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ABSTRACT

We estimate real interest rates, bounds on inflation expectations and inflation risk premia in a CCAPM framework under (four) different preference specifications. Given consumption patterns in Spain between 1979 and 1995, real interest rates below 4% can only be obtained if, given a small degree of relative risk aversion, we accept a relatively high degree of patience, an extremely high degree of intertemporal substitution or the existence of some degree of altruism in Spanish household preferences. Inflation risk premium terms are constant and small. Finally, inflation expectations react to movements in inflation trend though with some delay. Thus, agents seem to need "some" time to believe that a new inflation pattern reflects a permanent change. These last two results are robust to the choice of household preferences.

1. INTRODUCTION

When central banks steer (short-term) nominal interest rates in order to reach their monetary policy targets, disentangling the relationships between nominal interest rates, real interest rates and inflation expectations is crucial to understanding the relative importance of different channels in the monetary transmission mechanism.

The theoretical relationship linking these variables dates back to Fisher (1907), who originally claimed that in the long term, nominal interest rates are driven by real interest rates and public's inflation expectations. Thus, in most countries policymakers usually look at long-term nominal interest rates in order to measure agents' expectations about future inflation. In general, increases in long-term nominal interest rates are seen as indicating rising inflation expectations, so that some monetary policy tightening might be needed. In other words, a rise in short-term nominal interest rates might convince people that the central bank means to crush inflation and thus limit, or even reverse, any increase in long-term rates.

This channel holds when real interest rates are stable -at least when compared with inflation expectations-, so changes in nominal interest rates mainly reflect changes in inflation expectations. Empirically, the level of such expectations can be retrieved, provided that an estimate of the level of the real interest rates is available.

An alternative channel, also based on Fisher's view, is that emphasized in traditional IS-LM textbook models. In this case, by contrast, inflation expectations are considered stable and any increase in nominal short-term interest rate increases long-term real interest rates. This movement induces income, wealth and substitution effects in consumption and investment decisions and the economy slows down, thus relieving inflationary pressures.

In this paper we aim at retrieving real interest rates and inflation expectations from Spanish nominal interest rates, in a Consumption Capital Asset Pricing Model (CCAPM) framework. In particular, we exploit the marginal rate of substitution between future and current (non-durable) consumption as a sufficient statistic of movements in those variables. This provides a simple and modern equilibrium approach to the Fisher equation.

Notwithstanding, we do not estimate any particular asset pricing model but consider how four different preference specifications (i.e. four different stochastic discount factors) alter the dynamic properties of asset prices. For each preference specification we obtain real interest rates and bounds on inflation expectation for a (sensible) set of values of the relevant structural parameters. Thus, we can analyse the sensitivity of real interest rates and inflation expectation to changes in a set of parameters that capture a series of important features in the public's utility functions: time preference, risk aversion, intertemporal substitution, durability and envy. Therefore, this paper extends and supplements previous work by Ayuso (1996) and Alonso and Ayuso (1996) in which real interest rate and risk premium terms are estimated under the assumption of isoelastic preferences.

The structure of the paper is the following. After this introduction, in Section 2 we present a CCAPM approach to jointly determine nominal interest rates, real interest rates and inflation expectations, under four different agents' utility functions. Section 3 shows estimates of real interest rates and bounds on inflation expectation in Spain. Finally, conclusions are drawn in Section 4.

2. THE THEORETICAL RELATIONSHIP BETWEEN NOMINAL INTEREST RATES, REAL INTEREST RATES AND INFLATION EXPECTATIONS.

2.1. A frictionless asset pricing model

In this section, we obtain the theoretical relationship between nominal interest rates, real interest rates and inflation expectations in the framework of the conventional intertemporal frictionless asset pricing model originally proposed in Lucas (1978).

Thus, suppose that our economy is populated by many homogeneous households having identical preferences about future consumption. Households choose the composition of their portfolios that maximises the expected utility of the infinite path of future contingent consumption and their only source of wealth is, precisely, the return on this portfolio. There are two financial assets in this economy. On the one hand, there is a 1-period default-free zero-coupon bond. Its return is riskless in nominal terms. On the other hand, there is also a perfectly indexed 1-period default-free zero-coupon bond. Its return is riskless in real terms. The latter can be understood as a "real bond" that returns units of consumption at its maturity date.[1]

Under these conditions, at each t , households solve the following problem

$$Max \ E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i})$$

subject to the following set of restrictions

$$P_s(C_s + WN_s + WR_s) = P_{s-1} WN_{s-1} i_{s-1,s} + P_s WR_{s-1} r_{s-1,s}; \quad s \geq t.$$

where β is a parameter of time preference; C_s is the real consumption of the household at moment s ; WN_s (WR_s) is the real quantity invested in the period s in the financial asset whose riskless nominal (real) return -including the principal returned- is $i_{s,s+1}$ ($r_{s,s+1}$) ; and, lastly, P_s is the general level of prices at s .

A little algebra shows that the first-order conditions of the household problem yield the following set of equilibrium equations relating interest rates (nominal and real), consumption and inflation expectations:

$$E_t[MRS_{t,t+1} \ r_{t,t+1}] = 1, \quad \forall t. \qquad (1.a)$$

$$E_t[MRS_{t,t+1} \ i_{t,t+1} \ \pi_{t,t+1}^{-1}] = 1 \quad \forall t. \qquad (1.b)$$

where

$$MRS_{t,t+1} = \frac{\beta \frac{\partial U(C_{t+1})}{\partial C_{t+1}}}{\frac{\partial U(C_t)}{C_t}} , \quad \pi_{t,t+1} = \frac{P_{t+1}}{P_t} , \quad \forall t,$$

and E_t represents the expectation operator conditional on information available at period t .

Three additional qualifications to the model are worth noting. First, under the existence of a representative household in the economy, these first-order conditions are satisfied not just for each household consumption, but also for per capita consumption.(2) Second, these conditions imply that households can trade financial assets in a frictionless market (i.e. with full information and costlessly). Third, equations (1.a) and (1.b) impose statistical restrictions on the comovements between interest rates (nominal and real), expected inflation and consumption. Thus, simple algebraic manipulation of equations (1.a) and (1.b) yields:(3)

$$\frac{1}{i_{t,t+1}} = \frac{1}{r_{t,t+1}} E_t [\frac{1}{\pi_{t,t+1}}] + COV_t [RMS_{t,t+1}, \frac{1}{\pi_{t,t+1}}] , \ \forall t. \quad (2)$$

Interestingly, this framework constitutes an equilibrium approach to the Fisher equation that explicitly takes into account the uncertainty effects of holding non-indexed zero-coupon bonds. Equation (2) states that the nominal interest rate is positively related to the real interest rate and the expected inflation as in the conventional Fisher's equation. But, the conditional covariance between the ratio of marginal utilities and the future inflation also determines this relationship. In fact, this term can be interpreted as an inflation risk premium. Notice that inflation uncertainty has an ambiguous effect on nominal interest rates according to the sign of the conditional covariance. If expected marginal utility of future consumption is high when future expected inflation is high, the covariance is negative. In this case, the nominal interest rates provides a poor hedge against unanticipated consumption changes and households require higher nominal interest rates.(4)

In the following sub-section we exploit equations (1.a), (1.b) and (2) to decompose the nominal interest rates into their three components.

2.1.a. Real interest rates

Real interest rates can be easily estimated according to equation (1.a). Observe that the real return on perfectly indexed zero-coupon bonds is known at t . Therefore, it is straightforward to see that

$$r_{t,t+1} = \frac{1}{E_t(MRS_{t,t+1})}, \quad \forall t. \tag{3}$$

Thus, we only need information on the marginal rate of substitution (i.e. information on preferences and per-capita consumption) in order to estimate this component of nominal interest rates.

2.1.b. Upper and Lower Bounds for Inflation Expectations

Estimating the other two components of nominal interest rates is not so easy. Notwithstanding, it is still possible to derive bounds for the inflation expectations through the implied bounds for the risk premium term in equation (2). We deal with this issue in this section.

Since the risk premium term is a covariance, then the following relation applies:

$$\rho_t[MRS_{t,t+1}, \pi_{t,t+1}^{-1}] = \frac{Cov_t[MRS_{t,t+1}, \pi_{t,t+1}^{-1}]}{\sigma_t[MRS_{t,t+1}]\,\sigma_t[\pi_{t,t+1}^{-1}]}$$

where ρ_t and σ_t denote conditional correlation and conditional standard deviation, respectively. But the correlation coefficient must lie inside the interval [-1, 1]. Thus, the covariance reaches an upper bound when correlation is 1, and a lower bound at the opposite extreme. Formally:

$$
\begin{aligned}
&- \sigma_t [MRS_{t,t+1}]\, \sigma_t [\pi^{-1}_{t,t+1}] \leq \\
&Cov_t [RMS_{t,t+1}, \pi^{-1}_{t+1}] \leq \\
&\sigma_t [RMS_{t,t+1}]\, \sigma_t [\pi^{-1}_{t,t+1}]
\end{aligned}
\qquad (4)
$$

Under an additional assumption on inflation volatility, namely:[5]

$$
\sigma_t [\pi^{-1}_{t,t+1}] \leq E_t [\pi^{-1}_{t,t+1}] \qquad (5)
$$

equations (1.a), (2), (4) and (5) yield

$$
\begin{aligned}
&i_{t,t+1} \{E_t [RMS_{t,t+1}] - \sigma_t [MRS_{t,t+1}]\} \\
&\leq \{E_t [\frac{-}{\pi_{t,t+1}}]\}^{-1} \leq \\
&\{E_t [RMS_{t,t+1}] + \sigma_t [MRS_{t,t+1}]\}\, i_{t,t+1}
\end{aligned}
\qquad (6)
$$

Since $\{E_t(1/\pi_{t,t+1})\}^{-1} \approx E_t(\pi_{t,t+1})$, equation (6) defines bounds on expected inflation. Observe that, as in the case of real interest rates, all we need to estimate those bounds is data on $MRS_{t,t+1}$.

To gain intuition on those bounds, observe that by using equation (3), equation (6) can be rewritten as

$$
\begin{aligned}
&\frac{i_{t,t+1}}{r_{t,t+1}} - i_{t,t+1}\sigma_t [MRS_{t,t+1}] \\
&\leq \{E_t [\frac{1}{\pi_{t,t+1}}]\}^{-1} \leq \\
&\frac{i_{t,t+1}}{r_{t,t+1}} + i_{t,t+1}\sigma_t [MRS_{t,t+1}]
\end{aligned}
$$

and $i_{t,t+1}/r_{t,t+1}$ is the inflation expectation estimate provided the inflation premium is zero. Therefore, equation (6) yields a band for the inflation expectations centred around the inflation forecast under risk neutrality, (half) the width of that band being the (absolute) maximum value for the inflation premium.

2.2. Investor Preferences

In the previous section we have shown that both real interest rates and inflation expectations can be estimated from data on the marginal rate of substitution. But $MRS_{t,t+1}$ depends on consumption dynamics through household preference specifications. In this section we present different preference specifications that allow us to investigate the links between the unobserved components of the nominal interest rates. In doing so, we consider four different utility functions, commonly used in the asset-pricing literature.(6) The first one is the isoelastic utility function. The other three functions encompass the isoelastic as a particular case and allow us to analyse (i) the effect of distinguishing between risk aversion and intertemporal substitution (Epstein and Zin, 1989; Weil, 1990), (ii) the habit formation effect (Constantinides, 1990; Heaton, 1993), and (iii) the relative consumption effect (Abel, 1990; Galí, 1994).

For a given specification of household preferences, the observed behaviour of per-capita consumption will determine the joint course of real interest rates and inflation expectations.

2.2.a. Risk aversion: the isoelastic utility function

The most usual utility function in the financial literature is the isoelastic utility function:

$$U(C_t) = \frac{C_t^{1-\gamma}-1}{1-\gamma}, \qquad \gamma \neq 1.$$

As usual, $\gamma = 1$ implies the log utility function. In this case, preferences are not time-dependent and γ measures both the household degree of (constant) relative risk aversion and the inverse of the (constant) elasticity of intertemporal substitution between future and current consumption. It is easy to prove that, in this case

$$MRS_{t,t+1} = \beta\,(g_{t+1})^{-\gamma} \tag{7}$$

where

$$g_{t+1} = \frac{C_{t+1}}{C_t}$$

Given an observed path for consumption growth, changing γ in equation (7) will allow us to analyse the sensitivity of real interest rate and inflation expectation to household degree of risk aversion.

2.2.b. Distinguishing between risk aversion and intertemporal substitution

As noted before, the isoelastic utility function restricts the coefficient of relative risk aversion to the inverse of the elasticity of intertemporal substitution. The generalized isoelastic preferences analyzed in Epstein and Zin (1989) and Weil (1990) allow such an assumption to be relaxed. These preferences can be represented recursively as

$$U_t = \left\{ C_t^{1-\rho} + \beta\, [E_t(U_{t+1}^{1-\gamma})]^{\frac{1-\rho}{1-\gamma}} \right\}^{\frac{1}{1-\rho}}$$

where $U_t = U(C_t)$, γ measures, as before, (constant) household relative risk aversion and $1/\rho$ is the (constant) elasticity of substitution between future and current consumption. Observe that this expression reduces to the isoelastic case if $\gamma = \rho$.

The existence of time dependence in preferences induces higher dynamics in the marginal rate of substitution. That is because in such a preference structure there exists an overlapping relationship between consumption decisions across time. Thus, current consumption is determined by current and one-period-ahead marginal utilities. Following Kocherlakota (1990), the marginal rate of substitution takes the following form:

$$MRS_{t,t+1} = \beta \left[E_t(U_{t+1}^{1-\gamma})\right]^{\frac{\gamma-\rho}{1-\gamma}} U_{t+1}^{\rho-\gamma}\, g_{t+1}^{-\rho} \qquad (8.a)$$

Notice that, contrary to the previous case, $MRS_{t,t+k}$ depends on non-observable variables (U_{t+1} and its expected value). However, if consumption growth evolves over time independently and identically distributed (say, iid), then utility at t can be expressed as a timeindependent constant proportion of consumption growth at t and, therefore, equation (8.a) simplifies to

$$MRS_{t,t+1} = \beta\left[E_t(g_{t+1}^{1-\gamma})\right]^{\frac{\gamma-\rho}{1-\gamma}} g_{t+1}^{-\gamma} \tag{8.b}$$

where all of the variables are (ex-post) observable. Thus, given an observed path for consumption growth, changing ρ in equation (8.b) will allow us to analyze the sensitivity of real interest rate and inflation expectation estimates to household elasticity of intertemporal substitution.

Strictly speaking, the iid assumption is usually rejected (see, for instance, Deaton, 1993). However, even being formally rejected, the assumption can still be useful if the induced error is empirically small. In that these preferences encompass the isoelastic case, we can evaluate such an error simply by comparing the different results provided by equation (7) and equation (8.b) constraining ρ to be equal to γ. Should the error be small, we could still exploit (8.b) despite the formal rejection of the iid assumption.

2.2.c. Time Non-Separabilities: Habit Formation or Durability

A different way of introducing time dependence in preferences is in terms of the existence of habits or durability in household decisions. Following Constantinides (1990), a parsimonious way of capturing these effects is to specify the following utility function:

$$U_t = \frac{(C_t - \lambda C_{t-1})^{1-\gamma}}{1-\gamma}, \quad \gamma \neq 1.$$

where λ measures the degree of habits or durability and, for U_t to be defined, $\lambda > Min\{g_t\}$ is assumed. Notice that $\lambda > 0$ implies that current utility is a negative function of past consumption, so there are habits present (it takes more consumption today to make an investor happier if he consumed more yesterday). Obviously, one can generate durability by making $\lambda < 0$ and, by setting $\lambda = 0$, that expression reduces to the isoelastic utility function. Notice also that the degree of relative risk aversion is not constant but a function function of γ, λ and g_t :

$$RRA = \gamma \frac{1}{1 - \lambda / g_t}$$

Thus, agents become more risk averse the higher γ and λ , and the lower g_t . Thus, risk aversion increases in lean times, i.e., when consumption growth is low.

After some algebraic manipulation we can obtain the corresponding marginal rate of substitution:

$$MRS_{t,t+1} = \beta \frac{(g_{t+1}g_t - \lambda g_t)^{-\gamma} - \lambda\beta (g_{t+1}g_t)^{-\gamma}(g_{t+1} - \lambda)^{-\gamma}}{(g_t - \lambda)^{-\gamma} - \lambda\beta g_t^{-\gamma}(g_{t+1} - \lambda)^{-\gamma}} \qquad (9)$$

λ being the relevant parameter in analysing the effects of household habits (or durability) on real interest rates and inflation expectations.

2.2.d. Relative Consumption Effects

The last feature of household preferences we are interested in is the presence of externalities in the utility functions. In particular, following Abel (1990) or Galí (1994), household preferences do not only depend on own consumption but also on the aggregate (economy-wide) level of consumption. A simple way of capturing this aspect of preferences has been proposed by Abel (1990), who assumes the following utility function:

$$U_t = \frac{c_t^{1-\gamma}}{1-\gamma} C_{t-1}^{\phi}$$

where c_t is individual consumption at t , as opposed to per capita consumption in the economy C_t . The parameter ϕ measures the dependence of the individual utility on the general level of consumption in the economy. A positive value of ϕ implies that the individual is altruistic in that the more the society consumes the better off he is. On the contrary, a negative value means that the household is invidious. Finally, the utility function reduces to the isoelastic case when $\phi = 0$.

Evaluated in equilibrium, where individual and per-capita consumption coincide, the marginal rate of substitution takes the following form:

$$MRS_{t,t+1} = \beta\,[g_{t+1}]^{-\gamma}\,[g_t]^{\phi} \qquad (10)$$

In the next section we estimate real interest rates and inflation expectation bounds under the different specifications for the marginal rate of substitution in equations (7) to (10).

3. EMPIRICAL RESULTS

There are different ways of obtaining the real interest rates and the inflation expectations (both unobserved variables) implied by the Lucas model. The most standard way is based upon statistical analysis through estimation. This can be thought of as a two-step approach. First, for a given specification of preferences, the time series of consumption, nominal interest rates and ex-post inflation rates can be used to obtain GMM estimates of the parameters of the model (say, θ) from the sample analogue of previous equilibrium (moment) conditions. Second, using these GMM estimates of θ, real interest rates and bounds on inflation expectations can be recovered from equations (3) and (4).

In this paper we use a different, although complementary, approach based upon a statistical analysis through calibration. That is, we derive both real interest rates and bounds on the inflation expectations for different preference specifications and for different (sensible) values of the relevant parameters.(7) As opposed to the estimation approach, we do not impose any prior parameterizacion of preferences but generate a range of both expected inflation and real interest rates compatible with the observed consumption patterns. Thus, we simply analyse how the degree of household impatience, risk aversion attitudes, the degree of altruism or envy, or intertemporal substitution behaviour affect the joint evolution of inflation expectations and real interest rates, given the observed pattern of consumption growth.

Our strategy is, thus, quite simple. In each of the four cases in section 2.2, we set different vectors θ and generate the ex-post marginal rate of substitution (equations (7), (8.b), (9) and (10)), given per capita consumption data. Then we estimate an univariate model for $MRS_{t,t+1}$ that provides estimates of both $E_t(RMS_{t,t+1})$ and $\sigma_t(RMS_{t,t+1})$ -we assume that the conditional standar deviation is constant and estimate it as the standar error of the regression-. Given those estimates, equations (3) and (4) are used to obtain, respectively, real interest rates and inflation expectation bounds.

In particular, we consider two different empirical definitions of the theoretical concept of "1-period": 1 year and 3 years. Therefore, we aim at estimating 1-year and 3-year real interest rates and at bounding inflation expectations to such horizons. Nevertheless, in order to have a sufficiently large data set, we use the quarterly per capita private non-durable consumption in Spain from 1970:I to 1995:IV, provided by the Instituto Nacional de Estadistica. Thus, we face a classical data overlapping problem that is solved by including the corresponding MA terms in the univariate models for the 1-year and 3-year marginal rates of substitution. Moreover, in order to obtain the bounds on inflation expectations we also use the 1-year nominal interest in the domestic interbank market and the 3-year zero-coupon bond nominal interest rate estimated in Nuñez (1995). Both series are the longest available, but even so they only cover the period 1979:III - 1995:IV, in the first case, and the period 1991:I - 1995:IV, in the second case.

3.1. Real Interest Rates

Tables 1, 2, 3 and 4 offer the sample means and the sample standard deviations of the 1-year and 3-year real interest rates estimated from equations (7), (8b), (9) and (10), for different values of the relevant parameters.

A number of general results in tables 1 to 4 are worth commenting.

The first feature of household preferences we are interested in is time preference, measured by parameter β. Using montly data, Ayuso (1996) estimated this parameter at 0.996, which implies an annual value of 0.95. Available estimates for other countries offer a range centred on 0.95 and with a small degree of dispersion (see, for instance, Canova and Marrinan, 1996). Therefore, in Table 1 three possible values for β are considered: 0.925, 0.95 and 0.975. These values imply annual discount rates of 8.11%, 5.26% and 2.56%, respectively. In Tables 2-4, only the last two are reported. In any case, it is clear from those tables that increasing β reduces the real interest level without affecting its variability. Taking $\beta = 0.95$ as a benchmark, making households more worried about the future by increasing β to 0.975 reduces average real interest rates by 3 percentage points. Similarly, making households more impatient ($\beta = .925$) increases them by about 3 percentage points.

The intuition behind that result is the following. A higher value for β implies that agents are more patient and, therefore, that they assign more weight to future consumption. The higher β is, the more willing they are to save today in order to consume tomorrow, thus pushing down real interest rates.

The degree of risk aversion is another relevant characteristic of agents' preferences. Alonso and Ayuso (1996) offer a summary of different estimates of γ in the Spanish case. According to Table 2 in their paper, the coefficient ranges from negative values to a maximum of about 7, with a mean value around 2. Thus, we report estimates for four different values of γ : 0.1, 0.5, 1.5 and 5.[8] As can be seen in Table 1, increasing the relative risk aversion raises both the average and the variability of the real interest rates.[9] For $\gamma = 0.1$ (and $\beta = .95$) average real interest rates under the isoelastic preferences are comparable with those in Ayuso (1996): 5.48% -one year- and 5.44 -three years-. Furthermore, interest rates are also quite stable. Raising γ from 0.1 to 5 increases the average 1-year (3-year) real interest rate to 17.44% (14.73%) and multiplies its volatility by more than 50. As we will discuss below, these effects are robust to the presence of habits or relative consumption effects in the utility function.

The effects of γ on real interest rates can be explained as follows. Notice that risk averse agents will try to smooth their consumption path. As consumption grows steadily, agents will attempt to increase current consumption and, thus, to borrow today. The higher γ is, the higher this desire and, therefore, the higher the real interest rate.[10] At the same time, the higher γ is, the more sensitive agents are to any unexpected change in the consumption path. This explains the relationship between the risk aversion degree and the volatility of the real interest rates.

In Table 2 we distinguish relative risk aversion (γ) from the inverse of intertemporal substitution (ρ). In particular we allow ρ to vary 5% and 90% up and down around the isoelastic case $(\gamma=\rho)$. The third line in panels A and B shows, first, that the results for $\gamma=\rho$ are rather comparable with those in Table 1. Thus, equation (8.b) offers a good empirical approach to equation (8.a). And second, disentangling risk aversion from intertemporal substitution has no effect on real interest rate volatility but it modifies the real interest rate level. This last effect, however, crucially depends on the choice of γ. When γ is low, increasing the degree of intertemporal substitution reduces the real interest rate level. For instance, when $\gamma=0.1$, raising the degree of intertemporal substitution from 10 (corresponding to the isoelastic case) to 100, reduces 1-year real interest rate from 5.49% to 4.80%. The higher γ is, the higher is the decline in real interest rates.

Introducing durability ($\lambda<0$) in preferences does not modify real interest rate estimates under the isoelasticity assumption. As commented in the previous section, λ is bounded by the minimum rate of consumption growth in the data. In our case, that means that it has to be less than 0.97. Thus, a grid of between -0.6 and 0.6 has been considered. As can be seen in Table 3, only by imposing a relatively high degree of habits ($\lambda=0.6$) is it possible to affect the average real interest rates and their variability. A (high) positive value of λ increases both the 1-year real interest rate level (from 5.48% to 6.58% in the $\gamma=.1$ case) and its variability (from .24 to .69 in the same case) with respect to the isoelastic case.[11] Moreover, the effect is exponential in γ : for $\gamma = 1.5$, the sample mean and the sample standard deviation increase from 8.62% and 3.81 to 20.16% and 14.91, respectively.

These results are easy to understand recalling that, in this case, the degree of relative risk aversion depends positively on λ . Thus, the same reasoning behind the effects of γ can be applied here.

Finally, we have considered values for ϕ between -1 and 1. Observe that $1-\gamma = |\phi|$ can be seen as an extreme case in that social and individual consumption are equally weighted in the household utility function. The non-negativeness restriction on γ makes 1 a natural choice for bounding $|\phi|$. Table 4 shows that the level of real interest rates is inversely related to the value of ϕ , whereas their variability increases with $|\phi|$. Thus, the more altruistic (less envious) agents are, the lower is the average real interest rates. Average 1-year (3-year) real interest rates change from 5.48% (5.44%) to 7.70% (7.26%) if agents are extremely envious and to 3.35% (3.36%) if they are extremely altruistic. The corresponding standard deviations multiply by about 10 in both cases.

In order to understand the effect of ϕ on the real interest rates, notice that the same consumption path gives a smoother utility path the higher ϕ is. If consumption grows steadily, this additional smoothing effect reduces the above-mentioned need by risk averse agents for borrowing today, thus pushing down real interest rates.

By way of a summary, Figures 1 and 2 show the pattern of 1-year and 3-year real interest rates in several cases chosen to illustrate the aforementioned effects for sensible values of the relevant parameters. In all figures, we take the isoelastic with $\gamma = 0.1$ and $\beta = .95$ as our benchmark. This is so because, as noted before, it is the closest to the real interest rate estimates in Ayuso (1996).

As it can be seen, taking as given the per-capita consumption pattern in Spain, real interest rates below 4% can be obtained only if, given a small degree of relative risk aversion, we are willing to accept a relatively high degree of patience, an extremely high degree of intertemporal substitution or the existence of some degree of altruism in Spanish households. In the latter case, real interest rates are also more variable than in Ayuso (1996). This higher variability can also be obtained increasing agents' relative risk aversion or accepting an important degree of habits in their utility functions. In such cases, however, the average level of real interest rates notably increases.

But the choice of a set of parameters also has important implications for the inflation expectations that can be derived from the observed behaviour of nominal interest rates and consumption growth. This is the subject of the next section.

3.2. Inflation Expectations

In this section we analyse the relationships between the observed (i.e. ex-post) inflation rate and the bounds on inflation expectations estimated using our approach. Given the large number of bounds that can be derived from Tables 1 to 4, we decided to report four of the six cases presented in Figures 1 and 2. These cases allow us to analyse the effects on inflation expectations of the main determinants of the level and volatility of the real interest rates: risk aversion, habit formation and relative consumption.(12) Thus, in the top left panels of Figures 3 and 4 we plot the bounds on inflation expectations for our benchmark case (i.e, the isoelastic with γ=0.1 and β=0.95). The top right panel plots the effects on inflation expectations of a higher household risk aversion. The bottom left panel shows the effects of relative (aggregate) consumption on the utility function, and the bottom right panel displays the effects of habit formation. In Figure 3, 1-year inflation expectations are depicted, whereas in Figure 4, 3-year inflation expectations are considered. In both figures, 1-year and 3-year ahead observed inflation are also depicted in order to discuss how inflation expectations react to movements in inflation.(13)

We first discuss 1-year inflation expectations by looking at their behaviour in our benchmark (i.e. the top left panel of Figure 3). From this Figure four main messages emerge.

(i) From the course of observed inflation there is supporting evidence of a clear downward trend dominating the behaviour of this variable over the period 1979-1995. For instance, since 1992 it appears that the inflation rate has been around a new level below the 5.5% mean level for the period 1988-1991, or the 10% mean level for the period 1979-1986. We interpret this evolution as reflecting the behaviour of two different components: a permanent change in the mean of the inflation rate that has been consolidated in the latter part of our sample period, and a series of fluctuating transitory inflation swings. Accordingly, the way in which inflation evolves over time will depend upon the persistence of the transitory shocks, i.e. the way in which inflation returns to its mean value after a shock, and the process describing how the inflation mean switches. Bearing this in mind is crucial for the analysis of inflation expectations over this period.

(ii) From 1979 to 1982 agents' inflation expectations were systematically lower than observed inflation. From 1983 to 1986 observed inflation and inflation expectations were more closely related, although in the first part of this period inflation expectations were higher than actual inflation. This behaviour changed during 1984 and 1985. Overall, inflation expectations fell sharply during the period 1983-1985, and did not return to the high levels of the 1979-1982 period. Notwithstanding, from 1987 to 1992 (with the exception of 1988) agents' expectations were systematically higher than observed inflation. But again, from 1993, inflation expectations changed considerably.

(iii) From comments (i) and (ii) it seems that it takes some time for the new pattern of inflation to be understood and incorporated into agents' inflation expectations. That is to say, inflation expectations reflect the movements in the inflation trend with some delay. The episode from 1989 to 1992 can illustrate this point. In this period, expected inflation tended (on average) to overpredict observed inflation in that it did not immediately react to its observed decreasing path.[14] Thus, agents seemed not to be convinced that the inflation reduction would last. In other words, they needed "some" time to believe that the course of inflation reflected a permanent change (i.e. a change in the mean or a change in the inflation regime). To make this situation compatible with the rational expectations hypothesis, one can argue that a sort of "peso-problem" is behind such behaviour: during the period of apparently irrational behaviour (that is, the overpridicting 1989-1992 period), agents expectations were swayed by the feeling that movements in observed inflation would not be consolidated in subsequent periods (i.e. were not permanent).

(iv) Clearly, upper and lower bounds are very closely related and move together. This indicates that risk premium terms are rather constant and very small for the entire period we are considering. This evidence is consistent with that presented by Alonso and Ayuso (1996).

Remember that all these comments about inflation expectations and risk premium are based upon the hypothesis that an isoelastic utility function with a lower degree of risk aversion is a good approximation of our CCAPM model. But reasonable caveats arise when judging the goodness of such a preference specification. The remaining charts in Figure 3 illustrate the sensitivity of inflation expectations and risk premia to a higher degree of risk aversion, to the existence of habit formation and to the presence of relative consumption effects in household utility functions.

Thus, from the top right panel of Figure 3, increasing relative risk aversion raises the risk premium (although it is still constant over time) and tends to relax the peso problem affecting inflation expectations. As noted before, increasing risk aversion heightens the level and volatility of real interest rates. From the bottom left panel of Figure 3, allowing for relative consumption effects has no significative effects upon risk premium, but exacerbates the peso problem in some particular episodes. As noted before, real interest rates are lower and more volatile than in the isoelastic case. Finally, from the bottom right panel of Figure 3, allowing for habit formation greatly increases the risk premium (although it is still constant over time) and reduces the peso problem effects in inflation expectations. The level and volatility of real interest rates are quite similar to those of the isoelastic case.

In all four cases, inflation expectations markedly decreased in 1993 due, perhaps, to the fact that agents started to look at the process of inflation reduction as a permanent one. The expectation increase in 1994 seems to have been reversed in 1995 and by the end of that year 1-year inflation expectations were below 4%.

Unfortunately, 3-year nominal interest rates cover a very short period that does not allow an analysis as rich as in the 1-year case. Despite that, Figure 4 shows that comment (ii) is still valid for the 3-year horizon: inflation premia seem to be stable and small. Moreover, for the available period, 1-year and 3-year inflation expectations show a similar pattern and overprediction is also present in the 3-year case since 1991. It also seems that these medium-term inflation expectations are less sensitive to the considered changes in preference specifications than 1-year expectations. In any case, by the end of 1995, 3-year inflation expectations were still high -about 4.6%- and clearly above the minimum level reached at the beginning of 1994.

4. CONCLUSIONS

In this paper we retrieve real interest rates and inflation expectations from Spanish nominal interest rates, in a Consumption Capital Asset Pricing Model (CCAPM) framework. This provides a simple and modern equilibrium approach to the Fisher equation. In particular, we exploit the theoretical relationship between these variables to obtain real interest rates and bounds on inflation expectations. In doing so, we take the marginal rate of substitution between future and current (non-durable) consumption as a sufficient statistic of movements in the variables. Notwithstanding, we do not estimate any particular asset pricing model but consider instead four different preference specifications. For each preference specification we estimate real interest rates and bounds on inflation expectations for a (sensible) set of values for the relevant structural parameters. Thus, we can analyse the sensitivity of real interest rates and inflation expectations to changes in a set of parameters that capture a series of important features in the public's utility functions: time preference, risk aversion, intertemporal substitution, durability and envy.

The main conclusions of our analysis can be summarized as follows:

(i) 1-year and 3-year real interest rates below 4% can be obtained only if, given a small degree of relative risk aversion, we are willing to accept a relatively high degree of patience, an extremely high degree of intertemporal substitution or the existence of some degree of altruism in Spanish households. In these cases, real interest rates are also quite stable. More volatility in the real interest rates can be obtained if agents' relative risk aversion is above 0.5 or an important degree of habits is present in their utility functions. In such cases, however, the average level of real interest rates notably increases.

(ii) From the joint pattern of observed inflation and inflation expectations it seems that it takes some time for a new pattern of inflation to be understood and incorporated into agents' inflation expectations. Specifically, inflation expectations reflect movements in the inflation trend with some delay and therefore agents seem to need "some" time to believe that the new inflation course reflects a permanent change (i.e. a change in the mean or a change in the inflation regime). To make this situation compatible with the rational expectations hypothesis, we argue that a sort of "peso-problem" is behind such behaviour: systematic overprediction of the inflation rate during a relatively protacted period might reflect that agents expectations are swayed by the feeling that movements in observed inflation will not be consolidated in subsequent periods (i.e. are not permanent). On the other hand, risk premium terms are constant and small for the entire period we are considering.

(iii) As to the effects of agents' preference specifications on inflation expectations and inflation risk premia, the higher the relative risk aversion, the higher the risk premium (although it is still constant over time), and the smaller the peso problem affecting inflation expectations. Allowing for relative consumption effects has no significant influence on risk premia but exacerbates the peso-problem in some particular episodes. Allowing for habit formation greatly increases the risk premium (although it is still constant over time), and contributes to reduce peso problem effects in the evolution of inflation expectations.

(iv) In most of the cases considered, 1-year inflation expectations markedly decreased in 1993 reflecting, perhaps, the fact that agents started to perceive the process of inflation reduction as a permanent one. Thus, by the end of 1995, 1-year inflation expectations were below 4%.

NOTES

1. Of course, the existence of other risky assets or more maturity dates in the economy does not affect the results that we present in this section. On the empirical performance of CCAPM under isolastic preferences in the Spanish case, see Ayuso (1996) and Rubio (1996).

2. Notice that allowing for many homogeneous agents is a sufficient but not a necessary condition for the representative agent assumption. The necessary condition is the existence of complete markets. That is to say, it is possible to construct a representative agent from heterogeneous agents because, after trading in complete markets, households become marginally homogeneous (Constantinides, 1982).

3. To derive equation (2) from (1.a) and (1.b) note that for any two random variables x and y, Cov(x,y) = E(x.y)-E(x)E(y).

4. A simple way of gaining intuition on these risk premium effects on nominal interest rates is to consider that: (i) consumption growth and inflation are jointly log-normally distributed, and (ii) utility is of the Hyperbolic absolute risk aversion (HARA) class. Under these hypotheses equation (2) becomes:

$$i_{t,t+1}=r_{t,t+1}+E_t[\log\pi_{t,t+1}]+\frac{1}{2}Var_t[\log\pi_{t,t+1}]-\gamma Cov_t[\Delta\log C_{t+1},\log\pi_{t+1}]$$

where γ reflects relative risk aversion attitudes. See, for a more detailed discussion, Evans and Wachtel (1990).

5. (Non-reported) Estimates of an AR-ARCH model for Spanish inflation show that the conditional standard deviation has never been above 0.01 times the conditional expectation during the period we analyse.

6. See, for instance, Cochrane and Hansen (1992) and Kocherlakota (1996).

7. A similar approach is taken by Smith (1993) and Ireland (1996).

8. Estimates for $\gamma = 10$ are also available and do not change our conclusions.

9. These results also hold in Tables 3 and 4.

10. There is also an opposite effect: increasing γ also increases precautionary savings. For sufficiently high values of γ this second effect might dominate.

11. For values of λ higher than .4 -for which some effect is detected- our estimates do not converge for 3-year real interest rates. It seems plausible to think of a smaller value for λ in the 3-year case in that habits refer to a notably longer period.

12. As can be expected from the results in Tables 1 and 2, increasing β or decreasing ρ simply moves the bounds in the top left pannels up in parallel.

13. Our inflation data correspond to Spanish CPI. Using non-durable consumption prices instead of total consumption prices does not modify our conclusions.

14. Including taxes in the analysis might affect the magnitud of this overprediction error. See the Appendix for a more detailed discussion.

TABLE 1
REAL INTEREST RATES (%): ISOELASTIC

PANEL A = ONE YEAR

β	γ = 0.1	γ = 0.5	γ = 1.5	γ = 5
0.925	8.35 [0.25]	9.23 [1.27]	11.56 [3.91]	20.61 [14.17]
0.95	5.48 [0.24]	6.36 [1.24]	8.62 [3.81]	17.44 [13.80]
0.975	2.77 [0.24]	3.63 [1.21]	5.84 [3.71]	14.42 [13.44]

PANEL B = THREE YEARS

β	γ = 0.1	γ = 0.5	γ = 1.5	γ = 5
0.925	8.29 [0.17]	9.01 [0.94]	10.86 [2.87]	29.46 [10.17]
0.95	5.44 [0.18]	6.14 [0.91]	7.95 [2.79]	14.73 [13.80]
0.975	2.74 [0.24]	3.42 [0.89]	5.18 [2.72]	11.79 [9.65]

Note: The figures are sample means. Sample standard deviations are in brackets. Sample Period: 1970.I-1995.IV. Both β and real interest rates are annualized.

TABLE 2

REAL INTEREST RATES (%): EPSTEIN-ZIN PREFERENCES

PANEL A = ONE YEAR

$\beta = 0.95$	γ			
$\rho = \gamma(1+\tau)$	0.1	0.5	1.5	5
$\tau = -90\%$	4.80 [0.24]	2.86 [1.19]	-2.56 [3.39]	-32.12 [7.91]
$\tau = -5\%$	5.45 [0.24]	6.08 [1.23]	9.55 [3.81]	17.64 [13.71]
$\tau = 0$	5.49 [0.24]	6.39 [1.23]	8.74 [3.78]	17.83 [13.73]
$\tau = +5\%$	5.53 [0.24]	6.74 [1.23]	8.18 [3.76]	18.06 [13.76]
$\tau = +90\%$	6.29 [0.25]	70.431 [1.97]	7.74 [3.74]	25.44 [14.62]

PANEL B = THREE YEARS

$\beta = 0.95$	γ			
$\rho = \gamma(1+\tau)$	0.1	0.5	1.5	5
$\tau = -90\%$	4.79 [0.18]	2.82 [0.87]	-2.66 [2.50]	-32.38 [5.82]
$\tau = -5\%$	5.40 [0.19]	5.84 [0.89]	8.77 [2.80]	14.56 [9.87]
$\tau = 0$	5.44 [0.18]	6.14 [0.90]	7.92 [2.76]	14.59 [9.87]
$\tau = +5\%$	5.48 [0.18]	6.47 [0.90]	7.33 [2.76]	14.67 [9.88]
$\tau = +90\%$	6.20 [0.18]	69.67 [1.43]	6.24 [2.73]	19.12 [10.26]

Note: See Table 1 for details.

TABLE 3
REAL INTEREST RATES (%): HABIT FORMATION

PANEL A = ONE YEAR

β = 0.95	γ			
λ	0.1	0.5	1.5	5
-0.6	5.477 [0.244]	6.342 [1.233]	8.577 [3.789]	17.274 [13.763]
-0.2	5.477 [0.245]	6.341 [1.237]	8.576 [3.801]	17.287 [13.793]
0.2	5.479 [0.251]	6.355 [1.273]	8.618 [3.911]	17.510 [14.282]
0.6	6.575 [0.692]	15.971 [5.001]	20.160 [14.913]	(*)
β = 0.975				
λ				
-0.6	2.77 [0.24]	3.62 [1.20]	5.79 [3.69]	14.27 [13.41]
-0.2	2.77 [0.24]	3.62 [1.21]	5.80 [3.72]	14.29 [13.50]
0.2	2.77 [0.24]	3.63 [1.24]	5.83 [3.81]	14.50 [13.91]
0.6	3.77 [0.64]	12.73 [4.77]	37.21 [19.21]	(*)

PANEL B = THREE YEARS

β = 0.95	γ			
λ	0.1	0.5	1.5	5
-0.6	5.43 [0.18]	6.11 [0.90]	7.85 [2.74]	14.42 [9.79]
-0.2	5.43 [0.18]	6.11 [1.90]	7.86 [2.73]	14.43 [9.83]
0.2	5.44 [0.17]	6.36 [0.90]	8.62 [2.75]	17.51 [8.84]
β = 0.975				
λ				
-0.6	2.73 [0.17]	3.39 [0.87]	5.08 [2.66]	11.46 [9.51]
-0.2	2.73 [0.17]	3.39 [0.87]	5.09 [2.67]	11.58 [9.61]
0.2	2.73 [0.17]	3.40 [0.88]	5.08 [2.66]	9.88 [8.50]

Note: The (*) indicates a value higher than 100%. For some parameters' specification the real interest rates are not reported due to convergence problems. See Table 1 for more details.

TABLE 4

REAL INTEREST RATES (%): RELATIVE CONSUMPTION

PANEL A = ONE YEAR

β = 0.95	γ			
φ	0.1	0.5	1.5	5
-1	7.70 [2.78]	8.61 [3.81]	10.95 [6.50]	20.104 [16.98]
-0.5	6.58 [1.50]	7.47 [2.51]	9.76 [5.13]	18.70 [15.39]
0.5	4.40 [0.98]	5.25 [0.32]	7.45 [2.56]	15.99 [12.33]
1	3.35 [2.18]	4.17 [1.27]	6.35 [1.41]	14.68 [10.88]
β = 0.975				
φ				
-1	4.94 [2.71]	5.82 [3.71]	8.11 [6.33]	17.02 [16.55]
-0.5	3.84 [1.45]	4.72 [2.45]	6.95 [5.00]	15.65 [14.99]
0.5	1.72 [0.96]	2.55 [0.31]	4.70 [2.49]	13.01 [12.02]
1	0.70 [2.12]	1.50 [1.24]	3.62 [1.38]	11.74 [10.60]

PANEL B = THREE YEARS

β = 0.95	γ			
φ	0.1	0.5	1.5	5
-1	7.26 [2.04]	6.109 [0.896]	7.849 [2.738]	14.417 [9.789]
-0.5	6.34 [1.10]	6.113 [1.894]	7.856 [2.734]	14.428 [9.827]
0.5	4.54 [0.72]	5.23 [0.13]	7.02 [1.83]	13.71 [8.81]
1	3.66 [1.60]	4.33 [0.94]	6.09 [0.97]	12.65 [7.57]
β = 0.975				
φ				
-1	4.51 [1.99]	3.390 [0.872]	5.085 [2.664]	11.462 [9.513]
-0.5	3.62 [1.07]	3.392 [0.871]	5.087 [2.671]	11.583 [9.609]
0.5	1.86 [0.70]	2.53 [0.13]	4.28 [1.78]	10.79 [8.58]
1	0.99 [1.56]	1.66 [0.91]	3.36 [0.94]	9.77 [7.56]

Note: See Table 1 for details.

FIGURE 1
1-YEAR REAL (EX-ANTE) INTEREST RATES

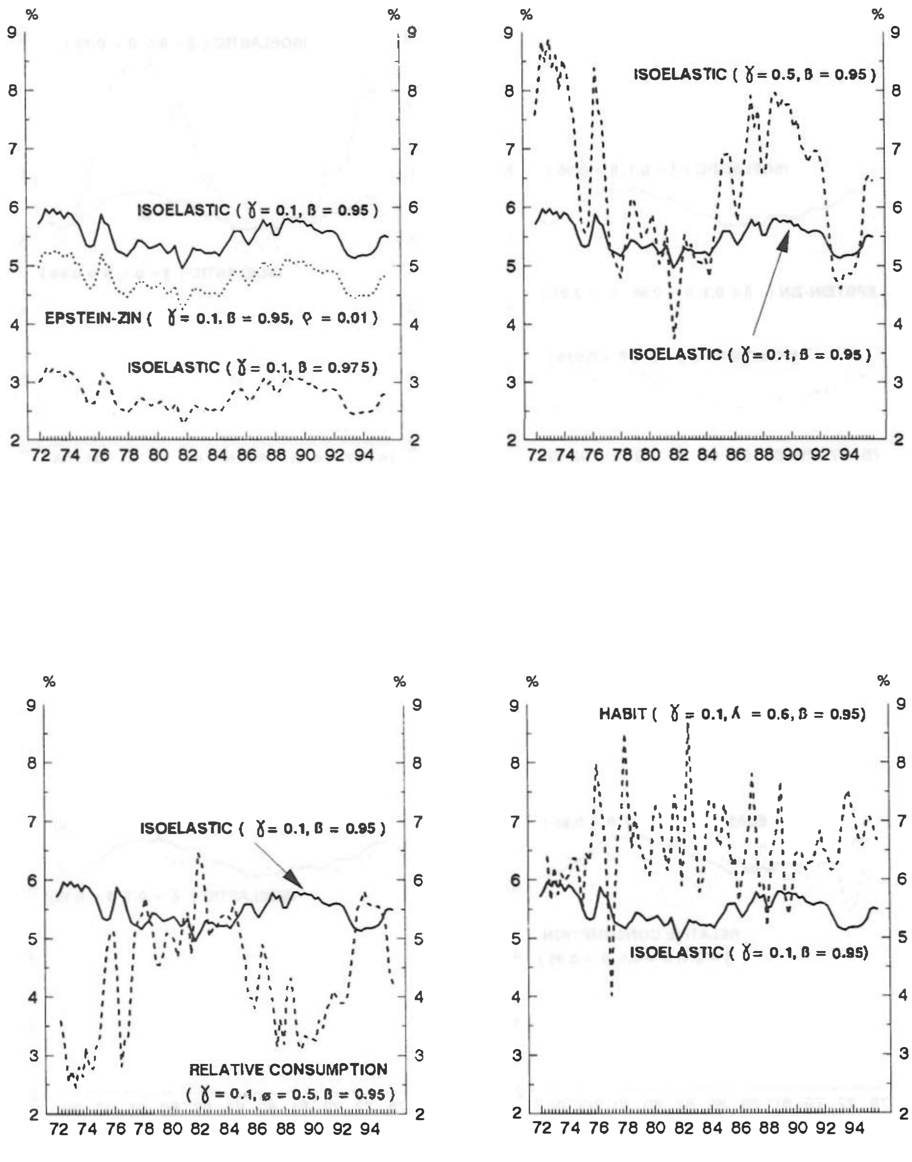


FIGURE 2
3-YEAR REAL (EX-ANTE) INTEREST RATES

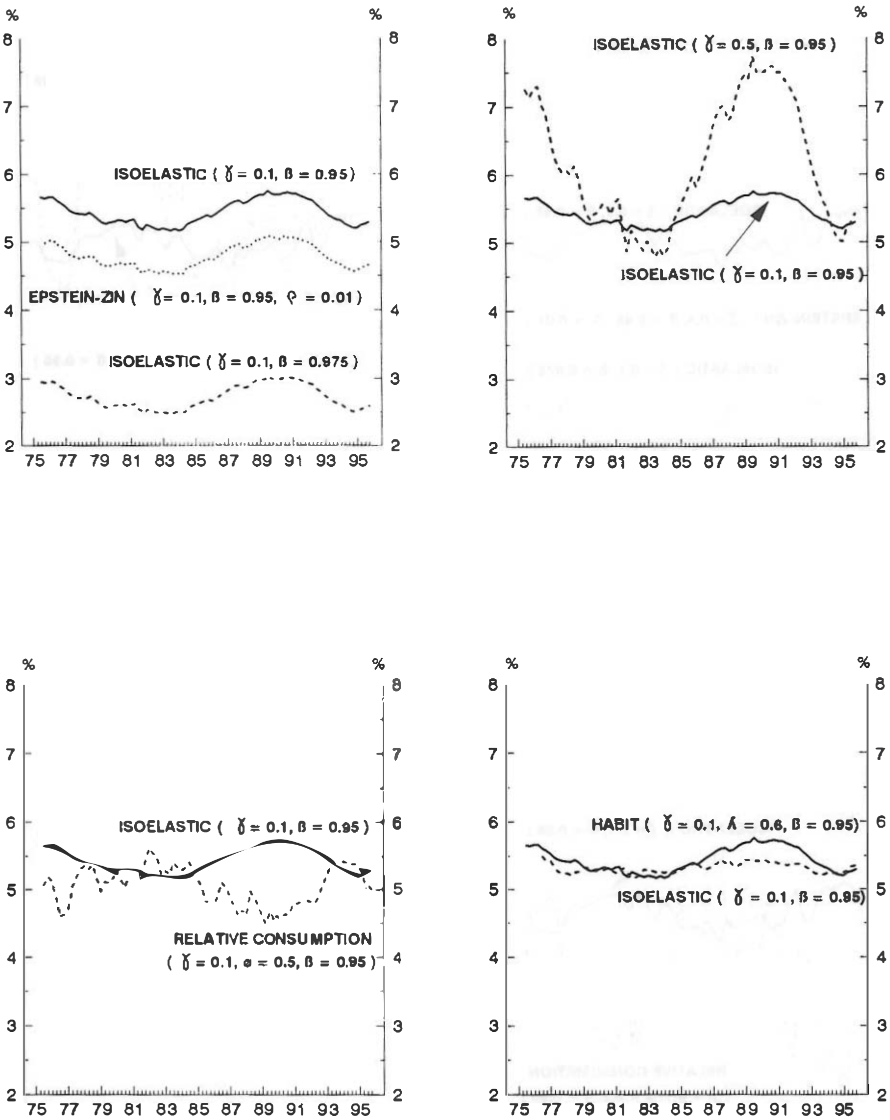


FIGURE 3
1-YEAR EXPECTED INFLATION BOUNDS

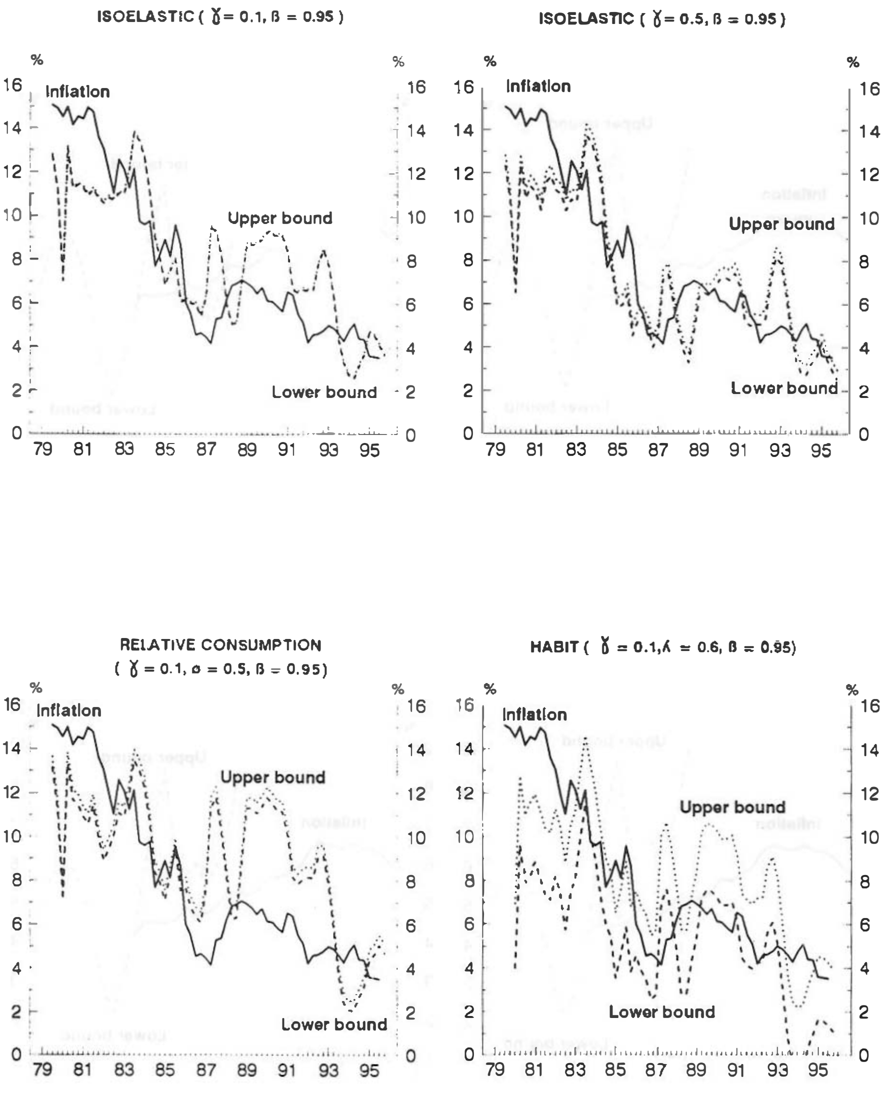
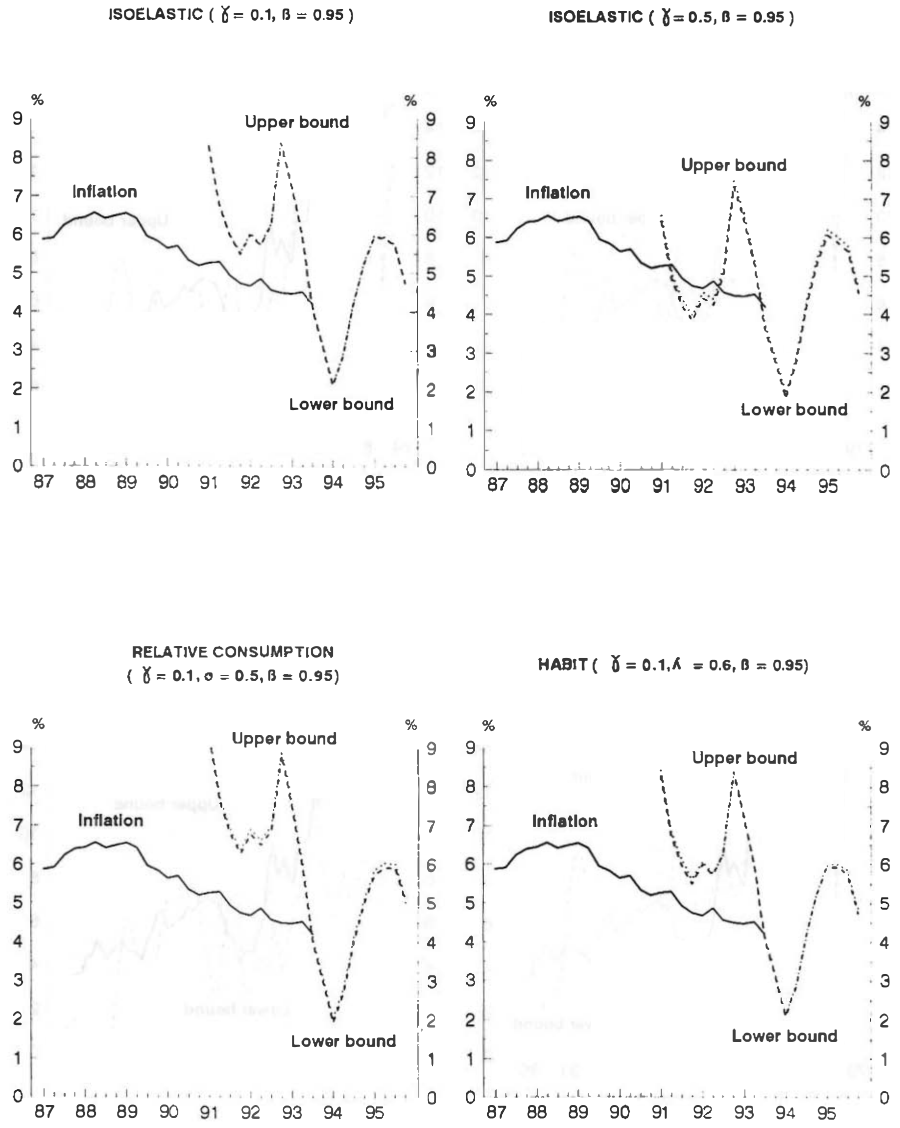


FIGURE 4
3-YEAR EXPECTED INFLATION BOUNDS



APPENDIX: THE EFFECTS OF TAXES

Considering a proportional tax -known at t-1- on agent's nominal income at t -say, τ_{t-1}- , modifies the budget constraint in the optimization problem as follows:

$$P_s(C_s + WN_s + WR_s) = (P_{s-1} WN_{s-1} i_{s-1,s} + P_s WR_{s-1} r_{s-1,s})(1-\tau_{s-1}),$$

where interest rates are now before-tax interest rates. Thus, equation (3) in the main text takes now the following form:

$$(1-\tau_t)\, r_{t,t+1} = \frac{1}{E_t(MRS_{t,t+1})}.$$

Since we have estimated the inverse of the expected marginal rate of substitution, our real interest rates in the main text can be taken as estimates of after-tax real interest rates.

Moreover, the Fisher equation - equation (2)- also changes:

$$\frac{1}{i_{t,t+1}(1-\tau_t)} = \frac{1}{r_{t,t+1}(1-\tau_t)} E_t\left[\frac{1}{\pi_{t,t+1}}\right] + COV_t\left[RMS_{t,t+1}, \frac{1}{\pi_{t,t+1}}\right].$$

Thus, the new bounds for inflation expectations are

$$(1-\tau_t)\frac{i_{t,t+1}}{r_{t,t+1}(1-\tau_t)} - i_{t,t+1}\sigma_t[MRS_{t,t+1}](1-\tau_t)$$

$$\leq \left\{E_t\left[\frac{-}{\pi_{t,t+1}}\right]\right\}^{-1} \leq$$

$$(1-\tau_t)\frac{i_{t,t+1}}{r_{t,t+1}(1-\tau_t)} + i_{t,t+1}\sigma_t[MRS_{t,t+1}](1-\tau_t).$$

Two remarks are in order. First, notice that introducing taxes narrows the width of our bounds on inflation expectations. Second, if there are taxes, the bounds in the main text correspond to after-tax real interest rates and before-tax nominal interest rates. Thus, we might also be overvaluing the mid point of the band. By way of an example, considering τ_t = 20% and τ_t = 25% in our benchmark would reduce the mean (inflation) overprediction error between 1989:I and 1993:II from 2.32 percentage points to .72 and .31 percentage points, respectively.

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