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Abstract

We study information processing in a simple endowment economy where the mean consumption growth rate are governed by a hidden state variable and agents have recursive preferences. We show that for typical parameter values, there is a strong incentive to commit to ignoring future information on the state of the economy, but that such commitment raises time-inconsistency problems. We estimate the model on postwar US data and find that the representative consumer can achieve a utility gain equivalent to a 20% increase in lifetime consumption simply by not paying attention to the state of the economy.

Keywords

Recursive preferences; Epstein-Zin preferences; Uncertainty aversion; Information processing; Time inconsistency

JEL Classification

D83, D84, E32

Information processing with recursive utility: some intriguing results*

Frode Brevik[†] Stefano d'Addona[‡]

1 Introduction

Information on the state of the economy can be valuable for two reasons. First, it can be used to make informed choices between different actions. Second, information alleviates uncertainty about future consumption.

We are interested in the second effect, so we isolate it by studying an endowment economy where agents have Epstein-Zin's preferences (See Kreps and Porteus, 1978; Epstein and Zin, 1989; Weil, 1989). The main framework is a standard one. Agents know the structure of the economy and observe consumption growth rates, but not the underlying time varying trend. What is new is that we let agents choose whether to use filtering algorithms to estimate the underlying hidden trend. The most intuitive example would be the case when processing the available informations entails some small mental costs. Instead of processing the information and incure the cost, the agent can choose to remain with his prior beliefs about the hidden state of the economy.

Our results are very different from what obtains when consumers *always process all available information*. In this case, a consumer has a preference for early resolution of uncertainty whenever his relative risk aversion is higher

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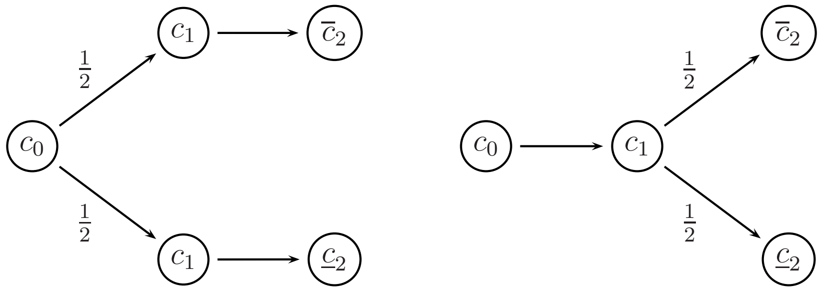
Figure 1: Preferences for resolution of uncertainty

(a) Early resolution (b) Late resolution



$$(a) \succ (b) \iff EIS > 1/CRRA$$

$$(a) \prec (b) \iff EIS < 1/CRRA$$

than the inverse of his elasticity of intertemporal substitution.[1] What this means is illustrated in Figure 1 which is taken from Kocherlakota (1990). Given a choice, an agent with a preference for early resolution of uncertainty would prefer tree (a) to tree (b): the two trees offer the same distribution of outcomes at each point in time, but in tree (a), time 2 consumption is revealed one period earlier.

A priori, one might think that a consumer who has a preference for early resolution of uncertainty *under perfect information processing* has no incentive to ignore information on the current state of the economy. Knowledge about the state of the economy reduces uncertainty about future consumption and would be welcome as such. However, if there is a persistent component to consumption growth rates, there is an effect that goes in the opposite direction. Agents with relatively high risk aversion also dislike a positive correlation between current consumption growth and expected consumption growth. By not updating their expectations about future growth rates they suffer from more consumption uncertainty, which lowers their utility, but also shut down any correlation between consumption realizations and expected future realizations. In the simple economy we study, the second effect typically dominates, so ignorant agents have a higher utility level.

[1] See e.g. Kocherlakota (1990) or Skiadas (1998).

We also show that there is a tension between consumers' desire to reduce uncertainty and their desire to shut down correlation between realized and expected future consumption growth rates. This tension generates time consistency issues. The optimal strategy for a consumer is to learn the current state of the economy but commit to never updating his beliefs in the future. Learning the current consumption level reduces uncertainty while leaving future correlations unchanged; committing to never updating beliefs in the future shuts down the correlation. However, in future periods, the optimal strategy will look the same. So, unless consumers can commit, they will always choose to update their beliefs.

The paper is organized as follows: section 2 introduces the model and our two laboratory economies. Section 3 establishes the utility gains or losses that an agent would face from learning the state of the economy. Section 4 provides an overview on the model's estimation and discusses the results for the two different economies, and section 5 concludes.

2 The Model

We base our model of the economy on the canonical one in Hansen et al. (2005).

2.1 Preferences

The infinitely lived representative consumer's preferences are given by:

$$V_t = \left[(1-\beta)\left(C_t\right)^{1-\rho} + \beta \mathcal{R}_t\left(V_{t+1}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{1}$$

where ρ is equal to the reciprocal of the elasticity of intertemporal substitution. The risk adjustment $\mathcal{R}_t$ is also specified as a CES:

$$\mathcal{R}_t\left(V_{t+1}\right) = \mathrm{E}\left[\left(V_{t+1}\right)^{1-\theta} \mid \mathcal{F}_t\right] \tag{2}$$

where θ is the Coefficient of Relative Risk Aversion (CRRA) and $\mathcal{F}_t$ is the period t information set. V_t is obviously homogeneous of degree 1 in the level of consumption. Let v_t denote the logarithm of the continuation value normalized by the consumption level. We rewrite the recursion above as

$$v_t = \frac{1}{1-\rho} \log\left[(1-\beta) + \beta \exp[(1-\rho)\mathcal{Q}_t(v_{t+1} + c_{t+1} - c_t)]\right], \tag{3}$$

where $\mathcal{Q}_t$ is

$$\mathcal{Q}_t(v_{t+1}) = \frac{1}{1-\theta} \log E_t \left[\exp\left((1-\theta)v_{t+1}\right)\right]$$

2.2 Stochastic Processes

Our laboratory is a simple endowment economy where the growth rate of the log of the representative agent's consumption is the sum of an AR(1) component and a white noise shock.

Let ϵ_t and ν_t be two series of i.i.d. standard normal innovation terms. Log consumption follows a random walk plus a time varying drift and its first difference is given by

$$c_{t+1} - c_t = \mu_c + x_{t+1} + \sigma_c \epsilon_{t+1}. \tag{4}$$

The expected log consumption growth rate at time t is a combination of a constant (μ_c) and a time varying component x_t. x_t follows an AR(1):

$$x_{t+1} = \kappa x_t + \sigma_x \nu_{t+1} \tag{5}$$

2.3 Alternative information sets

We focus on three specifications for the information set $\mathcal{F}_t$. In all specifications, consumers know their current consumption level as well as the stochastic processes governing the evolution of the endowment stream. In the first specification, consumers neither observe x_t nor try to infer its value from past consumption growth rates. The rationale for not trying to estimate the current state of the economy might either be that information processing is costly or, as we will show, that it reduces utility and that consumers can constrain themselves from estimating x_t. We will refer to this specification as the *no filtering economy.* In the second case, which we will refer to as *observable economy (I)*, the consumers also know the current value of the state variable x_t. As a third state we let the consumers have even more information and let them directly observe x_{t+1}. This is equivalent to letting the mean consumption growth rate for $t+1$ be given by $(\mu_c + x_t)$ instead of $(\mu_c + x_{t+1})$. We refer to this specification as *observable economy (II).* Summarizing:

1. *no filtering*: $\mathcal{F}_t = \{C_t, \mu_c, \sigma_c, \sigma_x, \kappa\}$

2. *observable economy (I)*: $\mathcal{F}_t = \{C_t, \mu_c, \sigma_c, \sigma_x, \kappa, x_t\}$

3. *observable economy (II)*: $\mathcal{F}_t = \{C_t, \mu_c, \sigma_c, \sigma_x, \kappa, x_{t+1}\}$

2.4 Value functions for $\rho = 1$

As in Tallarini (2000) we focus on the case $\rho = 1$. In conjunction with the Gaussian shock processes we assume, it allows for simple closed form solutions for the value function under the three information sets. The $\rho = 1$ limit of recursion (3) is[2]

$$v_t = \frac{\beta}{1-\theta} \log E\left(\exp[(1-\theta)(v_{t+1} + c_{t+1} - c_t)] \mid \mathcal{F}_t\right) \tag{6}$$

2.4.1 No filtering

We first look at the case when the consumers do not observe x and do not use historical consumption growth rates to infer its current value. In this case, the only variable in the consumers information set which changes over time is the current consumption level C_t. It follows that v_t is constant. We denote its value by $\tilde{v}$. From equation (6), $\tilde{v}$ is given by

$$\begin{aligned}
\tilde{v} &= \frac{\beta}{1-\theta} \log E\left[\exp[(1-\theta)(\tilde{v} + c_{t+1} - c_t]\right] \\
&= \frac{\beta}{(1-\beta)(1-\theta)} \log E\left[\exp[(1-\theta)(c_{t+1} - c_t]\right]
\end{aligned}$$

Unconditionally, $\Delta c_{t+1} \sim N\left(\mu_c, \sigma_c^2 + \sigma_x^2/(1-\kappa^2)\right)$. So

$$\tilde{v} = \frac{\beta}{1-\beta}\left[\mu_c + \frac{1-\theta}{2}\left(\sigma_c^2 + \frac{1}{1-\kappa^2}\sigma_x^2\right)\right]. \tag{7}$$

The second term in the squared parenthesis of equation (7) is a risk adjustment. Its magnitude depends on the sum of the variance of the white noise consumption shock and the unconditional variance of the trend consumption growth rate. The risk adjustment lowers utility whenever the coefficient of risk aversion θ is larger than 1.

[2]Equation (18) of Hansen et al. (2005)

2.4.2 Observable economy (I)

We denote v_t in the the case where the consumers observe x_t but not x_{t+1} by v_t^I. The solution for v_t^I is given by

$$v_t^I = \mu_v^I + U_v^I x_t, \tag{8}$$

where

$$\mu_v^I = \frac{\beta}{1-\beta}\left(\mu_c + \frac{1-\theta}{2}\left(\sigma_c^2 + \frac{1}{(1-\kappa\beta)^2}\sigma_x^2\right)\right) \tag{9}$$
$$U_v^I = \frac{\kappa\beta}{1-\kappa\beta}.$$

Notice that μ_v^I is the unconditional expectation of v_t^I, because the mean of x_t is 0. A change with respect to the no filtering case is that, while $\tilde{v}$ depends on the unconditional variance of the trend growth rate, μ_v^I depends on the discounted long run impact of a shock to next period's trend growth rate.

2.4.3 Observable economy (II)

We denote v_t in the the case where the consumers know x_{t+1} by v_t^{II}. The solution for v_t^{II} is given by

$$v_t^{II} = \mu_v^{II} + U_v^{II} x_{t+1}, \tag{10}$$

where

$$\mu_v^{II} = \frac{\beta}{1-\beta}\left(\mu_c + \frac{1-\theta}{2}\left(\sigma_c^2 + \frac{\beta^2}{(1-\kappa\beta)^2}\sigma_x^2\right)\right) \tag{11}$$
$$U_v^{II} = \frac{\beta}{1-\kappa\beta}.$$

The normalized value function for economy (II) looks very much like the one for economy (I). The coefficient on the observed state of the economy is $1/\kappa$ higher, because the observed state in this economy is the actual growth rate for next period and not that of the current one. An innovation to the trend growth rate will first have an effect two periods in the future instead of next period. As a result its risk adjustment is multiplied with the discount factor β.

3 Utility effect of learning the state of the economy

Having established expressions for the value functions under different information assumptions, we can now proceed to the core of the paper: establishing the utility gain from learning the state of the economy. We compute the expected gain by taking the difference between the unconditional expectation of v_t with full information and $\tilde{v}$. In the observable economy (I) case, the difference is given by

$$E[v_t^I] - \tilde{v} = \frac{\beta}{1-\beta}\frac{1-\theta}{2}\left(\frac{1}{(1-\kappa\beta)^2} - \frac{1}{1-\kappa^2}\right)\sigma_x^2 \quad (12)$$

In the observable economy (II) case, it is given by

$$E[v_t^{II}] - \tilde{v} = \frac{\beta}{1-\beta}\frac{1-\theta}{2}\left(\frac{\beta^2}{(1-\kappa\beta)^2} - \frac{1}{1-\kappa^2}\right)\sigma_x^2. \quad (13)$$

The sign of the difference depends on the sign of the difference inside the large parenthesis as well as on the risk aversion parameter θ. We are particularily interested in the case when the coefficient of relative risk aversion θ is larger than the inverse of the elasticity of intertemporal substitution. If $\theta > 1$, then we need the difference within the large parentheses to be negative to generate a positive utility gain from knowing the state of the economy. In both economies, this requires the discounted future impact of innovations to the underlying growth state to be larger than the unconditional variance of the mean growth rate. In the full information economy (I), this holds when

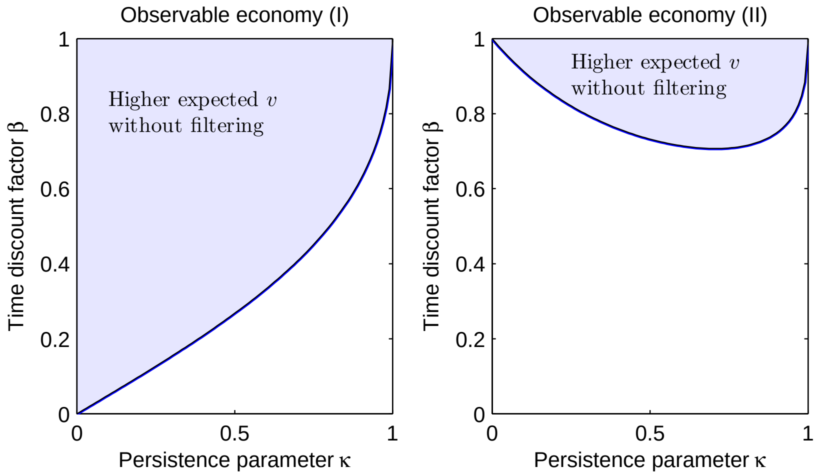
$$\kappa^2\beta^2 - 2\kappa\beta + \kappa^2 > 0.$$

When β is in the neighborhood of 1, this will never be true as long as x is stationary and $\kappa > 0$. How low β has to be in order for the inequality to hold depends on the size of κ. As the process for x becomes less persistent, we need a very high discount factor to make the inequality hold. This is illustrated in the left hand side panel of figure 2. The shaded area gives combinations of β and κ where expected utility is lower when $x_t \in \mathcal{F}_t$.

As discussed above, innovations to the trend growth rate in economy (II) will first have an impact two periods ahead, which makes the discounted aggregate impact of such innovations smaller. For this economy, the large parenthesis has a negative sign whenever

Figure 2: Parameter regions where information lowers utility when $\theta > 1$

The shaded areas in both panels give parameter values for which there is a utility loss from always learning the state of the economy compared to the no filtering case.



$$\beta^2(2\kappa^2 - 1) - 2\kappa\beta + 1 > 0.$$

As confirmed by the right hand side panel of Figure 2, this is less stringent than in the observable economy (I). But also this condition will typically be violated when consumption growth rates are positively correlated and the time discount factor is close to one.

3.1 The time inconsistency problem

In the last section we saw that typically consumers' utility is higher when they constrain themselves from updating their state beliefs. In this section, we show that implementing such constraints raises time inconsistency issues: in each period the optimal strategy is to learn the current state of the economy and commit to never update the state beliefs.

Consider a consumer who has no information on the current state of the economy beyond the current consumption level. We let $\hat{v}_t(n)$ denote the normalized utility level of an agent who learned the current state of the economy n periods ago and credibly committed to never update his beliefs thereafter. One can verify that

$$\begin{aligned}\hat{v}_t^I(n) =& \frac{\beta}{1-\beta}\left(\mu_c + \frac{1-\theta}{2}\left[\sigma_c^2 + \frac{1}{1-\kappa^2}\sigma_x^2\right]\right) \\ &+ \frac{\beta\kappa^{n+1}}{1-\beta\kappa}x_{t-n} - \frac{1-\theta}{2}\frac{\beta\kappa^{2(n+1)}}{(1-\kappa^2)(1-\beta\kappa^2)}\sigma_x^2\end{aligned} \tag{14}$$

and

$$\begin{aligned}\hat{v}_t^{II}(n) =& \frac{\beta}{1-\beta}\left(\mu_c + \frac{1-\theta}{2}\left[\sigma_c^2 + \frac{1}{1-\kappa^2}\sigma_x^2\right]\right) \\ &+ \frac{\beta\kappa^{n}}{1-\beta\kappa}x_{t-n} - \frac{1-\theta}{2}\frac{\beta\kappa^{2n}}{(1-\kappa^2)(1-\beta\kappa^2)}\sigma_x^2\end{aligned} \tag{15}$$

The temptation the consumer faces is that, by updating his beliefs, he achieves an expected utility increase of

$$\begin{aligned}T^I(n) &= E\left[\hat{v}_{t+n}(0) - \hat{v}_{t+n}(n) \mid x_t\right] \\ &= -\frac{1-\theta}{2}\frac{\beta\kappa^2}{(1-\kappa^2)(1-\beta\kappa^2)}\left(1-\kappa^{2n}\right)\sigma_x^2\end{aligned} \tag{16}$$

in economy (I) and

$$\begin{aligned}T^{II}(n) &= E\left[\hat{v}_{t+n}(0) - \hat{v}_{t+n}(n) \mid x_t\right] \\ &= -\frac{1-\theta}{2}\frac{\beta}{(1-\kappa^2)(1-\beta\kappa^2)}\left(1-\kappa^{2n}\right)\sigma_x^2\end{aligned} \tag{17}$$

in economy (II). For $\theta > 1$ there is always a positive temptation to update information and this temptation increases as n increases. However, as we will see in the next section, the temptation remains quantitatively modest even for $T(\infty)$.

4 Application to the US data

4.1 Data and Estimation

To quantify the effects we documented above, we estimate the state space system for consumption growth on the US postwar data. Our data-set consists of quarterly data from the first quarter of 1952 to the third quarter of 2006. The series used are taken from the NIPA tables published on the Bureau of Economic Analysis' website (http://bea.gov/). We use the consumption of services and non-durables (NDS) as our consumption measure. Since a NDS series is not available from BEA we constructed it from the series of durables and personal consumption expenditures. In doing so, care was taken to avoid the problems related to the addition of chain-weighted series by using the Tornqvist formula (see Whelan, 2002).

We use Gibbs sampling to estimate the relevant parameters of Equations (4) and (5). The consumption growth process is the observation equation and the AR(1) process for x is the state equation.

First, we jointly estimate the four process parameters using an informative prior on the volatility of the hidden state and an uninformative one on the persistence (κ). In particular, following Hansen (2007) closely, the prior on σ_x^2 is an inverse gamma with shape parameter 10 and scale parameter 2.209×10^{-06}, which implies a mode of 0.00047 for σ_x. The prior for κ is normal, conditional on σ_x, with mean 0 and standard deviation $\sigma_x \times 1.41 \times 10^6$. We use rejection sampling to truncate the support of κ to $[-1 \quad 1]$ (see Gelfand et al. (1992)).

To see the predictions of our model over a larger set of parameter values for the crucial parameter κ, we repeat the estimation procedure fixing it to different levels and keeping the same prior on σ_x. The means and the standard deviations of the estimates, reported in Table 1, are obtained with $50,000$ draws, after discarding the first $5,000$ draws.

The unconditional estimation, reported in the shaded rows in Table 1, shows a relatively high persistence of the hidden state of the economy, with κ equal to 0.81. This feature is confirmed by Figure 3, where the posterior distribution of the κ estimates is plotted along with the given prior. It is also worth noting that, by performing the estimation for given values of κ, the σ_x estimates are not to be greatly affected. This is probably due to the rather informative prior we have chosen (cf. Figure 4).

In Figure 5 we plot the smoothed estimates of the hidden state of the economy, for three different values of κ: from a very low level of persistence (0.2) to the extreme persistent case (0.979). The gray areas point out the official NBER recession periods. The estimates with higher levels of κ are smoother and the fluctuations are of larger magnitude.

Table 1: Estimated process parameters

Reported are the estimated parameters for the US postwar data (Q1:1952–Q3:2006; source: BEA). Estimation is performed with $50,000$ draws from a Gibbs sampler, discarding the first $5,000$. The shaded rows shows the results from the unconditional estimation where the prior on σ_x^2 is an inverse gamma with shape parameter 10 and scale parameter 2.209×10^{-06}, which implies a mode of 0.00047 for σ_x. The prior for the persistence parameter is normal, conditional on σ_x, with mean 0 and standard deviation $\sigma_x \times 1.41 \times 10^6$ truncated with support $[-1 \quad 1]$. The other rows show the estimates for fixed values of κ and the same priors for the other parameters.

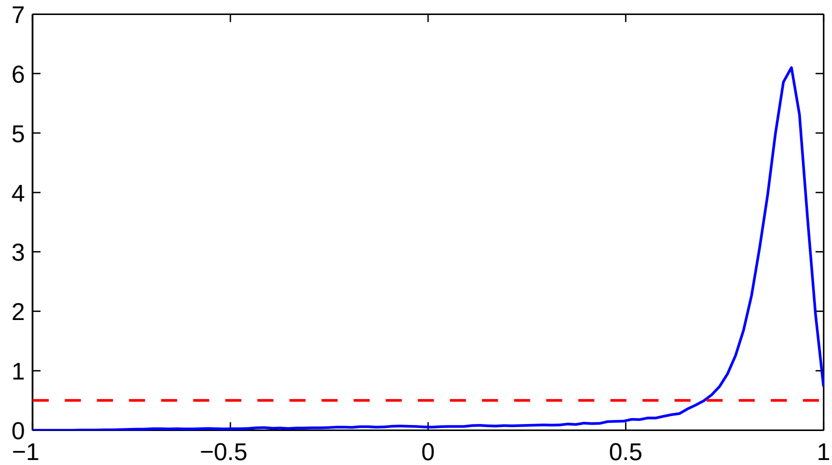
κ	σ_x	μ_c	σ_c
0.20000	0.00051	0.00509	0.00474
—	(0.00009)	(0.00032)	(0.00023)
0.70000	0.00059	0.00508	0.00462
—	(0.00015)	(0.00034)	(0.00025)
0.81060	0.00060	0.00513	0.00451
(0.24706)	(0.00014)	(0.00091)	(0.00026)
0.95000	0.00057	0.00506	0.00447
—	(0.00011)	(0.00078)	(0.00024)
0.97900	0.00054	0.00500	0.00448
—	(0.00010)	(0.00153)	(0.00024)

4.2 Quantitative Results

Table 2 reports the utility gains (or losses) for a consumer facing the information sets in the two studied economies with respect to the case when they do not observe the hidden state and they do not use the historical consumption growth rates to infer it. In particular, Panel A line 1, reports the amount of consumption an agent would require to be indifferent between learning the current state with certainty and not processing the available information. Lines 2 and 3 report the same measure from learning only once the hidden state, and from committing not to process the available future information (knowing the current state). The same gains are reported for the economy

Figure 3: Prior and posterior probabilities of the persistence coefficient (κ)

Reported are the prior (dashed line) and the posterior (solid line) distributions of the κ estimate. The prior is normal conditional on σ_x with mean 0 and standard deviation $\sigma_x \times 1.41 \times 10^6$ truncated with support $[-1 \quad 1]$. The posterior is obtained with $50,000$ draws from a Gibbs sampler, discarding the first $5,000$.



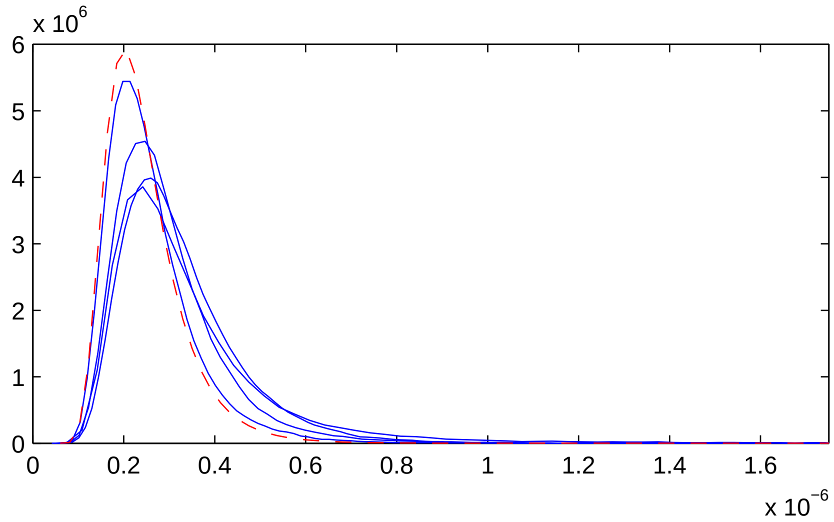
(II) case in Panel B. All numbers are reported for a quarterly time discount factor (β) of 0.9925, with a CRRA of 10 and are given in percentage points.

The results highlight the crucial role of the persistence parameter κ in determining the value of knowing the state of the economy. If the state of the economy is very persistent, knowing the current state will reveal a lot about future economic conditions. When the persistence parameter is low, the results show that there are no significant utility gains to be made from processing available information in both the experimental economies (cf. Table 2, column 2). As the persistence parameter increases, the numbers become sizable. Always learning the state of the economy corresponds to almost a 20% drop in lifetime consumption when $\kappa = 0.979$. The results for the very high persistence parameter are particularly interesting, because the long run risk literature has shown that we need such a high level of κ to explain the equity premium. (See e.g. Bansal and Yaron, 2004.)

Having established that there might be large gains to be made from ignoring information on the state of the world, we now want to check whether

Figure 4: Prior and posterior probabilities of the variance of the hidden state (σ_x)

This figure reports the prior (dashed line) and the posterior (solid lines) distributions of the σ_x estimates, where the posteriors are obtained obtained with $50,000$ draws from a Gibbs sampler, discarding the first $5,000$. Each line correspond to another fixed level of κ from $\{0.2, 0.7, 0.811, 0.95, 0.979\}$



or not the time inconsistency issues discussed in section 3.1 might prevent us from achieving them. As we see from lines 2 and 5, the theoretical time inconsistency issues documented above is negligible. Even for the highest persistence level considered, it amounts to only 0.062% when measured in terms of an equivalent increase in consumption. Even a minor information processing cost would hence suffice to make committing to not processing information time consistent. Lines 3 and 6 of the table confirm that committing to not processing information yields a high and positive utility gain.

5 Conclusion

In this paper, we have investigated the role of information processing in a simple endowment economy where the agents have Epstein-Zin's preferences.

Figure 5:

Plotted are the smoothed estimates of the hidden state x for different values of the persistence parameter. The gray areas indicate official NBER recession periods.

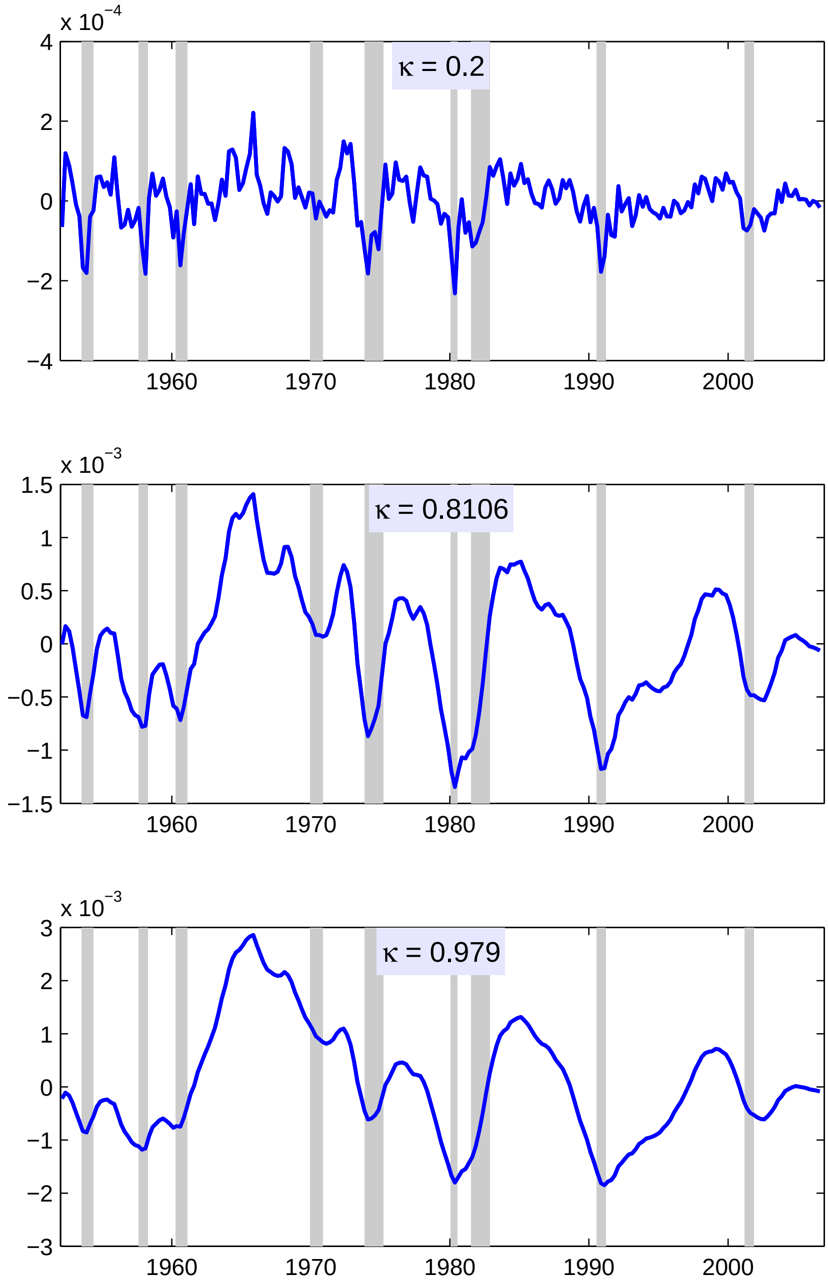


Table 2: Utility gains

Reported are the estimated utility gains (or losses) by agents in the two analyzed experimental economies. Numbers are reported for a quarterly time discount factor (β) of 0.9925 and a CRRA parameter of 10. Numbers are in percentage points. Panel A reports the figures for the economy (I) while Panel B reports the figures for the economy (II).

κ	0.200	0.700	0.811	0.950	0.979
σ_x	0.00051	0.00059	0.00060	0.00057	0.00054
Panel A: Economy I					
$E[v_t] - \tilde{v}$	-0.008	-0.180	-0.495	-5.540	-19.277
$E[\hat{v}_t(0) - \tilde{v}]$	0.000	0.000	0.001	0.013	0.062
$\hat{v}_t(0) - v_t$	0.008	0.180	0.498	5.878	23.958
Panel A: Economy II					
$E[v_t] - \tilde{v}$	-0.008	-0.178	-0.491	-5.498	-19.145
$E[\hat{v}_t(0) - \tilde{v}]$	0.000	0.001	0.001	0.014	0.065
$\hat{v}_t(0) - v_t$	0.008	0.177	0.490	5.785	23.554

The maintained assumption is that agents do not directly observe the growth state of the endowment good but know the parameters of the process that governs it.

Within this framework, we have documented a time inconsistency problem: The same parameter constellation that makes an agent prefer to have consumption uncertainty resolved today rather than in the future also gives him an incentive to commit to not processing information on the state of the economy in future periods.

We provide analytical expressions for both the gains from processing information today and for committing to not processing information in the future. We show that the gains that can be achieved from committing to not processing information in the future far outweigh the gains that can be achieved by reneging on the commitment. A small information processing cost would be sufficient to make the commitment time consistent.

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