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Salience effect and yield curve

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ABSTRACT

This paper studies the influence of salience on nominal and real yield curves by introducing the salience effect in the Piazzesi and Schneider model (hereafter PS). We construct the salience values based on the expected consumption growth using U.S. data. We find that salience values are negatively correlated with the expected consumption growth rates. Based on U.S. data from 1960q1 to 2020q4, we find that the salience model can generate upward nominal and real yield curves within reasonable risk aversion coefficients (less than 10), as well as well-fitted average yields with actual data. The salience model compensates for the PS or recursive preference model's inability to generate an upward nominal or real yield curve within reasonable risk aversion. Furthermore, we provide empirical support for model implications.

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1. Introduction

The Treasury yield curve is an important image that central banks and financial institutions focus on, and is a basic tool for analysing interest rate trends and market pricing. Understanding the shape of the Treasury yield curve is important for both theory and practice. There is considerable literature on this topic, however, most of the literature focuses on the analysis of the shape of the yield curve under the hypothesis of rational man, while neglecting the influence of psychological factors. The rational models, mostly built on exponential or recursive utility, cannot generate upward yield curves within reasonable risk aversion coefficients (Backus & Zin, 1993; Bansal et al., 2012; Constantinides & Ghosh, 2011). Additionally, a major research direction in behavioural finance is to explain the phenomena of financial markets and

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study the development of financial markets from micro-individual psychology. This paper aims to understand the shape of the yield curve from the perspective of behavioural finance and to compensate for the shortcomings of the rational man hypothesis model. Specifically, we construct a consumption-based asset pricing model with a salience effect.

The psychological feature of behavioural finance in this paper is the salience effect. Salience is a concept in neuroscience, where a state or a characteristic of an item is more prominent compared to its neighbourhood. The salience is an important attentional mechanism that allows organisms to focus their limited perceptual and cognitive resources on the most relevant subset of the available sensory data set, thereby facilitating learning and survival. The salience causes cognitive biases in individuals, who will focus their attention on more salient items and ignore non-salient items when making decisions, and weigh more heavily on more salient items. There has been no research about the influence of salience on the yield curves as far as we know, therefore this paper would investigate the salience effect on Treasury bond pricing.

This paper introduces a consumption-based asset pricing model with salience built on PS (hereafter, salience model). The salience effect affects the agent's utility by influencing the agent's expectation of future utility. Based on U.S. data, we construct salience values (or weights) for expected consumption growth rates and find that log salience values are negatively correlated with expected consumption growth rates, i.e., agent is more salient about the low expected consumption growth state. We find that the salience model produces upward U.S. nominal and real yield curves within reasonable risk aversion coefficients, while the benchmark model (i.e., Piazzesi et al., (2006), hereafter PS) cannot. Additionally, we find salience measure is positively correlated with bond term spread in empirical analysis.

The salience model demonstrates that the agent is less salient about the high expected consumption growth. Consequently, the agent tends to underestimate the consumption growth and experiences diminished satisfaction when the expected consumption growth is in high states. The salience model reveals that the agent does not feel that satisfied meanwhile the long-term bond payoff is low when expected consumption growth is in the high state. This contributes to an increase in the real risk premium and a tendency for the real yield curve to slope upward. The risk premium is higher when the negative sensitivity between salience and expected consumption growth is more extreme, as the agent's dissatisfaction intensifies in states of high expected consumption growth. This leads to the following hypothesis:

H1: The sensitivity between salience and expected consumption growth could positively affect the term spread.

H2: The sensitivity between salience and expected consumption growth could positively affect agent underestimations of expected consumption growth.

Our paper makes several contributions to the literature. Compared with the existing literature, the marginal contributions of the article are reflected in the following four aspects. First, our paper utilises a consumption-based asset pricing model that incorporates the salience effect into the recursive utility to explore the impact of the salience effect on Treasury bond prices. Second, we apply the salience model to calculate the prices of nominal and real Treasury bonds of different maturities and explain the upward yield curve from the perspective of the salience effect. Thirdly, compared with the traditional recursive utility model, the risk aversion coefficient required by the salience model is more reasonable. Lastly, we formulate three distinct salience measures, and empirical findings substantiate the model implications.

The paper is organised as follows: Section 2 reviews the relevant theoretical and empirical studies. Section 3 presents the salience model which is constructed based on PS and Bordalo et al. (2013b). Section 4 presents the calibration results. Section 5 presents the empirical results. Section 6 discusses and concludes. Section 7 presents policy implications.

2. Literature review

The literature related to this paper can be divided into two areas. The first area is the research related to the salience effect, which explores the impact of the salience effect on consumer choice and stock market pricing Bordalo et al. (2012) explained the endowment effect experiment[1] from the perspective of the salience effect, where decision makers put more weights on salient payoffs when choosing lotteries. The authors argued that the salience function should satisfy ordering and diminishing sensitivity. Bordalo et al. (2013b) divided the attributes of goods into quality and price, and showed consumers attached disproportionately high weight to salient attributes. Bordalo et al. (2013a) constructed an asset pricing model with salience effect, where the salience function is homogenous of degree zero and individual investors put more weight on salient payoffs. Shleifer, et al(2020) constructed a model where salience influences the agent memory and the agent choices.

Recent studies discuss the salience effect through empirical analysis. Cosemans and Frehen (2021) empirically investigated the asset pricing theory with salience in the U.S. They found that the larger the salience indicator, the lower the stock return in the next month. Cakici and Zaremba (2021) support Cosemans and Frehen research based on 49 countries' data. Kumar et al., (2017) found that daily top winners or losers are more salient. Li et al. (2018) discussed the salience effect and cryptocurrencies' price. Ghosh, et al., and (2021) studied the salience effect could induce investors to think more narrowly and exacerbate disposition effect. Liu (2022) found that loan officers are drawn to salient hard information.

There has been no research on the salience impact in the Treasury bond market as far as we know, hence this paper investigates the effect of the salience on Treasury bond pricing to fill the gap.

The second area is the literature on consumption-based asset pricing models and yield curves. These models assume the presence of a representative agent, with consumption growth rate and inflation rate as exogenous processes, and bond yields are calculated using Euler's equation. Exponential utility functions were utilised in the early studies. However, Backus and Zin (1993) proposed the "bond premium puzzle," which states that the excess return on long-term bonds is negative and relatively small for relative risk aversion coefficients less than 10. Later, other researchers proposed a habit-forming utility function to improve the exponential utility function (Abel, 1990;

Campbell & Cochrane, 1999), and Wachter (2006) generated an upward yield curve based on this utility function.

Epstein and Zin (1989) and Weil (1989) introduced a recursive utility function that could discriminate between risk aversion and intertemporal substitutability, and it has since become a popular utility function in academia. Bansal and Yaron (2004) proposed a long-run risk model (hereinafter LRR) based on the recursive utility, which may account for the equity premium puzzle, time-varying risk premium, and produce data similar to the actual risk-free rate, stock return, and its volatility. Since then, some researchers have explored whether recursive utility function models could generate upward nominal and real yield curves. Researchers found that recursive utility models cannot generate upward real return curves in studying real yield curves (Bansal et al., 2012; Beeler & Campbell, 2012; Constantinides & Ghosh, 2011). For the study of nominal yield curves, PS and Bansal and Shaliastovich (2013) added a negative correlation constraint between consumption growth rate and inflation rate to the recursive utility model and thus generate upward nominal yield curves. However, the model cannot generate an upward U.S. real yield curve. As the negative correlation between consumption growth rates and inflation rates shifts to a positive correlation after the twenty first century, the reliance on this negative correlation to generate upward nominal yield curves is criticised (Campbell, et al., 2020).

Numerous researchers have modified the recursive preference model to solve the problem of the recursive preference model failing to generate upward nominal and real yield curves. Wu (2008) constructed a dynamic affine model of the yield curve based on LRR that allows for dynamic changes in the price of risk. Doh and Wu (2016) assumed that the stochastic discount factor, expected consumption growth rate, and expected inflation rate are quadratic polynomials in the state variables in a recursive model, thus the paper can generate an upward bond yield curve. Albuquerque et al. (2016) argued that the volatility time preference determines the price dividend ratio, stock returns, and bond yields to maturity. They argued that long-term bonds have higher risk exposure to fluctuations in time preference, therefore long-term bonds have a higher risk premium and can generate upward yield curves. The yield curve is studied in our work using a recursive utility function, but unlike the prior perspective, the model claims that the agent's psychological factor, the salience effect, creates shocks on the demand side.

3. Model

3.1. Model setup

We consider an endowment economy with a representative agent. The endowment are denoted as aggregate consumption $\{C_t\}$ and inflation $\{\pi_t\}$, given exogenously. Equilibrium prices adjust such that the agent is happy to consume the endowment.

We introduce the salience effect into the PS model, which applied the Epstein and Zin (1989) preference to distinguish the relative risk aversion from the intertemporal elasticity of substitution (hereafter IES). PS model assumes a unitary IES[2] and homoscedastic log-normal shocks to simplify the calculation. We apply the same assumption and the time t utility V_t of a consumption stream $\{C_t\}$ is defined by:

$$V_t = C_t^{1-\beta}[CE_t(S_{t+1}V_{t+1})]^{\beta} \tag{1}$$

where the certainty equivalent CE_t is defined by:

$$CE_t(S_{t+1}V_{t+1}) = \left[E_t(S_{t+1}V_{t+1})^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{2}$$

β denotes the time preference. S_{t+1} denotes the salient weight at different states, and the impact of salience to the utility would be specifically analysed in the subsequent part. The utility function shows that the current utility of the representative agent depends on the current consumption and the agent's expected future utility. The utility of the model will degenerate to PS when $S_{t+1} = 1$. PS is considered as the benchmark model in this paper. γ denotes the risk aversion coefficient.

The vector of consumption growth and inflation $z_{t+1} = (\Delta c_{t+1}, \pi_{t+1})^T$ has the same state-space representation as PS.

$$\begin{aligned} z_{t+1} &= \mu_z + x_t + e_{t+1} \\ x_{t+1} &= \phi_x x_t + \phi_x K e_{t+1} \\ e_{t+1} &= (z_{t+1} - E_t z_{t+1}) \sim N(0, \Omega) \end{aligned} \tag{3}$$

where μ_z denotes the unconditional mean of z_{t+1}, the state vector x_{t+1} is 2-dimensional and contains expected consumption and inflation, ϕ_x is the 2×2 autoregressive matrix and K is a 2×2 gain matrix. Agent's beliefs about future growth and inflation are described by this state-space system evaluated at the point estimation.

3.2. Salience

Salience weight S_{t+1} acts on V_{t+1} in the model. We first identify the state variables of $V_{t+1|t}$ such that we could measure the salience. Since the state variables that affect the log-form utility $v_{t+1|t}$ is identical to $V_{t+1|t}$, we identify the state variables by examining $v_{t+1|t}$. Without considering the salience effect, both sides of Equation (1) are divided by C_t and taken as logarithms, then combined with the state-space process (3). $v_{t+1|t}$ can be written as a function of x_{t+1} and Δc_{t+1} as shown in (4), where $\phi_c = [1, 0]$, $\beta\phi_c x_{t+1}(I - \beta\phi_x)^{-1}$ denotes the sum of expected future consumption growth rate, and the constant term denotes the variance. The state variables affecting $v_{t+1|t}$ are $\Delta c_{t+1} + \beta\phi_c x_{t+1}(I - \beta\phi_x)^{-1}$. Since the magnitude of $\beta\phi_c x_{t+1}(I - \beta\phi_x)^{-1}$ is substantially larger than that of Δc_{t+1}, only the former term is considered in this paper due to the simplicity the convenience. The state variable affecting the former term is $\phi_c x_{t+1}$. Unfortunately, $\phi_c x_{t+1}$ cannot be observed in the raw data. In order not to affect the state but to be easily observed, this paper chooses $\mu_c + \phi_c x_{t+1}$ as the state variable for constructing salience.

$$v_{t+1|t} = c_t + \Delta c_{t+1} + \beta\phi_c x_{t+1}(I - \beta\phi_x)^{-1} + \text{constant} \tag{4}$$

We use the actual data to measure the state variables and construct the salience function based on the measured state variables. Following the ideas of Wu (2008) and Beeler and Campbell (2012), the moving average of the consumption growth rates over the past 12 quarters is used as a proxy for the expected consumption growth rate $\mu_c + \phi_c x_{t+1}$. The expectation of the expected consumption growth rates perceived by the agent is assumed to be the moving average of the expected consumption growth rates over the past 20 quarters. In this paper, $x_{c,t}$ denotes the expected consumption growth rate and $\overline{x_{c,t}}$ denotes the expectation of the expected consumption growth rates. Following Bordalo et al. (2013b), the salience function is as follows:

$$\sigma(x_{c,t+1}) = \frac{|x_{c,t+1} - \overline{x_{c,t+1}}|}{|x_{c,t+1}| + |\overline{x_{c,t+1}}|} \tag{5}$$

Figure 1 presents a time series of $x_{c,t}$ and $\sigma(x_{c,t+1})$ in the U.S., whereas Figure 2 presents a scatter plot of both. The dashed line in Figure 1 indicates the quarter expected consumption growth rate, the solid line indicates salience value and the grey area indicates the NBER recession. During the recession in the mid-1970s, early 1980s and 1990s, 2008 financial crisis, and Covid-19 period, the expected consumption growth was low while the salience value is high. Although the salience value is not monotonically related to the expected consumption growth according to equation (5), the correlation is negative in the actual data, as shown in Figure 2. Most of the time, we find that $x_{c,t}$ is lower than its expectation. The correlation between the expected consumption growth rate and salience value is −0.6071.

This paper constructs continuous salience weight since the state variable is continuous, referring to Bordalo et al. (2013b), which introduces the continuous weight distortion method based on measured salience weight: multiply a continuous weight $\delta(\sigma(\bullet))$ before the utility, where $\delta(\sigma(\bullet)) = \exp[(1-\delta)\sigma(\bullet)]$, $\sigma(\bullet)$ is the salience value and δ is the degree of salience, taking values in the range (0,1]. If $\delta = 1$, then the representative agent does not have weight distortion. The smaller δ is, the larger weight the agent assigns to the salient state and the higher the degree of distortion. We define the continuous weighting function based on their principles.

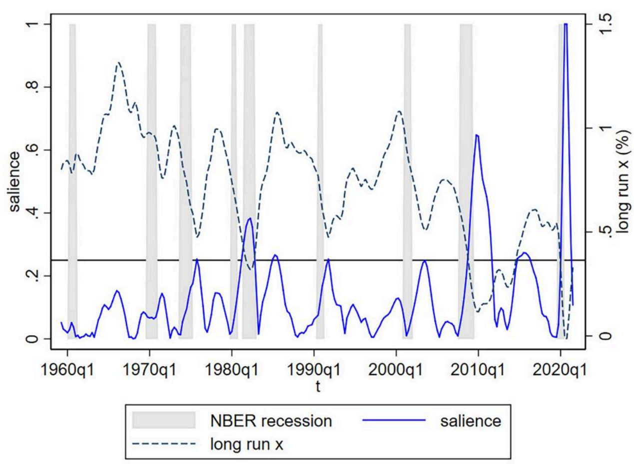

Figure 1. Time series of expected consumption growth rate and salience value.
Source: Author's calculation.

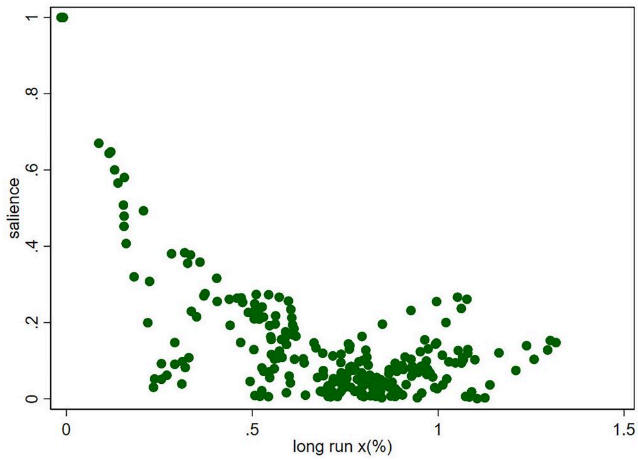

Figure 2. Scatter plot of expected consumption growth rate and salience value.
Source: Author's calculation.

$$S_{t+1} = \exp\left(s_{t+1}\right) = \exp\left(\tan\left(\left(\sigma\left(x_{c,t+1}\right) - 0.25\right) \times \frac{\pi}{2} \times \left(1 - \delta\right)\right)\right) \tag{6}$$

When evaluating the degree of stock salience, Cosemans and Frehen (2021) set $\delta = 0.7$, while we set $\delta = 0.9$ to evaluate the consumption growth than stock payoffs.[3] Since $\sigma(x_{c,t+1})$ takes a range of [0,1], the salience weight S_t will always be greater than 1, suggesting that the agent would assign a weight greater than 1 to all states if $\sigma(x_{c,t+1})$ does not subtract a constant term. We calculate the weight by subtracting a constant from $\sigma(x_{c,t+1})$ to comprehend it more intuitively. This does not affect the relative weight between different states, and therefore basically does not affect the results[4]. We find that $\sigma(x_{c,t+1})$ greater than 0.25 in the data usually means high salient states according to Figure 1, therefore we calculate the weights by subtracting 0.25 from $\sigma(x_{c,t+1})$, which means that when $\sigma(x_{c,t+1})$ is greater (less) than 0.25, the weight is greater (less) than 1. Additionally, we consider that the log salience weight varies with the salience value in a nonlinear relationship. The larger the salience value, the larger the change rate of the log salience weight. We use the tangent function to describe the nonlinear relationship[5]. Finally, we find the trend of the log salience weight is similar to that of salience value[6]. There is also a negative correlation (-0.6069) between s_t and $x_{c,t}$.

To simplify the model solution process, we assume that $s_t = \ln\left(S_t\right)$ is an exogenous process, according to the ideas of Campbell and Cochrane (1999).

$$s_t = \phi_s s_{t-1} + \lambda(s_{t-1})\phi_c e_t \tag{7}$$

$$\lambda(s_{t-1}) = a + b \times s_{t-1} \tag{8}$$

ϕ_s denotes the autocorrelation coefficient of the log salience weights, and $\lambda(s_{t-1})$ denotes the sensitivity of the log salience weights to the consumption growth rate shock at t. The correlation between $x_{c,t}$ and s_t depends on the sensitivity function

$\lambda(s_{t-1})$ according to equations (3) and (7). The parameters of the dynamic process of the sensitivity function are a and b.

We interpret the sensitivity function $\lambda(s_{t-1})$ by deriving the approximate forms of $\sigma(x_{c,t})$ and s_t. Firstly, we start with deriving the approximate form of $\sigma(x_{c,t})$. Although $\overline{x_{c,t}}$ is time-varying, we assume that $\overline{x_{c,t}}$ is $\tau\bar{x}$ for the convenience of model derivation. The expected consumption growth rate is lower than its expectation in most cases according to Figure 2, therefore we assume that $x_{c,t} \leq \tau\bar{x}$ and the Taylor expansion of $\sigma(x_{c,t})$ at $x_{c,t-1}$ can be written as:

$$\sigma(x_{c,t}) = \frac{|x_{c,t} - \tau\bar{x}|}{|x_{c,t} + \tau\bar{x}|} = \frac{\tau\bar{x} - x_{c,t}}{x_{c,t} + \tau\bar{x}} \approx \sigma(x_{c,t-1}) - \left(1 + \sigma(x_{c,t-1})\right)\frac{\phi_c\phi_x K e_t}{x_{c,t-1} + \tau\bar{x}} \tag{9}$$

Equation (9) shows that the salience value $\sigma(x_{c,t})$ satisfies two characteristics of the salience effect: ordering and diminishing sensitivity. The larger the deviation of $x_{c,t}$ from $\tau\bar{x}$, i.e., the larger the disturbance term, the larger $\sigma(x_{c,t})$, which is consistent with the ordering characteristic. $\sigma(x_{c,t})$ is smaller when $x_{c,t-1}$ and $\tau\bar{x}$ become larger, which is consistent with the diminishing sensitivity characteristic.

Secondly, we derive the approximate form of log salience weight s_t in equation (10), which be obtained after taking the logarithm of equation (6) and Taylor expansion at 0, and substituting into (9). The specific derivations are in the online Appendix.

$$s_t \approx \alpha s_{t-1} - (1 + \sigma(x_{c,t-1}))\frac{\phi_c\phi_x K e_t}{x_{c,t-1} + \tau\bar{x}} \times \frac{\pi}{2} \times (1 - \delta) \tag{10}$$

where:

$$\alpha = \frac{(\sigma(x_{c,t-1}) - 0.25) \times \frac{\pi}{2} \times (1 - \delta)}{\tan\left((\sigma(x_{c,t-1}) - 0.25) \times \frac{\pi}{2} \times (1 - \delta)\right)} \in (0, 1)$$

The derivations indicate that it is reasonable to assume that s_t satisfies the process of equations (7) and (8). The specific analysis is in online appendix.

Based on the above approximate forms of $\sigma(x_{c,t})$ and s_t, we can obtain that the log salience weights are proportional to the salience values, as shown in equation (11), and the sensitivity (i.e., $\lambda(s_{t-1})$) is proportional to the coefficients of the disturbance term in equation (10), as shown in equation (12). The sensitivity is less than zero.

$$s_t \propto \sigma(x_{c,t}) \tag{11}$$

$$\lambda(s_{t-1}) \propto -\left(1 + \sigma(x_{c,t-1})\right)\frac{1}{x_{c,t-1} + \tau\bar{x}} \tag{12}$$

3.3. Pricing kernel

The utility function (1) could be written as a linear recursion according to Euler's Theorem since the utility function is homogenous of degree one, which leads to the real pricing kernel, and the specific derivations are in the online Appendix. The log real pricing kernel is:

$$\begin{aligned} m_{t+1} = ln\beta - \Delta c_{t+1} - (\gamma - 1)\left(\sum_{i=0}^{\infty}\beta^i(E_{t+1} - E_t)(\Delta c_{t+1+i} + s_{t+1+i})\right) \\ -\frac{1}{2}(\gamma - 1)^2 var_t\left(\sum_{i=0}^{\infty}\beta^i E_{t+1}(\Delta c_{t+1+i} + s_{t+1+i})\right) \end{aligned} \tag{13}$$

β denotes time preference, and the larger the value of β, the greater the marginal utility of future consumption to agent compared to current consumption. The agent feels bad in the future when the growth rate of future consumption Δc_{t+1} is low, in which the marginal utility m_{t+1} is high. Recursive utility introduces a new term that reflects the concern about the temporal distribution of risk. In the case we consider, $\gamma > 1$, the agent is risk-averse and fears downward revisions of expected consumption growth. Salience could lower (heighten) the agent evaluations about revisions of expected consumption growth when the log salience weight is negatively (positively) correlated with the expected consumption growth. The variance term is due to Jensen's inequality.

We define the log nominal pricing kernel as the log real pricing kernel minus the inflation rate following PS:

$$m^{\$}_{t+1} = m_{t+1} - \pi_{t+1} \tag{14}$$

3.4. Bond prices and yields

$P_t^{(n)}$ denotes a real bond price at time t that pays one unit of consumption n periods later. The agent's Euler equation determines the price as the expected value of its payoff next period weighted by the real pricing kernel following PS:

$$P_t^{(n)} = E_t\left(P_{t+1}^{(n-1)}M_{t+1}\right) = E_t\left(\prod\nolimits_{i=1}^{n} M_{t+i}\right) \tag{15}$$

The recursive operation of the real bond price in the above equation begins with the price of the 1-period bond at $P_t^{(1)} = E_t(M_{t+1})$. Following PS, taking the logarithm of both sides in (15) yields the log real 1-period bond price under the assumption that m_{t+i} is identically normally distributed and uncorrelated:

$$\begin{aligned} p_t^{(n)} &= E_t\left(p_{t+1}^{(n-1)} + m_{t+1}\right) + \frac{1}{2}var_t\left(p_{t+1}^{(n-1)} + m_{t+1}\right) \\ &= E_t\left(\sum_{i=1}^{n} m_{t+i}\right) + \frac{1}{2}var_t\left(\sum_{i=1}^{n} m_{t+1}\right) \end{aligned} \tag{16}$$

Analogously the log n-period nominal bond price and yield, attached with dollar symbol, could be written as:

$$p_t^{(n)\$} = E_t\left(\sum_{i}^{n} m^{\$}_{t+i}\right) + \frac{1}{2}var_t\left(\sum_{i=1}^{n} m^{\$}_{t+i}\right) \tag{17}$$

The specific solutions are in online appendix. The log real (nominal) prices and yields are determined by the future expected real (nominal) marginal utility. The real short rate at time t, denoted by $\mu_t^{(1)}$, is equal to the yield of a 1-period real bond, i.e., $y_t^{(1)}$.

$$\mu_t^{(1)} = y_t^{(1)} = -\frac{1}{n}p_t^{(1)} = -\ln\beta + \mu_c + \phi_c x_t - \frac{1}{2}\text{var}_t(\Delta c_{t+1}) \\ -(\gamma-1)\text{cov}_t\left(\Delta c_{t+1}, \sum_{i=1}^{\infty}\beta^i(E_{t+1}-E_t)(\Delta c_{t+1+i}+s_{t+1+i})\right) \tag{18}$$

The first three terms of equation (18) represent the effect of the intertemporal smoothing motive on the 1-period real yield. When β is larger, the agent is more patient and more willing to buy bonds or save instead of consumption, so the 1-period real bond price increases and real yield decreases. The intertemporal smoothing motive also increases the real bond yield when $\mu_c + \phi_c x_t$ is high.

The last two terms of equation (18) represent the effect of the precautionary saving motive. When the uncertainty of consumption growth rate, i.e., $\text{var}_t(\Delta c_{t+1})$ is large, the agent prefers to buy bonds due to precautionary saving motive and the real bond yields is high. Additionally, recursive preference introduces a covariance term that influences the agent precautionary saving motive. When there is no salience effect, it lowers the real yields when Δc_{t+1} covaries more with the expected consumption growth rate. When the salience effect is considered and if the log salience weight and the expected consumption growth rate were negatively correlated, it would reduce the covariance between Δc_{t+1} and the future expected consumption growth rate, then the agent's willingness to hold bonds decrease and real yields increase.

The intertemporal smoothing motive dominates the precautionary saving motive, therefore, we focus on the impact of factors on short rates through intertemporal smoothing motive.

Analogously, the nominal short rate or 1-period yield could be written as:

$$\mu_t^{(1)\$} = y_t^{(1)\$} = \mu_t^{(1)} + E_t(\pi_{t+1}) - \frac{1}{2}\text{var}_t(\pi_{t+1}) - \text{cov}_t(\Delta c_{t+1}, \pi_{t+1}) \\ -(\gamma-1)\text{cov}_t\left(\pi_{t+1}, \sum_{i=1}^{\infty}\beta^i(E_{t+1}-E_t)(\Delta c_{t+1+i}+s_{t+1+i})\right) \tag{19}$$

The nominal short rate depends additionally on the expected inflation rate, the volatility of the inflation rate, and the inflation risk premium. The nominal short rate is larger when the expected inflation rate is higher. Jensen's inequality introduces the inflation uncertainty term. The covariance between expected consumption growth rate and inflation rate affects the inflation risk premium, referring to PS and Bansal and Shaliastovich (2013).

We define the real bond excess return or risk premium as the return in excess of the real short rate obtained by buying an n-period bond at time t for $p_t^{(n)}$ and selling it at $t+1$ for $p_{t+1}^{(n-1)}$, i.e., $rx_{t+1}^{(n)} = p_{t+1}^{(n-1)} - p_t^{(n)} - y_t^{(1)}$. Substituting equation (15) and taking the expectation, the expected real excess return could be written as:

$$E_t(rx_{t+1}^{(n)}) = -\mathrm{cov}_t\left(m_{t+1}, p_{t+1}^{(n-1)}\right) - \frac{1}{2}\mathrm{var}_t\left(p_{t+1}^{(n-1)}\right) \tag{20}$$

The first term is the risk premium and the second term is the variance term due to Jensen's inequality. Equation (20) shows that if marginal utility is negatively (positively) correlated with bond prices, this means that long-term bonds have lower (higher) payoffs when marginal utility is higher (lower), which results in less (more) attractive long-term bonds, more (less) compensation to hold them and the positive (negative) bond risk premium.

Analogously the expected the nominal bond excess return could be written as:

$$E_t(rx_{t+1}^{(n)\$}) = -\mathrm{cov}_t\left(m_{t+1}^{\$}, p_{t+1}^{(n-1)\$}\right) - \frac{1}{2}\mathrm{var}_t\left(p_{t+1}^{(n-1)\$}\right) \tag{21}$$

The bond excess returns would then be examined. Moving the Jensen inequality variance terms to the left side, Equations (21) could be written in the following forms according to Equation (13) and (15). Detailed derivations are in the online Appendix.

$$\begin{aligned} &E_t\left(rx_{t+1}^{(n)}\right) + \frac{1}{2}\mathrm{var}_t\left(p_{t+1}^{(n-1)}\right) \\ &= -\mathrm{cov}_t(m_{t+1}, p_{t+1}^{(n-1)}) \\ &\approx -\mathrm{cov}_t\left(-\Delta c_{t+1} - (\gamma - 1)\left(\sum_{i=0}^{\infty}\beta^i(E_{t+1} - E_t)(\Delta c_{t+1+i} + s_{t+1+i})\right),\right. \\ &\qquad \left. E_{t+1}\sum_{i=1}^{n-1} - \Delta c_{t+1+i}\right) \end{aligned} \tag{22}$$

$$\begin{aligned} &E_t\left(rx_{t+1}^{(n)\$}\right) + \frac{1}{2}\mathrm{var}_t\left(p_{t+1}^{(n-1)\$}\right) \\ &= -\mathrm{cov}\left(m_{t+1}^{\$}, p_{t+1}^{(n-1)\$}\right) \\ &\approx -\mathrm{cov}_t(-\Delta c_{t+1} - (\gamma - 1)\left(\sum_{i=0}^{\infty}\beta^i(E_{t+1} - E_t)(\Delta c_{t+1+i} + s_{t+1+i})\right) - \pi_{t+1}, \\ &E_{t+1}\sum_{i=1}^{n-1}(-\Delta c_{t+1+i} - \pi_{t+1+i})) \end{aligned} \tag{23}$$

The real risk premium is negative if the salience effect is ignored because the positive consumption growth shock induces persistent positive expected consumption growth revisions. In other words, the marginal utility and expected bond prices is negatively correlated when not considering the salience effect. If the salience effect is considered, the agent is less salient about the high expected consumption growth due to the negative correlation between the log salience weight and the expected consumption growth. The agent does not feel that satisfied meanwhile the long-term bond payoff is low when expected consumption growth is in the high state. The real risk premium becomes larger and the real yield curve tends to be upward sloping. The risk premium is higher when the negative sensitivity between salience and expected consumption growth is more extreme.

The nominal bond risk premium is additionally affected by the inflation risk premium. When the correlation between the inflation rate and the expected consumption growth rate is negative, a positive inflation shock leads to a decline in the expected consumption growth and a rise in marginal utility, meanwhile, it reduces the payoff on the bond. Hence the agent requires higher compensation for holding bonds, the nominal risk premium is higher.

Based on the definition of n-period bond excess return, the term spread could be written as the following equation:

$$y_t^{(n)} - y_t^{(1)} = \frac{n-1}{n}\left(y_{t+1}^{(n-1)} - y_t^{(1)}\right) + \frac{1}{n} rx_{t,t+1}^{(n)} \tag{24}$$

This is an accounting identity. Iterate the Equation (24) and take conditional expectation to get the real term spread, which is the sum of the expected forward short rate and expected bond excess returns.

$$y_t^{(n)} - y_t^{(1)} = \frac{1}{n} E_t\left(\sum_{i=1}^{n-1} y_{t+j}^{(1)} - y_t^{(1)}\right) + \frac{1}{n} E_t\left(\sum_{j=0}^{n-1} rx_{t+j,t+j+1}^{(n-j)}\right) \tag{25}$$

Analogously, the nominal term spread could be written as the following equation in a similar way:

$$y_t^{(n)\$} - y_t^{(1)\$} = \frac{1}{n} E_t\left(\sum_{i=1}^{n-1} y_{t+j}^{(1)\$} - y_t^{(1)\$}\right) + \frac{1}{n} E_t\left(\sum_{j=0}^{n-1} rx_{t+j,t+j+1}^{(n-j)\$}\right) \tag{26}$$

The expected term spread could be divided into two parts. The first part is the bond level change, which could be viewed as the level change of bond term structure. It represents the difference between forward short rate and short rate. The second part is bond excess return (or bond risk premium).

4. Calibration

4.1. Data

The data sources and measurement methods refer to PS. Real personal consumption expenditure and price index data (both seasonally adjusted) are downloaded from the Bureau of Economic Analysis (BEA). Then the price index and real consumption index for nondurable goods and services are constructed. The inflation rates and real consumption growth rates are constructed by taking the logarithmic difference of the index and removing the impacts of outliers. The quarterly data sample period is from

1952Q2 to 2021Q3 and we assume constant population size. The 1-year to 5-year Treasury bonds yields are obtained from the CRSP Fama-Bliss discount bond files, and the short-term interest rates are obtained from the CRSP Fama risk-free rate file for the quarterly period 1952M6 to 2020M12. The Treasury bond yields are taken as the sample values of the last month of each quarter, and the sample period is 1952Q2 $\sim$ 2020Q4.

4.2. Beliefs about fundamentals

The estimation results of the state-space model (3) are shown in Table 1 based on quarterly U.S. data, with a sample from 1952q2 to 2021q3, following the estimation methodology of PS.

Figure 3 depicts the influence of lagged macroeconomic variables on contemporaneous variables using covariance functions between contemporaneous and lagged variables. The solid and dashed lines represent the covariance functions estimated from the model and the raw data respectively. The number of lags is indicated on the

Table 1. State-space estimation in the U.S.

	μ	$Chol(\Omega)$		ϕ_x		$\phi_x K$	
Δc	0.725	0.179	0.000	0.705	−0.013	1.654	0.096
		(0.006)		(0.027)	(0.040)	(0.047)	(0.046)
π	0.834	−0.031	0.128	0.029	0.911	0.191	1.804
		(0.008)	(0.005)	(0.027)	(0.018)	(0.051)	(0.022)

Note: Table presents the state-space estimation results based on the data from 1952q2 to 2021q3. $Chol(\Omega)$ denote the Cholesky decomposition of $\text{var}(e_{t+1}) = \Omega$. Brackets indicate maximum-likelihood asymptotic standard errors computed from Hessian. Source: Author's estimation.

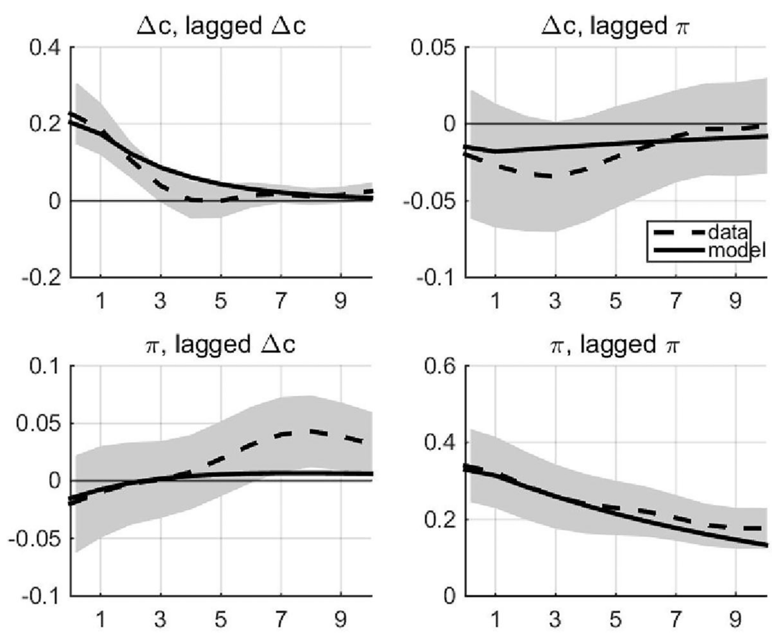

Figure 3. Covariance functions.
Note: Sample period is from 1952q2 to 2021q3. Source: Author's calculation.

horizontal axis, and when the lag is zero, the covariance function provides variance or covariance with contemporaneous variables. The shaded region represents twice the standard deviation of the covariance function obtained using the raw data, estimated using the GMM approach.

According to Figure 3, the 10th order covariance function of the consumption growth will diminish around 0, while the 10th order covariance function of the inflation will diminish around 0.2, which implies more persistent inflation. According to the upper right panel in Figure 3, the lagged inflation has a persistent negative impact on the consumption growth, and the covariance of the lagged 10-period covariance is still negative, while 0 is within two standard errors which means the leading impact is weakly significant. The lower left panel shows that the lagged consumption growth has a negative effect on the short period inflation and a positive effect on long-run inflation. It is worth noting that the covariance is 0 is within two standard deviations, hence the significance level is weak.

According to (7)(8), Table 2 shows the regression results of s_t on s_{t-1} and $\phi_c e_t$. The sample period is from 1960q2 to 2021q3 since a sample of at least 32 quarters is required to construct s_t. Regression (1) shows the regression results of Equation (7) with an estimated coefficient of −1.108 on the error term, which indicates that the sensitivity function is on average negative. In other words, expected consumption growth and the log salience weights are negatively correlated. Regression (2) adds the interaction term to regression (1). Regression (2) demonstrates the regression results of the combination of Equations (7) and (8), with R-square 90.3%. The regression results correspond to the model setting (7)(8), $a = -1.157, b = -9.231,\ \lambda(s_{t-1}) = -1.157 - 9.231\times\ s_{t-1}$.

4.3. Model implied bond yields

Similar results are obtained by replicating PS using the same sample interval (1952q2 to 2005q4) and methodology. PS calibrates the time preference and risk aversion coefficients by minimising the sum of squares of the difference between short-term nominal rates and long-term rates in the model and data. They generate an upward nominal yield curve based on the PS sample, but not an upward real yield curve. We obtain coefficients similar to those of PS[7], $\beta = 1.005,\ \gamma = 56,$ and similar nominal and real yield curves. The risk aversion coefficient calibrated by the benchmark model

Table 2. Log salience weight process estimations.

	(1)	(2)
	s_t	s_t
s_{t-1}	0.959***	0.968***
	(0.020)	(0.021)
$\phi_c e_t$	−1.108***	−1.157***
	(0.369)	(0.370)
$\phi_c e_t \times s_{t-1}$		−9.231
		(7.084)
Obs.	246	246
R-squared	0.902	0.903

Note: Brackets indicate the standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The sample period is from 1960q2 to 2021q3. Source: Author's estimation.

Table 3. Nominal and real yield (1960q2–2005q4).

	Data	Benchmark				Salience	
	Nominal	Nominal	Real	Nominal	Real	Nominal	Real
beta		1.005		1.005		1.005	
gamma		61.898		6.569		6.569	
yield 1quarter	5.635	5.635	0.987	5.154	1.105	5.635	1.714
yield 1 y	6.064	5.801	0.741	5.147	1.084	5.867	1.905
yield 2 y	6.271	6.044	0.567	5.142	1.073	6.100	2.004
yield 3 y	6.440	6.270	0.454	5.137	1.067	6.299	2.046
yield 4 y	6.572	6.471	0.367	5.132	1.063	6.480	2.068
yield 5 y	6.648	6.648	0.296	5.127	1.061	6.648	2.082

Source: Author's calculation.

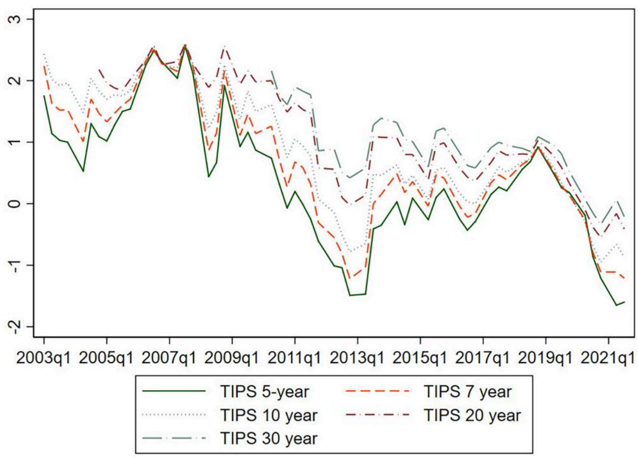

Figure 4. U.S. 5- to 30-year TIPS yields.
Source: FRED

is too large, and Mehra and Prescott (1985) recommend a risk aversion coefficient of less than 10. The results of the benchmark model from 1952q2 to 2005q4 are not shown due to space limitations.

This paper first compares the risk aversion coefficients, the average annualised nominal and real yields generated by PS, and salience models calibrated based on the same method as PS. Since the value of the salience function starts at 1960q2, we apply the sample from 1960q2 to 2005q4 to estimate the log salience weight process. We apply the state space estimation of PS. The estimation results are not shown in the main text due to space limitations. The model produced and actual yields are in Table 3.

Table 3 shows that the nominal curve for the U.S. in the data is upward sloping from 1960q2 to 2005q4. The second column of Table 3 shows the average nominal yields in the data ranging from 5.635% to 6.648%. Figure 4 shows the time series of TIPS yields. The inflation-protected bonds (TIPS) yields are generally used as real yields, with TIPS maturities of 5, 7, 10, 20, and 30 years. Although real yields have generally declined in recent years, the real yield curve remains upward. Additionally, J. Huston McCullogh constructed the real yield curve from TIPS data as of October 30, 2009, and the U.S. real yield curve is upward sloping according to his website[8].

The third to eighth columns in Table 3 show the average nominal and real yields of the benchmark and salience model. The risk aversion in the benchmark model γ is 63.211, The nominal yields in the benchmark model range from 5.653% to 6.690%, showing an upward sloping curve, based on its calibration. The benchmark model cannot generate an upward real yield curve, which ranges from 0.991% to 0.284%.

The seventh and eighth columns in Table 3 show that the salience model can generate an upward nominal and real yield curve, ranging from 1.732% to 2.108% for real yields, from 5.653% to 6.690% for nominal yields, based on its calibrations, in which γ is 6.689. The benchmark model applying the same parameters (i.e., γ is 6.689 and β is 1.005) produces downward nominal and real yield curves, as shown in the fifth and sixth columns of Table 3.

We apply a longer sample from 1960q2 to 2020q4 to do a robustness analysis. Based on the same methodology, the nominal and real yield curves generated by different models are calculated and compared. The results are in Table 4.

The second column of Table 4 shows the average nominal yields for different maturities in raw data are upward sloping, ranging from 4.514% to 5.539%.

In the long sample, the salience model can also produce upward nominal and real yield curves with reasonable risk aversion, while the benchmark model cannot. The benchmark model requires a risk aversion of −29.937, which indicates risk loving and is not in line with common sense economics. The risk aversion required by the salience model is 7.782 producing an average upward nominal yield similar to the data, ranging from 1.036% to 2.182%. Applying the risk aversion calibrated in the salience model, the nominal yields produced in the benchmark model range from 4.289% to 3.981%, and real yields range from 0.764% to 0.581%. Hence the benchmark model cannot produce upward nominal and real yield curves using reasonable risk aversion.

The numbers in calibrations are unconditional moments, therefore the term spread difference between salience model and PS is determined by risk premium. In the short sample, the benchmark model could only produce an upward nominal yield curve within high risk aversion. The risk aversion is extremely high and unreasonable. The reason is that inflation and expected consumption growth rates are negatively but weakly correlated during the period. For the specific estimations see PS. A high risk aversion is required to fit the high term spread in data.

The benchmark model could not produce an upward real yield curve in the short sample. The reason is that the real risk premium is negative in the benchmark model.

Table 4. Nominal and real yield (1960q2–2020q4).

	Data	Benchmark				Salience	
	Nominal	Nominal	Real	Nominal	Real	Nominal	Real
beta		1.005		1.005		1.005	
gamma		−29.937		7.982		7.982	
yield 1quarter	4.514	4.514	1.057	4.289	0.764	4.514	1.036
yield 1 y	4.896	4.983	1.616	4.193	0.686	4.939	1.513
yield 2 y	5.091	5.284	1.987	4.110	0.632	5.232	1.840
yield 3 y	5.273	5.425	2.171	4.054	0.605	5.386	2.011
yield 4 y	5.432	5.498	2.275	4.012	0.590	5.478	2.114
yield 5 y	5.539	5.539	2.340	3.981	0.581	5.539	2.182

Source: Author's calculation.

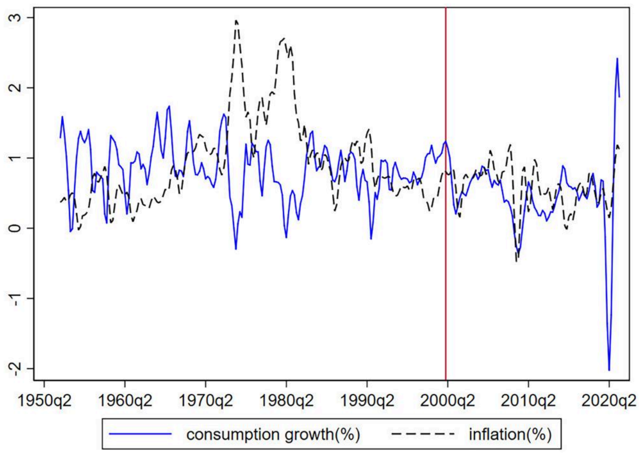

Figure 5. Consumption growth and inflation.
Source: Author's calculation

The downward sloping real yield curve is consistent with Beeler and Campbell (2012).

The salience model could produce upward nominal and real yield curves in the short sample. The reason why producing an upward real yield curve is that the log salience weight and expected consumption growth rate are negatively correlated according to Equation (23). An upward nominal yield curve is additionally because the inflation and the expected consumption growth are significantly negatively correlated from 1960q2 to 2005q4.

In the long sample, the salience model can also produce upward nominal and real yield curves with reasonable risk aversion, while the benchmark model cannot. The failure of the benchmark model is due to the fact that the negative correlation between inflation and consumption growth rates no longer exists after the twenty first century (Campbell et al., 2020). Figure 5 illustrates the time series in quarterly consumption growth and inflation rates, with the solid line indicating the consumption growth and the dashed line indicating the inflation. The correlation between consumption growth rates and inflation rates changes from −0.4549 (1952q2-1999q4) to 0.4814 (2000q1-2021q3).

5. Empirical analysis

The salience model indicates that the extreme sensitivity between salience weights and expected consumption growth would result in an elevated bond risk premium. The salience model posits that the agent would be more salient on the low expected consumption growth states. The sensitivity is positively determined by salience measure. Therefore, we infer that salience measure could positively affect the term spread and agent underestimations of consumption growth. The significantly positive effect provides support for H1 and H2.

The effects of salience to nominal bond yield[9] are firstly evaluated. We measure the salience according to the salience Equation (5) based on the real consumption growth data. We use the moving average of the past 12 quarters' real consumption growth as the proxy for expected consumption growth. We also utilise the past 10 to 16 quarters' data as alternatives. We use the moving average of the past 20 quarters' expected consumption growth as the proxy for evoked set. We also use the past 16 to 24 quarters' data as the alternatives.

$$\mu_c + x_t = \frac{1}{12}\sum_{s=0}^{i-1} \Delta c_{t-s} \tag{27}$$

$$\mu_c + \bar{x}_t = \frac{1}{20}\sum_{s=0}^{i-1} \mu_c + x_{t-s} \tag{28}$$

We use the following regression model to test the effect of salience on nominal yield spreads:

$$spread_t(n) = \alpha + \beta s_t + \varepsilon_t \tag{29}$$

Table 5 shows the results of the above regressions. The salience measure is positively correlated with different yield spreads, with coefficients ranging from 0.488 to 1.628, and Newey West t stats ranging from 1.84 to 2.02. The coefficients are significant and positive. The expected real consumption growth rate and evoked set are computed based on alternative windows. We find that alternative salience measures can also positively and significantly affect the nominal bond term spread. Thus H1 is valid.

Then the impacts of salience on estimation attitudes are examined. We use the Survey of Professional Forecasters data (hereafter, SPF) to test the mechanism. SPF is the oldest quarterly survey of macroeconomic forecasts in the U. S. The survey is now conducted by The Federal Reserve Bank of Philadelphia. We download the real GDP growth probability from SPF. This file contains the mean probabilities of annual real GDP growth falling into various ranges. The probabilities sum to 100. The sample period is from 1981Q3 to 2022Q3. The real GDP growth ranges in the survey are represented in the online appendix Table A1.

We construct 3 measures to reflect the agent estimation attitudes. To simplify the description, we suppose there are 3 ranges of the real GDP growth in the survey, $(-\infty, a_1]$, (a_1, a_3), $[a_3, +\infty)$. The mean probabilities are p_1, p_2 and p_3 respectively,

Table 5. Salience and yield spread.

	(1) Spread(2)	(2) Spread(3)	(3) Spread(4)	(4) Spread(5)
salience	0.488*	0.865*	1.286*	1.628**
	(1.84)	(1.86)	(1.96)	(2.02)
Intercept	0.132**	0.264***	0.368***	0.431***
	(2.49)	(3.05)	(3.24)	(3.24)
N	244	244	244	244
adj. R^2	0.041	0.052	0.070	0.082

Note: Numbers in parenthesis are Newey West adjusted t stats. *Significant at 10% level; **Significant at 5% level;***Significant at 1% level. Source: Author's calculation.

$p_1 + p_2 + p_3 = 1$. We denote $a_2 = \frac{a_1 + a_3}{2}$. The mean probability data may be interpreted as a discrete distribution with 3 values a_1, a_2, a_3, and the responding probabilities are p_1 、p_2 and p_3.

The first measure is the mean of expected real GDP growth:

$$E_t(\Delta RGDP) = \sum_{i=1}^{3} a_i p_i \tag{30}$$

The median value of each range interval and the interval probability are used to compute the first measure. If the range interval is an infinite interval, the endpoint of the interval and the interval probability are used to compute the first measure.

The second measure is the skewness of expected real GDP growth. The agent would perceive a high probability of low expected real GDP growth when the skewness is high.

$$Skew_t(\Delta RGDP) = E_t\left[\left(\frac{\Delta RGDP - E_t(\Delta RGDP)}{\sigma_t(\Delta RGDP)}\right)^3\right] \tag{31}$$

$$\sigma_t(\Delta RGDP) = E_t\left[(\Delta RGDP - E_t(\Delta RGDP))^2\right]$$

The third measure is the correlation between expected real GDP growth and corresponding probability. The agent would put more weights on low real GDP growth when the correlation is low.

$$\rho_t(\Delta RGDP) = \frac{Var_t(\Delta RGDP, p)}{\sigma_t(\Delta RGDP) \cdot \sigma_t(p)} \tag{32}$$

We regress these measures on the salience measure to test the effect of salience on the agent estimation attitudes and the results are showed in Table 6. The coefficient of salience on $E_t(\Delta RGDP)$, $Skew_t(\Delta RGDP)$, $\rho_t(\Delta RGDP)$ is −5.227, 1.914, and −0.661. The Newey West adjusted t stats is −3.63, 2.43, and −3.13 respectively. All the coefficients are significant at least at 5% level. The results support the mechanism in salience model where the agent put more weights to low expected real GDP growth when the salience is high. Thus H2 is valid.

In summary, the empirical analysis in this paper shows that the salience measure can significantly and positively affect the nominal term spread, and the empirical

Table 6. Salience and estimation attitudes.

	(1) $E_t(\Delta RGDP)$	(2) $Skew_t(\Delta RGDP)$	(3) $\rho_t(\Delta RGDP)$
salience	−5.227***	1.914**	−0.661***
	(−3.63)	(2.43)	(−3.13)
Intercept	3.141***	−0.775***	0.206***
	(14.70)	(−6.05)	(5.72)
N	161	161	161
adj. R^2	0.271	0.103	0.139

Source: Author's calculation.

analysis supports the model mechanism: agents assign more weights to states with lower expected consumption growth, which contributes to the higher Treasury bond term premium thus the term spread becomes larger. The empirical results lend credence to H1 and H2.

6. Discussion and conclusion

The yield curve is an important plot that central banks and financial institutions focus on, and is a fundamental tool for analysing interest rate trends and asset pricing in the market. It is important to understand the shape of the yield curve and its relationship with fundamentals for both theory and practice.

This paper explores the impact of salience on bond prices by incorporating it into the model of PS (2006). The article starts with a salience function for the expected consumption growth based on the literature. We find that the salience value is negatively correlated with the expected consumption growth, i.e., the representative agent is more salient for low expected consumption growth states. When not considering the salience effect (i.e., PS model), it produces an upward nominal yield curve with unreasonable risk aversion and a downward real yield curve. When considering the salience, the model generates upward nominal and real yield curves with a normal risk aversion coefficient (less than 10). The salience model compensates for the PS or recursive preference model's inability to generate an upward real yield curve.

The upward real and nominal yield curves suggested by salience model within small relative risk aversion coefficients align with Backus and Zin (1993), which proposed the "bond premium puzzle". Additionally, the salience model contributes significantly to the research surrounding recursive preference models, as exemplified by the works of Wu (2008), Doh and Wu (2016), and Albuquerque et al. (2016). The salience effect on Treasury bond yield is consistent with Bordalo et al. (2012), emphasising the impact of salience on consumer choice and stock market pricing.

Empirical findings suggest that salience measure, representing the sensitivity between salience weights and expected consumption growth, could significantly and positively affect the nominal term spread. Furthermore, empirical analysis supports the underlying model mechanism: agents assign more weights to states with lower expected consumption growth, leading to the higher Treasury bond term premium and subsequently enlarge the term spread. The corroborated mechanism aligns with Ghosh et al.(2021), which discovered that salience effect could induce investors to think more narrowly and exacerbate disposition effect. The empirical findings expand the existing salience literature exploring the salience effect on stock market returns, as exemplified by the works of Kumar et al. (2017).

7. Policy implications

Based on the findings of this study, the following policy insights can be drawn. Firstly, the importance of psychological factors in influencing yield curve should be acknowledged. Economic phenomena emerge as equilibrium outcomes individual decisions. Humans, inherently emotional, make decisions driven by psychological factors. The policymakers should therefore thoroughly consider the psychological factors.

Secondly, this study provides a method for policymakers to assess the impact of psychological factors on yield curves and anticipate potential policy ramifications. The global financial crisis, the European sovereign debt crisis, and the high inflation during the COVID-19 have all contributed to the 20-year period's instability and crisis-ridden atmosphere. We take high inflation and high credit risk as the instance. The expected consumption growth would be reduced since both high inflation and high credit risk inhibit consumption, which induces high sensitivity between expected consumption growth and salience weights. The bond risk premium would be expected to be high. Meanwhile, the bond level change would be high since expected consumption growth would be low. Combining the two effects the expected term spread would be high. Furthermore, this paper delineates qualitative impacts of the low interest rate and low inflation in the online appendix.

Notes

1. The "endowment effect" experiment: the experiment had two phases, in the first phase the experimenter was given a mug, and in the second phase the experimenter could exchange the mug for a pen of similar value. The "endowment effect" states that almost all experimenters do not choose to trade in the second phase. (Thaler 1980).
2. Malloy et al. (2009) and Hansen et al. (2008) applied the same assumptions.
3. High salience degree would increase the term spreads generated by the model. The purpose of setting $\delta = 0.9$ is to show that the model could still generate high term spreads with less salience degree.
4. The correlation between the log salience weight and the expected consumption growth rate affects the shape of the yield curve. Subtracting a constant does not affect the correlation between the log salience weight and the expected consumption growth rate, therefore it does not affect conclusions.
5. We compared the effect of the tangent function and linear function, and found that the difference between them is little. The tangent function is chosen in this paper.
6. The figure is omitted since the space limitations.
7. PS (2006) calibrates the coefficients to $\beta = 1.005$ and $\gamma = 59$. The slight difference with the parameters calibrated in this paper is because the price or quantity indexes in the NIPA data used in 2006 are benchmarked to the 2000 index = 100, while the benchmark of the NIPA data used in this paper is made to the 2012 index = 100.
8. https://www.asc.ohio-state.edu/mcculloch.2/ts/ts.html.
9. One-period TIPS yields are not available, thus we only utilise the nominal term spreads.

Disclosure statement

The authors report there are no competing interests to declare.

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