}	σ_{rf_1}
Habits	0.035	15.049	1.800	1.467	0.328	13.033	10.474	7.406
Standard	0.988	1.012	0.012	-0.001	0.013	3.693	0.000	0.000
Data	-	-	1.800	0.198	1.602	7.500	4.800	0.700

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\nu = 7$, $\rho = 0.15$. For relative habits $\tau_r = 1.5$ and $\gamma_r = 0.9759$, for survival habits $\gamma_s = 0.7745$, and $\tau_s = 1.0120$. For standard preferences $\tau = 1.0120$.

Table 2: The effect of τ

Relative		Survival		Values of		
τ_r	γ_r	τ_s	γ_s	IES	RRA	(TP/EP) (%)
0.300		0.300	0.872	0.035	14.582	81.713
0.500		0.500	0.836	0.035	14.713	81.659
0.700		0.700	0.808	0.035	14.844	81.604
0.900		0.900	0.784	0.035	14.975	81.548
*1.500	0.975	1.012	0.772	0.035	15.049	81.517
2.500	0.912	1.132	0.760	0.035	15.128	81.483
4.000	0.831	1.508	0.727	0.034	15.379	81.375
5.000	0.783	1.868	0.700	0.034	15.620	81.269
10.000	0.598	4.614	0.562	0.033	17.529	80.375

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\nu = 7$, $\rho = 0.15$.

Table 3: The effect of serial correlation

	Relative	Survival		Values of				
ρ	γ_r	τ_s	γ_s	IES	RRA	TP (%)	EP^*	$(TP/EP)^*$ (%)
-0.600	0.955	1.023	0.717	0.055	9.714	91.142	4.457	94.853
-0.450	0.962	1.019	0.736	0.047	11.197	90.215	3.292	92.993
-0.300	0.967	1.016	0.749	0.042	12.433	88.791	2.645	90.825
-0.150	0.971	1.015	0.759	0.039	13.476	86.931	2.241	88.272
0.000	0.973	1.013	0.766	0.036	14.349	84.562	1.975	85.222
*0.150	0.975	1.012	0.772	0.035	15.049	81.517	1.800	81.517
0.300	0.976	1.012	0.775	0.033	15.547	77.503	1.694	76.925
0.450	0.977	1.012	0.777	0.033	15.775	72.020	1.652	71.096
0.600	0.976	1.012	0.776	0.033	15.599	64.231	1.689	63.492

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\nu = 7$. For relative habits $\tau_r = 1.5$.

Table 4: The effect of leverage

	Relative	Survival		Values of		
ν	γ_r	τ_s	γ_s	IES	RRA	(TP/EP) (%)
1.000	0.978	1.011	0.781	0.032	16.354	97.120
*7.000	0.975	1.012	0.772	0.035	15.049	81.517
11.000	0.973	1.013	0.766	0.037	14.244	72.579
50.000	0.948	1.026	0.702	0.061	8.736	25.465
100.000	0.908	1.046	0.625	0.101	5.519	9.091

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\rho = 0.15$. For relative habits $\tau_r = 1.5$.

Table 5: Matching the term premium (I)

Relative		Survival		Values of		
τ_r	γ_r	τ_s	γ_s	IES	RRA	EP
0.300		0.300	0.793	0.094	5.490	0.318
0.500		0.500	0.738	0.093	5.623	0.319
0.700		0.700	0.696	0.093	5.759	0.321
0.900		0.900	0.662	0.092	5.896	0.322
1.500	0.917	1.042	0.640	0.092	5.995	0.322
2.500	0.771	1.343	0.600	0.091	6.208	0.324
4.000	0.613	2.160	0.517	0.088	6.807	0.330
5.000	0.534	2.865	0.463	0.085	7.350	0.335
10.000	0.307	7.236	0.284	0.067	11.161	0.378

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\nu = 7$, $\rho = 0.15$.

Table 6: Matching the term premium (II)

	Relative	Survival		Values of		
ρ	γ_r	τ_s	γ_s	IES	RRA	EP
-0.600	0.857	1.071	0.550	0.150	3.894	0.288
-0.450	0.878	1.061	0.579	0.129	4.420	0.283
-0.300	0.892	1.054	0.600	0.115	4.877	0.286
-0.150	0.903	1.049	0.616	0.106	5.284	0.294
0.000	0.911	1.045	0.629	0.098	5.654	0.306
0.150	0.917	1.042	0.640	0.092	5.995	0.322
0.300	0.922	1.039	0.649	0.087	6.312	0.345
0.450	0.926	1.037	0.657	0.082	6.613	0.376
0.600	0.930	1.035	0.665	0.078	6.925	0.418

Asset returns are in percentage and quarterly terms. We have assumed $\sigma_\varepsilon = 0.0052$, $\beta = 0.99$, $\overline{x} = 0.0044$, $\nu = 7$, $\tau_r = 1.5$.