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Income Uncertainty, Risk Aversion, and Consumption Behavior: The Japanese Experience from 1987 to 2009*

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We investigate the effect of precautionary savings derived from monthly data in Japan from 1987 to 2009, by formulating a Euler consumption equation that consists of a tri-variable function, in which the growth rate of the income uncertainty indicator, the consumption growth rate, and the earning assets rate are the explanatory variables. As a result, the model's evaluation of the over identification condition is improved and it is thus confirmed that the estimation result for relative risk aversion is stable. We illustrate that the rise in income uncertainty and the protracted zero interest policy after the bubble's implosion were possible causes of risk averse behavior, which eventually triggered dynamic optimization among households. Furthermore, we clarify that the estimation result for excessive relative risk aversion, which became an issue during the bubble period, could have been improved by investigating the case studies of this period.

1. Introduction

The main purpose of the permanent income hypothesis investigation has been the estimation of the Euler consumption equation (subjective discount rate and relative risk aversion) based on the Consumption-based Capital Asset Pricing Model (C-CAPM) after Hansen and Singleton's analysis (1982). However, it is difficult to consider estimates of relative risk aversion as reliable for analysts, due to their frequently unstable values, which depend on the length of the estimation period. Hamori (1996) estimated a Euler equation derived from a Constant Relative Risk Aversion (CRRA) utility function based on monthly data for the real rate of return on stocks, the short-term real interest rate, and the long-term real rate of return on government securities, from January 1971 to December 1990, in order to derive a stable parameter value for relative risk aversion. However, Fukuda (1993), Morisawa (2008), and Tanigawa (1994) conducted a similar analysis and reported a negative value for relative risk aversion that does not satisfy the sign condition.

In addition, Hansen and Singleton (1983) reported a negative value for relative risk aversion of −0.359, when they analyzed monthly data for the U.S.. Furthermore, Mehra and Prescott (1985) conceptualized the well-known problem that the restrictions imposed on the average return ratio of the stock index and treasury securities tend to become too severe if we adopt yearly rates of return for stock indices and treasury securities and annual growth rates for consumption between 1890 and 1979. Moreover, using the same sample as Mehra and Prescott (1985), Mankiw and Zeldes (1991) calculated relative risk aversion from a Taylor approximation of the Euler equation and obtained a value 26.3. This value increases to 89

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when the sample is taken from the postwar period in the U.S. between 1948 and 1988.

Meanwhile, in the theoretical model of precautionary savings, the larger income uncertainty is, the greater savings and the higher the consumption growth rate are. This theory is built on the concept that when income uncertainty increases, the utility function shifts to the lower right, and eventually the future marginal utility of consumption increases relatively. More specifically, when there is a relative change in future income uncertainty, the indifference curve will shift during multiperiod optimization according to the relative positional change in the utility function due to uncertainty between the present and the future. Estimation of the Euler consumption equation, however, is typically undertaken using a bi-variable function that merely takes the consumption growth rate and earning assets rate as explanatory variables under a fixed indifference curve, without considering the impact of relative changes in income uncertainty between the present and the future (here in after referred to as the "NM model"). In this case, however, the estimated value of relative risk aversion may itself contain a bias, since the estimation is based on changes in the earning assets rate, with no consideration of relative changes in income uncertainty, even when changes in the earning assets rate and relative changes in income uncertainty occur simultaneously. In this article, as mentioned previously, we formulate a Euler consumption equation (hereinafter referred to as the "CV model") and then carry out a parameter estimation of this equation, treating the consumption growth rate, the earning assets rate, and the income fluctuation coefficient growth rate as explanatory variables, while simultaneously considering changes in the earning assets rate and relative changes in income uncertainty. We also illustrate that the estimation result for relative risk aversion can be interpreted using two covariances: the covariance between the earning assets rate and the consumption growth rate, and the covariance between the earning assets rate and the income fluctuation coefficient growth rate. Moreover, we implement the method employed by Mankiw and Zeldes (1991) in order to facilitate a clear comparison between our results and those derived from their NM model, where the consumption growth rate and earning assets rate were derived using data from Japan.

Although Skinner (1988), Pemberton (1993, 1997), and Irvine and Wang (1994) conducted landmark studies in which the variation coefficient of either income or expected human assets (as an income uncertainty index) is clearly incorporated into the consumption model, none of these studies intended to incorporate the income variation coefficient directly into the Euler consumption equation, as we do here.

The remainder of this article is structured as follows. Section 2 attempts to derive an optimal consumption model under income uncertainty, not only to formulate a Euler equation that can be used for GMM Estimation, but also to clarify the features of the dual-duration and CV models using a model that has been extended through the method of Mankiw and Zeldes (1991). Section 3 introduces a demonstrative analysis conducted with a GMM Estimation of the CV model based on monthly data in Japan between 1987 and 2009 that uses the income variation coefficient, the reciprocal of the jobs-to-applicants ratio, and the total unemployment ratio as income uncertainty indexes. This section also describes the screening results obtained from the estimation results and interprets the parameters and Sargan conditions. Finally, Section 4 provides the conclusion.

2. Model

2.1 The CV model under income uncertainty

This section sets up an optimal consumption model under income uncertainty using marginal utility influenced by an income variation coefficient. A CV model with an income variation coefficient is then derived by employing the same method as Skinner (1988). To accomplish this, the real consumption of an individual in period “t” is set to C_t, and the additive separable instantaneous utility function is set to $U(C_t)$ for time t. Assume that the degree of consumption fluctuation caused by income uncertainty is expressed as a standard deviation h_t: In this case, we can assume that individual consumption increases or decreases by h_t with a 50% probability.[1)] Here, taking into account the uncertainty of an individual’s consumption level C_t, utility can be expressed as follows:

$$U^*(C_t) = 0.5U(C_t - h_t) + 0.5U(C_t + h_t) \tag{1}$$

Here, suppose the downturn range of utility, derived from consumption C_t, caused by income uncertainty is $\rho(C_t, h_t)$. Then the following equation is obtained from $\rho(C_t, h_t) = U(C_t) - U^*(C_t)$ and Equation (1).

$$U(C_t) - \rho(C_t, h_t) = 0.5U(C_t - h_t) + 0.5U(C_t + h_t) \tag{2}$$

Then, using a Taylor expansion, if data up to the second section of $U(C_t - h_t)$ and $U(C_t + h_t)$, respectively, on the right side of Equation (2) are substituted into Equation (2) again for further sorting, $\rho(C_t, h_t)$ can be expressed as follows:

$$\rho(C_t, h_t) = -0.5U''(C_t)h_t^2 \tag{3}$$

We now specify the utility function to the following Constant Relative Risk Aversion (CRRA) form:

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

However, since γ indicates relative risk aversion, $1/\gamma$ indicates the intertemporal elasticity of substitution. In addition, the double differential of the CRRA utility function becomes $-\gamma / C_t^{\gamma+1}$ and thus, $\rho(C_t, h_t)$ can be expressed by substituting into Equation (3) as

$$\rho(C_t, h_t) = 0.5\gamma C_t^{1-\gamma}\left(h_t / C_t\right)^2 \tag{4}$$

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1) Otake (2003) compared the transitions of the consumption and income inequality between 1984 and 1999 based on a special tally in a “national survey of family income and expenditure” and reported that the distribution of logarithmic consumption tends to be lower than the distribution of logarithmic income. Figure 1-7 in his report shows the behavior of the consumption distribution associated with the performance of income distribution.

However, since $(h_t / C_t)^2$ indicates the squared value of the consumption variation coefficient in period t, it is expressed further with CV_t^2 .

By substituting the CRRA utility function and Equation (4) into $U^*(C_t) = U(C_t) - \rho(C_t, h_t)$ and solving it, the expected utility function of an individual under income uncertainty can be expressed as follows:

$$U^*(C_t) = C_t^{1-\gamma} /(1-\gamma)\left[1 - 0.5(\gamma - \gamma^2)CV_t^2\right] \tag{5}$$

The expected marginal utility function of an individual under income uncertainty can then be expressed by differentiating and sorting Equation (5) as follows:[2)]

$$U^{*}{}'(C_t) = C_t^{-\gamma}\left[1 + 0.5(\gamma + \gamma^2)CV_t^2\right] \tag{6}$$

According to Equation (6), the expected marginal utility of an individual can be obtained by multiplying $1 + 0.5(\gamma + \gamma^2)CV_t^2$ with the expected marginal utility of a conservative model, and thus the expected marginal utility increases proportionally with the squared value of the consumption variation coefficient. Furthermore, this method of deriving expected marginal utility is the same as the method proposed by Skinner (1988), who derived the marginal utility associated with the balance of financial assets. Thus, Equation (6) is equivalent to Equation (7) in Skinner (1988).

Using the expected utility function (Equation (5)), the multiperiod optimal consumption model for an individual with income uncertainty can be set as follows:

$$\max \quad E_t[\sum_{i=0}^{\infty} \beta^i U^*(C_{t+i})] \tag{7}$$

$$\text{s.t.} \quad \sum_{j=1}^{N} q_{jt} A_{jt+1} + C_t = \sum_{j=1}^{N} (q_{jt} + d_{jt}) A_{jt} + Y_t \tag{8}$$

where β indicates the subjective discount rate $(0 < \beta < 1)$, q_{jt} indicates the price of the jth asset (j = 1, 2, ⋯, N), d_{jt} indicates the dividend obtained from the jth asset (j = 1, 2, ⋯, N), A_{jt} indicates the amount of the jth asset held, Y_t indicates non-asset income, and $E_t[\bullet]$ indicates a conditional expectation operator based on the available information, in period t.

We assume that there are N assets in the economy and hence an individual selects consumption flows and asset holdings such that the discounted flow of expected utility obtained from present (t = 0) to future consumption is maximized.

Solving the individual's optimization problem, the following first-order condition for utility maximization can be obtained:

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2) During the derivation from Equation (5) to Equation (6), $CV_t = h_t / C_t$ is replaced with $\partial CV_t / \partial C_t = -h_t / C_t^2$.

$$E_t[\beta \frac{U^{*}{}'(C_{t+1})}{U^{*}{}'(C_t)}(\frac{q_{jt+1}+d_{jt+1}}{q_{jt}})]-1=0 \tag{9}$$

Since the earnings rate r_{jt+1} of the j[th] asset is defined by $r_{jt+1}=(q_{jt+1}+d_{jt+1})/q_{jt}-1$, the term $(q_{jt+1}+d_{jt+1})/q_{jt}$ in Equation (9) can be replaced with $(1+r_{jt+1})$. Therefore, making this replacement and substituting Equation (6) into the result, the Euler equation for individual consumption under income uncertainty can be expressed as follows:

$$E_t[\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\frac{1+0.5(\gamma+\gamma^2)CV_{t+1}^2}{1+0.5(\gamma+\gamma^2)CV_t^2}(1+r_{jt+1})]-1=0 \quad (\text{j} = 1, 2, \cdots, \text{N}) \tag{10}$$

2.2 GMM Estimation

Although the CV model (Equation (10)) that we calculated in the preceding section includes the squared value of the variation coefficient for a typical Euler equation, the moment condition of the instrumental variable for the GMM Estimation cannot be completed regardless of the commensuration of the numerator and denominator, because the squared value of the consumption variation coefficient is independently included in the numerator and denominator of the intermediate term.

Therefore, to provide a specification that enables GMM Estimation, $1+0.5(\gamma+\gamma^2)CV_t^2$ can be obtained by transforming the primary approximation of a Taylor expansion of the exponential related to $1+0.5(\gamma+\gamma^2)CV_t^2 \cong \exp[0.5(\gamma+\gamma^2)CV_t^2]$ in the expected marginal utility of Equation (6). Thus, the intermediate term from Equation (10) is considered transformable, as mentioned below:

$$\frac{1+0.5(\gamma+\gamma^2)CV_{t+1}^2}{1+0.5(\gamma+\gamma^2)CV_t^2} \cong \frac{\exp[0.5(\gamma+\gamma^2)CV_{t+1}^2]}{\exp[0.5(\gamma+\gamma^2)CV_t^2]} = \frac{\exp(CV_{t+1}^2)^{0.5(\gamma+\gamma^2)}}{\exp(CV_t^2)^{0.5(\gamma+\gamma^2)}} = \left(\frac{\exp(CV_{t+1}^2)}{\exp(CV_t^2)}\right)^{0.5(\gamma+\gamma^2)}$$

By applying the intermediate term to Equation (10), the CV model can be obtained as follows. Here, not only the growth rate of the squared value of the consumption variation coefficient is added to the explanatory variable, but also the coefficient $0.5(\gamma+\gamma^2)$ of relative risk aversion is multiplied to the consumption variation coefficient.

$$\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\frac{\exp(CV_{t+1}^2)}{\exp(CV_t^2)}\right)^{0.5(\gamma+\gamma^2)}(1+r_{jt+1})=1 \tag{11}$$

This is the CV model under income uncertainty, where the tri-variable function of the consumption growth rate, the earning assets rate, and the consumption variation coefficient growth rate is formulated as the explanatory variable.

Although the error rate of the proximate intermediate term increases with a rise in relative risk aversion, good proximate results are obtained overall when relative risk aversion is 2 or less, as reported by Hansen and Singleton (1983). [3)]

2.3 Consideration based on the dual-duration model

Tallying the utility function for only the dual duration of "i = 0, 1" in Equation (7) and setting total utility to Z, the following formula is obtained:

$$Z = U^*(C_t) + \beta U^*(C_{t+1}) \tag{12}$$

The Euler equation of Equation (11) is the first-order condition for utility maximization derived from the multiperiod optimum consumption model. This condition implies that the marginal rate of substitution $-dC_{t+1}/dC_t$ between two different points on the indifference curve matches with the slope $(1+r_{t+1})$ of the budget constraint line. As such, $dZ = U^*{}'(C_t)dC_t + \beta U^*{}'(C_{t+1})dC_{t+1} = 0$ can be used with the total derivative of Equation (12) to calculate the marginal rate of substitution as follows:

$$-\left.\frac{dC_{t+1}}{dC_t}\right|_{dZ=0} = \frac{U^*{}'(C_t)}{\beta U^*{}'(C_{t+1})} = \frac{C_t^{-\gamma}[1+0.5(\gamma+\gamma^2)CV_t^2]}{\beta C_{t+1}^{-\gamma}[1+0.5(\gamma+\gamma^2)CV_{t+1}^2]} \tag{13}$$

Here, by incorporating the deformation using a Taylor expansion of the exponential on the variation coefficient term in Equation (13), as mentioned in the previous paragraph, the marginal rate of substitution for the indifference curve in the dual-duration model of the CV model can be expressed as follows: [4)]

$$-\left.\frac{dC_{t+1}}{dC_t}\right|_{dZ=0} = \frac{1}{\beta}\left(\frac{C_t}{C_{t+1}}\right)^{-\gamma}\left(\frac{\exp(CV_t^2)}{\exp(CV_{t+1}^2)}\right)^{0.5(\gamma+\gamma^2)} \tag{14}$$

On the other hand, since the marginal rate of substitution in the dual-duration model of the NM model is obtained by setting the variation coefficient of consumption CV_t in Equation (14) to zero, it can be expressed by the following formula, where $\exp(0)=1$ is substituted into the numerator and denominator of Equation (14):

$$-\left.\frac{dC_{t+1}}{dC_t}\right|_{dZ=0} = \frac{1}{\beta}\left(\frac{C_t}{C_{t+1}}\right)^{-\gamma} \tag{15}$$

Although the marginal rate of substitution for the indifference curve derived from Equation (15) does not change, even if income uncertainty increases between periods t and t + 1 and becomes

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3) The maximum error rate is confirmed using monthly sample data (January 1987–December 2009; minimum 0.580 and maximum 0.609). The variation coefficient is calculated according to the size of the relative risk aversion γ. More specifically, when γ = 0 the variation coefficient is 0.0000%, when γ = 0.2 it is 0.0032%, when γ = 0.6 it is 0.0459%, when γ = 1 it is 0.1721%, when γ = 2 it is 1.0182%, when γ = 3 it is 2.7049%, and when γ = 5 it is 8.5905%.

4) Set the marginal rate of substitution from Equation (14) equal to the slope of the budget constraint line $(1+r_{t+1})$, and rearrange the result to obtain the Euler consumption equation (Equation (11)).

$CV_{t+1} > CV_t$, the growth rate of the consumption variation coefficient $\exp(CV_t^2)/\exp(CV_{t+1}^2)$ on the right side of the third term subsequently goes below 1 in the CV model derived from Equation (14). Thus, the marginal rate of substitution declines along the entire indifference curve (focus on future consumption). On the other hand, although the marginal rate of substitution for the indifference curve derived from Equation (15) does not change, even if income uncertainty decreases between periods t to t + 1 to become $CV_t > CV_{t+1}$, the growth rate of the consumption variation coefficient $\exp(CV_t^2)/\exp(CV_{t+1}^2)$ available on the right side of the third term goes above 1 in the CV model derived from Equation (14). Hence, the marginal rate of substitution increases for the entire indifference curve (focus on current consumption).

2.4 Determination of relative risk aversion

Mankiw and Zeldes (1991) derived the equity premium and covariance relational expression between relative risk aversion and the earning assets rate/consumption growth rate, as mentioned in Equation (17) with a certain abbreviation. By applying the Taylor expansion of the bi-variable function to the Euler equation in which the bi-variable function of Equation (16)'s consumption growth rate/earning assets rate is set as an explanatory variable: [5)]

$$E[(1+r^i)(1+g^C)^{-\gamma}] = 1+\rho \qquad (16)$$

$$E[r_i] - \bar{r} \cong \gamma Cov(r^i, g^C) \qquad (17)$$

However, since $g^C = (C_{t+1}/C_t) - 1$, the time subscript is omitted. In addition, r^i indicates the earnings rate of risk assets, $\bar{r}$ indicates the earnings rate of non-risk assets, $E[r^i] - E[\bar{r}]$ indicates the equity premium and ρ indicates the rate of time preference (equivalent to $(1/\beta) - 1$).

According to Equation (17), relative risk aversion is defined as the equity premium divided by the covariance between the earning assets rate and the consumption growth rate. On the other hand, since the CV model sets the tri-variable function of the consumption growth rate, the earning assets rate, and the income fluctuation coefficient growth rate as an explanatory variable, it can be expressed in the same manner as the NM model of Equation (16) as follows:

$$E[(1+r^i)(1+g^C)^{-\gamma}(1+g^{\exp(CV^2)})^{0.5(\gamma+\gamma^2)}] = 1+\rho \qquad (18)$$

However, since $g^{\exp(CV^2)} = (\exp(CV_{t+1}^2)/\exp(CV_t^2)) - 1$, the time subscript is omitted. As such, $g^{\exp(CV^2)}$ is represented by g^{eCVSQ} and the target formula of the Taylor expansion is expressed as

5) The model and the relational expression described here are based on Romer (2001) Ch.7.

$$f(r^i, g^C, g^{eCVSQ}) = (1+r^i)(1+g^C)^{-\gamma}(1+g^{eCVSQ)})^{0.5(\gamma+\gamma^2)} \tag{19}$$

The following approximation can be obtained by evaluating the Taylor expansion around $r^i = g^C = g^{eCVSQ} = 0$, up to the second term:

$$\begin{aligned} f(r^i, g^C, g^{eCVSQ}) = 1 + r^i - \gamma g^C - \gamma r^i g^C + 0.5(\gamma+\gamma^2)(g^C)^2 \\ + 0.5(\gamma+\gamma^2)g^{eCVSQ} + 0.25(\gamma+\gamma^2)[0.5(\gamma+\gamma^2)-1](g^{eCVSQ})^2 \\ - 0.5\gamma(\gamma+\gamma^2)g^C g^{eCVSQ} + 0.5(\gamma+\gamma^2)r^i g^{eCVSQ} \end{aligned} \tag{20}$$

In addition, the first line of Equation (20) is equivalent to the result for the NM model. [6]
The following formula is obtained by substituting the results of Equation (20) into Equation (18):

$$\begin{aligned} E[r^i] - \gamma E[g^C] - \gamma\{E[r^i]E[g^C] + Cov(r^i, g^C)\} + 0.5(\gamma+\gamma^2)\{(E[g^C])^2 + Var(g^C)\} \\ + 0.5(\gamma+\gamma^2)E[g^{eCVSQ}] \\ + 0.25(\gamma+\gamma^2)\{0.5(\gamma+\gamma^2)-1\}\{(E[g^{eCVSQ}])^2 + Var(g^{eCVSQ})\} \\ - 0.5\gamma(\gamma+\gamma^2)\{E[g^C]E[g^{eCVSQ}] + Cov(g^C, g^{eCVSQ})\}\}) \\ + 0.5(\gamma+\gamma^2)\{E[r^i]E[g^{eCVSQ}] + Cov(r^i, g^{eCVSQ})\} \cong \rho \end{aligned} \tag{21}$$

Moreover, the first line of Equation (21) is equivalent to the result for the NM model. [7]
Here, $E[r^i]E[g^C]$, $(E[g^C])^2$, $(E[g^{eCVSQ}])^2$, $E[g^C]E[g^{eCVSQ}]$, and $E[r^i]E[g^{eCVSQ}]$ have relatively small values. If they are ignored and replaced with 0 (zero), the following formula can be obtained after solving for $E[r^i]$.

$$\begin{aligned} E[r^i] \cong \rho + \gamma E[g^C] + \gamma Cov(r^i, g^C) - 0.5(\gamma+\gamma^2)Var(g^C) \\ - 0.5(\gamma+\gamma^2)E[g^{eCVSQ}] - 0.25(\gamma+\gamma^2)\{0.5(\gamma+\gamma^2)-1\}Var(g^{eCVSQ}) \\ + 0.5\gamma(\gamma+\gamma^2)Cov(g^C, g^{eCVSQ}) - 0.5(\gamma+\gamma^2)Cov(r^i, g^{eCVSQ}) \end{aligned} \tag{22}$$

Furthermore, the first line of Equation (22) is equivalent to the result for the NM model. [8]
Here, assuming that the earnings rate of risk-free assets is not related to either the consumption growth rate or the income fluctuation coefficient growth rate, the following formula can be obtained by substituting $Cov(r^i, g^C) = 0$ and $Cov(r^i, g^{eCVSQ}) = 0$ into Equation (22):

6) Refer to Romer (2001) Ch.7 (7.37).
7) Refer to Romer (2001) Ch.7 (7.38).
8) Refer to Romer (2001) Ch.7 (7.39).

$$\bar{r} \cong \rho + \gamma E[g^C] - 0.5(\gamma+\gamma^2)Var(g^C) - 0.5(\gamma+\gamma^2)E[g^{eCVSQ}]$$
$$-0.25(\gamma+\gamma^2)\{0.5(\gamma+\gamma^2)-1\}Var(g^{eCVSQ})$$
$$+0.5\gamma(\gamma+\gamma^2)Cov(g^C, g^{eCVSQ}) \qquad (23)$$

The equity premium, relative risk aversion, the covariance between the earning assets rate and consumption growth rate, and the covariance between the income fluctuation coefficient growth rate and the earning assets rate are obtained by subtracting Equation (23) from Equation (22):

$$E[r^i] - \bar{r} \cong \gamma Cov(r^i, g^C) - 0.5(\gamma+\gamma^2)Cov(r^i, g^{eCVSQ}) \qquad (24)$$

Therefore, although relative risk aversion had previously been interpreted in the NM model of Equation (17) using on the covariance between the earning asset rate and the consumption growth rate, it is now interpreted using two covariances: The covariance between the earning assets rate and consumption growth rate and the covariance between the earning assets rate and the income fluctuation coefficient growth rate. This is the benefit of the extended CV model.

If we replace Equation (24) with relative risk aversion "γ," then the following formula can be obtained:

$$Cov(r^i, g^C)\gamma \cong E[r^i] - \bar{r} + 0.5Cov(r^i, g^{eCVSQ})(\gamma+\gamma^2) \qquad (25)$$

The following formula, which is the same as the decision formula (Equation (17)) for the NM model's relative risk aversion, can be obtained by applying $Cov(r^i, g^{eCVSQ}) = 0$ to Equation (25):

$$Cov(r^i, g^C)\gamma \cong E[r^i] - \bar{r} \qquad (26)$$

Figure 1 illustrates the decision relationship for relative risk aversion in the NM and CV models based on Equations (25) and (26), when the covariance between the earning assets rate and consumption growth rate is positive. The covariance between the earning assets rate and income fluctuation coefficient growth rate is positive or negative for a positive equity premium observed in a normal market. In this figure, the relative risk aversion of the NM model is determined by the γ^*_{NM} level that matches the equity premium of $E[r^i] - \bar{r}$ with which the line with $Cov(r^i, g^C)$ tilts on the left-hand side of Equation (26) is matching. On the other hand, the relative risk aversion of the CV model will be determined by the level of $\gamma^*_{CV\_a}$ that crosses with the $Cov(r^i, g^C)$ tilt line on the left side of Equation (25), as $\gamma+\gamma^2$ becomes a monotonically increasing function in the $\gamma > 0$ range and the right side of Equation (25) will be a downward-sloping curve from the intercept $E[r^i] - \bar{r}$ as mentioned in (a), when the covariance between the earning assets rate and income fluctuation coefficient growth rate is negative. When the covariance between the earning assets rate and income fluctuation coefficient growth rate is positive, the right side of Equation (25) will be an upward-sloping

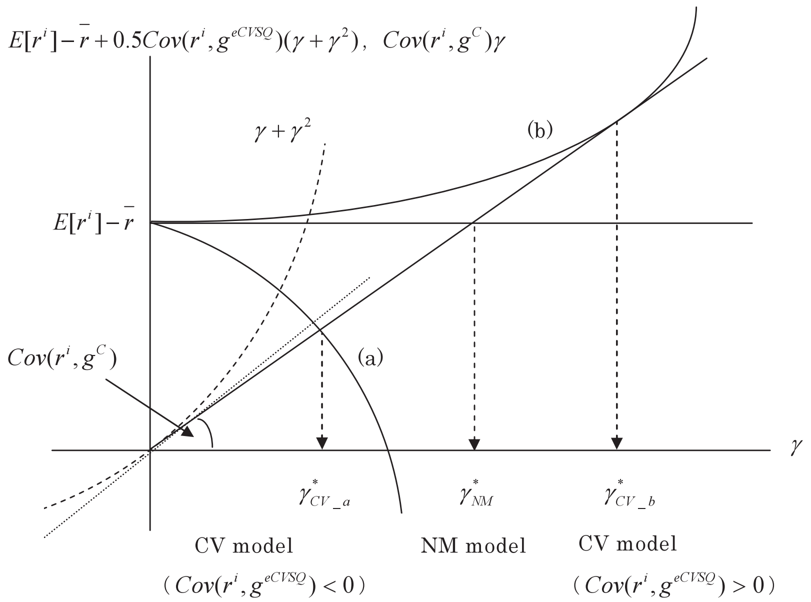

Figure 1 Determination of relative risk aversion (NM model and CV model)

curve from intercept $E[r^i]-\bar{r}$ as mentioned in (b), which will be determined by the level of $\gamma^*_{CV\_b}$ that crosses with the $Cov(r^i, g^C)$ tilt line on the left side of Equation (25). [9)]

Typically, the equity premium puzzle occurs when the level γ^*_{NM} of relative risk aversion derived from Equation (26) goes beyond a normally acceptable range, as the covariance between the earning assets rate and the consumption growth rate is small relative to the level of equity premium. In the CV model, where Equation (25) is used, relative risk aversion can be set at a $\gamma^*_{CV\_a}$ level that is much lower than γ^*_{NM} when the covariance between the earning assets rate and the income fluctuation coefficient growth rate takes on a large negative value. Thus, the estimation results can be improved considerably over the NM model.

3. Estimation

3.1 Data

The basic data used for estimating the Euler equation of the NM model (with the exception of the third term on the left side of Equation (11)) is monthly Japanese data for the real consumption growth rate and the real earning assets rate (housing, equity, and government

9) Since Equation (25) becomes the quadratic equation for γ, the conditions for γ to have actual roots among equity premiums, the covariance between the asset earnings rate and the consumption growth rate, and that between the asset earnings rate and the income fluctuation coefficient growth rate needs to be fulfilled. Moreover, when a negative risk premium, such as the bubble's implosion occurs, the data under observation would not comply with the model in which a household avoids risk. Therefore, we should note that the interpretation of the relative risk aversion from Equations (25) and (26) will be difficult.

bonds) between 1987 and 2009. To avoid the impact of durable goods consumed during this period on the utility of not only the current period but subsequent periods as well, we adopt expenditures on non-durable goods for our real consumption data. These expenditures are derived from the annual family income and expenditure survey report by subtracting expenditures on durable goods from total consumption expenditure. Here, a census method (X11) is used as a seasonal adjustment method for real consumption.

The Euler equation for the CV model (Equation (11)) is estimated using the data described in the preceding section and monthly index data for the period from 1987 and 2009. In addition, we use the income variation coefficient (as the income risk variable), the reciprocal of the jobs-to-applicants ratio, or the total unemployment ratio as income uncertainty data (as the employment risk variable). [10)]

Using the income variation coefficient (hereinafter, CV1) from income information published in the "National Livelihood Survey" between 1986 and 2009, we have created monthly data for the variation coefficient using data on number of households, head of household age (ten-year scale),[11)] household structure, and amount of income by level using the following steps: 1. create an income-level household distribution chart for 24 years, where the productive-age population is divided into four age groups from 20s to 50s (up to 59) and then into 25 income groups from the lowest income of 500,000 JPY and below to the highest income of 20,000,000 JPY and above; 2. calculate the variation coefficient from the average value and the variation coefficient of income for each year; 3. interpolate the nonlinear approximation on the results of step 2 by the third spline function.[12)] On the other hand, the reciprocal of the jobs-to-applicants ratio (hereinafter, CV2) is created using long-term chronological order data (per-month, seasonally adjusted figures) of the jobs-to-applicants ratio announced by the Health, Labour and Welfare Ministry. The total unemployment ratio (hereinafter, CV3) adopts the long-term chronological order data (per-month, seasonally adjusted figures) of the "labor force survey."

The abovementioned income uncertainty index data (hereinafter, respective CV sequences) are not integrated in terms of units, average values, and standard deviations. Stationarity of the data, which would be an assumption of the GMM estimation of the Euler equation, needs to be maintained. Therefore, we conduct the following process with in a range that retains the information contained in the data by conducting a standardization to secure data stationarity and obtain an average value for the income variation coefficient and integrate it with the standard deviation in the following manner:

1. Set the Hodrick-Prescott filter (λ = 14400) to the respective CV sequences and extract the sequences that consist only of cycles after removing the trend (hereinafter, the

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10) Doi (2004) concluded that "employment risk" has a higher explanation effect than "income risk," after comparing "income risk", which was derived by measuring the distribution of the expected growth rate of real disposable income, with "employment risk", which was derived using the reciprocal of jobs-to-applicants ratio and total unemployment ratio. Following Doi (2004), we implemented explanatory variables corresponding to the respective "income risk" and "employment risk" as the income uncertainty index.

11) For only the year 1986, we adopted a "5-year class" according to the original data.

12) The total number of households was broken down into four age groups. For the age groups between 20s and 50s (up to 59), nuclear family households occupy 66% in 2009. The numerical details are as follows: total; 3235, single; 639, nuclear family; 2124, three-generation family; 275, and other; 197.

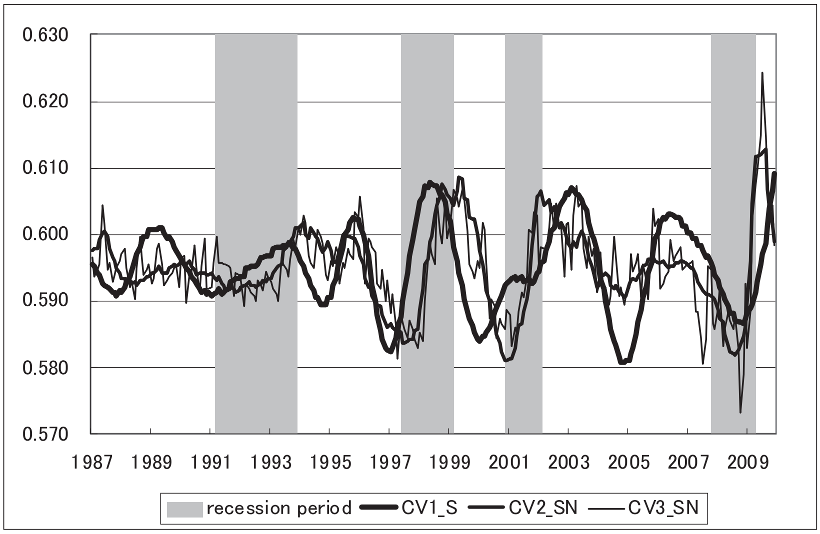

Figure 2 Income uncertainty index

respective CV_C sequences).

2. Consider the value of Jan. 1987 in the respective CV sequences as an initial value for creating steady sequences (hereinafter, respective CV_S sequences).
3. Calculate the average value and standard deviation of the steady sequence of the CV1 (hereinafter, CV1_S sequence), and standardize it so that the average values and the standard deviations of the CV2's steady sequence (hereinafter, CV2_S sequence) and the CV3's steady sequence (hereinafter, CV3_S sequence) match with the standard value and the standard deviation of the CV1_S sequence (steady sequences after standardizing CV2 and CV3 are called, respectively, CV2_SN sequence and CV3_SN sequence).

Figure 2 shows the CV1_S sequence, CV2_SN sequence, and CV3_SN sequence after the abovementioned process. The figure illustrates that the CV2_SN sequence (the reciprocal of jobs-to-applicants ratio) and CV3_SN sequence (total unemployment ratio) perform almost in the same manner.

Furthermore, in Figure 2, shadows illustrate recessionary periods. Every steady and standardized index rises during recession periods.

3.2 Estimation results

To estimate the respective features of the Japanese economy, centering on the bubble economy after the Plaza Accord (1985), the following estimation period is set in reference to

Table 1 Unit root test

variable	test		1987–1991 (N=60)	1992–2000 (N=108)	2001–2006 (N=72)	2007–2009 (N=36)	1987–2009 (N=276)
gcp11	ADF	lag order	1	0	1	0	1
		ADF statistics	−9.495 ***	−15.680 ***	−9.880 ***	−9.215 ***	−17.470 ***
		p-value	0.0000	0.0000	0.0001	0.0000	0.0000
	PP	PP statistics	−15.954 ***	−44.638 ***	−15.922 ***	−10.410 ***	−37.023 ***
		p-value	0.0000	0.0001	0.0001	0.0000	0.0001
r1	ADF	lag order	0	0	0	1	0
		ADF statistics	−11.011 ***	−9.964 ***	−9.460 ***	−6.856 ***	−20.239 ***
		p-value	0.0000	0.0000	0.0000	0.0000	0.0000
	PP	PP statistics	−11.233 ***	−12.277 ***	−9.460 ***	−8.761 ***	−20.411 ***
		p-value	0.0000	0.0000	0.0000	0.0000	0.0000
r2	ADF	lag order	0	0	0	0	0
		ADF statistics	−7.914 ***	−9.537 ***	−6.211 ***	−4.052 ***	−14.768 ***
		p-value	0.0000	0.0000	0.0000	0.0035	0.0000
	PP	PP statistics	−7.985 ***	−9.532 ***	−6.333 ***	−4.031 ***	−14.840 ***
		p-value	0.0000	0.0000	0.0000	0.0037	0.0000
r3	ADF	lag order	1	2	2	0	13
		ADF statistics	−7.284 ***	−9.347 ***	−7.226 ***	−4.345 ***	−3.665 ***
		p-value	0.0000	0.0000	0.0000	0.0016	0.0052
	PP	PP statistics	−12.921 ***	−8.103 ***	−12.609 ***	−4.409 ***	−14.011 ***
		p-value	0.0000	0.0000	0.0001	0.0013	0.0000
gecv1sq	ADF	lag order	3	3	3	2	15
		ADF statistics	−3.315 **	−4.453 ***	−2.802 *	−0.131	−3.581 ***
		p-value	0.0189	0.0004	0.0634	0.9375	0.0068
	PP	PP statistics	−1.840	−2.602	−1.702	0.815	−3.623 ***
		p-value	0.3580	0.0957 *	0.4257	0.9929	0.0059
gecv2sq	ADF	lag order	0	0	0	0	0
		ADF statistics	−5.523 ***	−5.255 ***	−4.966 ***	−2.046	−7.892 ***
		p-value	0.0000	0.0000	0.0001	0.2669	0.0000
	PP	PP statistics	−5.566 ***	−5.327 ***	−5.119 ***	−2.129	−8.106 ***
		p-value	0.0000	0.0000	0.0001	0.2353	0.0000
gecv3sq	ADF	lag order	6	0	3	0	1
		ADF statistics	−6.926 ***	−12.369 ***	−6.171 ***	−5.212 ***	−15.343 ***
		p-value	0.0000	0.0000	0.0000	0.0001	0.0000
	PP	PP statistics	−21.192 ***	−12.796 ***	−11.219 ***	−5.219 ***	−20.146 ***
		p-value	0.0001	0.0000	0.0001	0.0001	0.0000

(Note 1) Each variable is as follows.

gcp11： Real consumption growth rate (census method X11)
r1： Real housing earning rate
r2： Real rate of returns on stocks
r3： Real national bond earning rate
gecv1sq： Income uncertainty index growth rate (coefficient of variation of income)
gecv2sq： Income uncertainty index growth rate (the reciprocal of jobs-to-applicants ratio)
gecv3sq： Income uncertainty index growth rate (the total unemployment ratio)

(Note 2) ADF expresses ADF official approval, and PP expresses Phillips-Perron (PP) official approval, respectively.

(Note 3) ***, **, and * mean that the null hypothesis that each variable has a unit root under 1%, 5%, and 10% significance levels is rejected,

(Note 4) The determination of the number of lug terms in ADF official approval follows SBIC.

real economic growth rate (calendar year basis). [13)]

1987–1991: Business upturn period triggered by the formation of the bubble economy (hereinafter, Period I)

1992–2000: Economic stagnation period caused by the burst of the bubble economy and the balance sheet adjustment recession (hereinafter, Period II)

2001–2006: Economic recovery period linked with the implementation of an achievement-oriented system and a bubble economy in the U.S. (hereinafter, Period III)

2007–2009: Economic downturn period after the bubble's implosion in the U.S. (hereinafter, Period IV)

1987–2009: Entire estimation period (hereinafter, Entire Period)

First, the results of the unit root tests for the basic data and income uncertainty index data in each estimation period are shown in Table 1. Although Table 1 shows the unit root test results, all income uncertainty index data, except the CV1_S sequence (income variation coefficient) and the CV2_SN sequence (the reciprocal of jobs-to-applicants ratio) in 2007–2009, reject the null hypothesis, indicating that all data hold a unit root with a 10% significance level and each variable fulfills stationarity, a condition of the GMM estimation. Furthermore, the determination of the figures during the lag period at the time of the ADF screening follows the SBIC (Schwarz Bayesian Information Criterion). Since the estimation of the Euler equation follows GMM, the following two cases, which take two different lag periods for instrumental variables, are estimated to confirm the robustness of the estimation parameter for selecting the instrumental variable.[14)]

1: Takes one prior period of the explanatory variable and the constant terms as the instrumental variables.

2: Takes one and two prior periods of the explanatory variables and the constant terms as instrumental variables.

The estimation results by GMM for each estimation period are summarized in Tables 2 through 6. In each table, the NM column shows the NM model's estimation results and the CV1 through CV3 columns illustrate the CV model's estimation results. Each estimation result is displayed by the real earning assets rate (housing, equity, and government bonds) and the definitions of r1 through r3, as mentioned in Table 1. The "system" indicates the estimation results obtained when three Euler equations, which use three different earning assets rate from

13) In GMM, Ghysels and Hall(1990) have developed a Predictive Test that investigates unknown structural changes. It is conducted by investigating whether the parameters estimated for an estimation period can be similarly projected to other estimation periods. In this article we consider it preferable to reference the structural change point by this test before setting each estimation period. For more detail, see Kozuka(2006), in which structural changes in Japanese consumption behavior was investigated using the Predictive Test.

14) Tauchen (1986) declared that when the lag order of the instrumental variable in the GMM Estimation is short, it will bring about an asymptotic best, but when it is long, the estimated values tend to gather at a biased value. In this article, according to an earlier study, the constant term, each explanatory variable (consumption growth rate, assets earnings rate, and income uncertainty index growth rate) and the Period I and Period I / II lags are used as instrumental variables.

Table 2 estimation results (1987-1991)

	variable	instrumental variable lag order		NM	CV1	CV2	CV3
1987−1991 (N=59)	r1	1	β	0.990 ***	0.990 ***	0.982 ***	0.987 ***
			(S.E.)	(0.018)	(0.018)	(0.015)	(0.018)
			γ	**1.964**	**2.685**	**1.387**	**0.931**
			(S.E.)	(1.844)	(1.907)	(1.693)	(1.819)
			J−statistics	6.463	7.132	6.961	6.956
			(P−value)	(0.011)	(0.028)	(0.031)	(0.031)
			degree of freedom	1	2	2	2
		1・2	β	0.987 ***	0.990 ***	0.983 ***	0.984 ***
			(S.E.)	(0.016)	(0.013)	(0.014)	(0.016)
			γ	**0.176**	**0.449**	**0.002**	**−0.202**
			(S.E.)	(1.364)	(1.327)	(1.291)	(1.372)
			J−statistics	7.421	8.601	7.787	7.959
			(P−value)	(0.060)	(0.126)	(0.168)	(0.159)
			degree of freedom	3	5	5	5
	r2	1	β	1.003	1.000	1.000	1.003
			(S.E.)	(0.008)	(0.007)	(0.008)	(0.008)
			γ	**0.788**	**0.538**	**0.599**	**0.625**
			(S.E.)	(0.919)	(0.854)	(0.868)	(0.903)
			J−statistics	0.073	1.621	2.969	0.481
			(P−value)	(0.788)	(0.445)	(0.227)	(0.786)
			degree of freedom	1	2	2	2
		1・2	β	1.003	−	1.001	1.003
			(S.E.)	(0.007)	(−)	(0.007)	(0.007)
			γ	**0.222**	−	**0.023**	**0.307**
			(S.E.)	(0.594)	(−)	(0.585)	(0.589)
			J−statistics	1.334	−	4.283	3.564
			(P−value)	(0.721)	(−)	(0.509)	(0.614)
			degree of freedom	3	−	5	5
	r3	1	β	0.998 ***	0.997 ***	0.998 ***	0.998 ***
			(S.E.)	(0.001)	(0.001)	(0.001)	(0.001)
			γ	**0.191** **	**0.152** *	**0.236** ***	**0.197** **
			(S.E.)	(0.089)	(0.085)	(0.081)	(0.085)
			J−statistics	0.199	1.025	2.925	0.406
			(P−value)	(0.656)	(0.599)	(0.232)	(0.816)
			degree of freedom	1	2	2	2
		1・2	β	0.997 ***	0.997 ***	0.997 ***	0.997 ***
			(S.E.)	(0.001)	(0.001)	(0.001)	(0.001)
			γ	**0.198** **	**0.164** **	**0.214** ***	**0.201** ***
			(S.E.)	(0.076)	(0.072)	(0.074)	(0.066)
			J−statistics	6.684	7.786	7.083	7.305
			(P−value)	(0.083)	(0.168)	(0.215)	(0.199)
			degree of freedom	3	5	5	5
	system	1	β	0.998 ***	0.998 ***	0.997 ***	0.998 ***
			(S.E.)	(0.001)	(0.001)	(0.001)	(0.001)
			γ	**0.206** **	**0.170** **	**0.271** ***	**0.215** ***
			(S.E.)	(0.083)	(0.075)	(0.078)	(0.077)
			J−statistics	10.415	13.146	18.439	10.398
			(P−value)	(0.660)	(0.662)	(0.299)	(0.845)
			degree of freedom	13	16	16	16
		1・2	β	0.998 ***	−	0.997 ***	0.998 ***
			(S.E.)	(0.001)	(−)	(0.000)	(0.000)
			γ	**0.248** ***	−	**0.283** ***	**0.218** ***
			(S.E.)	(0.062)	(−)	(0.063)	(0.046)
			J−statistics	25.354	−	30.491	28.392
			(P−value)	(0.443)	(−)	(0.492)	(0.601)
			degree of freedom	25	−	31	31

(Note 1) ***, **, and * mean that each variable is significant at the 1%, 5%, and 10% siginificance levels.

Table 3 estimation results (1992-2000)

	variable	instrumental variable lag order		model NM	CV1	CV2	CV3
1992–2000 (N=107)	r1	1	β	1.011	1.011	1.009	1.014
			(S.E.)	(0.009)	(0.009)	(0.010)	(0.008)
			γ	**0.610**	**1.022**	**1.778**	**−0.295**
			(S.E.)	(1.599)	(1.580)	(1.512)	(1.333)
			J–statistics	0.025	0.461	1.935	1.421
			(P–value)	(0.873)	(0.794)	(0.380)	(0.491)
			degree of freedom	1	2	2	2
		1・2	β	1.011	1.013	1.009	1.011
			(S.E.)	(0.008)	(0.008)	(0.008)	(0.008)
			γ	**−0.129**	**0.459**	**1.118**	**−0.640**
			(S.E.)	(1.169)	(1.081)	(1.224)	(0.842)
			J–statistics	0.261	1.094	4.538	2.084
			(P–value)	(0.967)	(0.955)	(0.475)	(0.837)
			degree of freedom	3	5	5	5
	r2	1	β	1.000	1.000	1.001	0.998 ***
			(S.E.)	(0.006)	(0.006)	(0.005)	(0.005)
			γ	**0.982**	**1.389** *	**0.916**	**0.442**
			(S.E.)	(0.812)	(0.806)	(0.793)	(0.791)
			J–statistics	0.389	1.885	1.025	5.462
			(P–value)	(0.533)	(0.390)	(0.599)	(0.065)
			degree of freedom	1	2	2	2
		1・2	β	1.000	1.001	1.001	0.998 ***
			(S.E.)	(0.005)	(0.005)	(0.005)	(0.005)
			γ	**1.253**	**1.537** **	**1.225**	**0.822**
			(S.E.)	(0.774)	(0.774)	(0.764)	(0.695)
			J–statistics	1.703	4.154	2.996	8.660
			(P–value)	(0.636)	(0.528)	(0.701)	(0.123)
			degree of freedom	3	5	5	5
	r3	1	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.059**	**0.060**	**0.049**	**0.059**
			(S.E.)	(0.061)	(0.060)	(0.059)	(0.063)
			J–statistics	8.671	8.654	9.417	9.005
			(P–value)	(0.003)	(0.013)	(0.009)	(0.011)
			degree of freedom	1	2	2	2
		1・2	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.132** **	**0.121** **	**0.111** **	**0.114** **
			(S.E.)	(0.056)	(0.054)	(0.054)	(0.047)
			J–statistics	19.038	19.902	21.053	20.152
			(P–value)	(0.000)	(0.001)	(0.001)	(0.001)
			degree of freedom	3	5	5	5
	system	1	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.067**	**0.064**	**0.066**	**0.059**
			(S.E.)	(0.056)	(0.055)	(0.054)	(0.059)
			J–statistics	17.226	20.333	20.533	24.390
			(P–value)	(0.189)	(0.206)	(0.197)	(0.081)
			degree of freedom	13	16	16	16
		1・2	β	0.997 ***	0.997 ***	0.997 ***	0.997 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.162** ***	**0.146** ***	**0.158** ***	**0.135** ***
			(S.E.)	(0.048)	(0.046)	(0.046)	(0.041)
			J–statistics	35.689	42.116	38.682	43.803
			(P–value)	(0.076)	(0.088)	(0.162)	(0.063)
			degree of freedom	25	31	31	31

(Note 1) ***, **, and * mean that each variable is significant at the 1%, 5%, and 10% siginificance levels.

Table 4 estimation results (2001-2006)

	variable	instrumental variable lag order		model NM	CV1	CV2	CV3
2001–2006 (N=71)	r1	1	β	0.992 ***	0.992 ***	0.991 ***	0.993 ***
			(S.E.)	(0.011)	(0.011)	(0.011)	(0.011)
			γ	**−0.096**	**−0.167**	**−0.148**	**−0.152**
			(S.E.)	(1.730)	(1.661)	(1.716)	(1.729)
			J−statstics	1.194	1.219	2.032	2.003
			(P−value)	(0.275)	(0.544)	(0.362)	(0.367)
			degree of freedom	1	2	2	2
		1・2	β	0.992 ***	0.995 ***	0.991 ***	0.998 ***
			(S.E.)	(0.011)	(0.010)	(0.010)	(0.010)
			γ	**−0.044**	**−0.063**	**0.267**	**0.325**
			(S.E.)	(1.420)	(1.394)	(1.419)	(1.562)
			J−statistics	1.228	1.882	5.481	9.654
			(P−value)	(0.746)	(0.865)	(0.360)	(0.086)
			degree of freedom	3	5	5	5
	r2	1	β	0.993 ***	0.993 ***	0.993 ***	0.993 ***
			(S.E.)	(0.005)	(0.005)	(0.005)	(0.005)
			γ	**−0.633**	**−0.643**	**−0.700**	**−0.634**
			(S.E.)	(0.665)	(0.664)	(0.656)	(0.657)
			J−statstics	7.038	7.098	7.323	6.947
			(P−value)	(0.008)	(0.029)	(0.026)	(0.031)
			degree of freedom	1	2	2	2
		1・2	β	0.993 ***	0.992 ***	0.993 ***	0.992 ***
			(S.E.)	(0.005)	(0.006)	(0.000)	(0.005)
			γ	**−1.073**	**−1.038**	**−1.148**	**−1.089**
			(S.E.)	(0.588)	(0.558)	(0.000)	(0.553)
			J−statstics	8.324	8.418	8.723	8.274
			(P−value)	(0.040)	(0.135)	(0.121)	(0.142)
			degree of freedom	3	5	5	5
	r3	1	β	0.998 ***	0.998 ***	0.999 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**−0.081**	**−0.082**	**−0.072**	**−0.082**
			(S.E.)	(0.058)	(0.058)	(0.054)	(0.058)
			J−statstics	0.461	0.495	0.625	0.972
			(P−value)	(0.497)	(0.781)	(0.732)	(0.615)
			degree of freedom	1	2	2	2
		1・2	β	0.999 ***	0.999 ***	0.999 ***	0.999 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**−0.014**	**−0.006**	**0.006**	**−0.009**
			(S.E.)	(0.044)	(0.042)	(0.039)	(0.043)
			J−statstics	9.848	10.335	11.496	10.973
			(P−value)	(0.020)	(0.066)	(0.042)	(0.052)
			degree of freedom	3	5	5	5
	system	1	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**−0.086**	**−0.087**	**−0.085**	**−0.084**
			(S.E.)	(0.050)	(0.050)	(0.047)	(0.049)
			J−statstics	17.011	17.414	18.281	17.794
			(P−value)	(0.199)	(0.359)	(0.308)	(0.336)
			degree of freedom	13	16	16	16
		1・2	β	0.999 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.005**	**0.007**	**−0.008**	**0.008**
			(S.E.)	(0.030)	(0.027)	(0.029)	(0.029)
			J−statstics	29.483	30.949	36.017	37.395
			(P−value)	(0.244)	(0.469)	(0.245)	(0.199)
			degree of freedom	25	31	31	31

(Note 1) ***, **, and * mean that each variable is significant at the 1%, 5%, and 10% siginificance levels.

Table 5 estimation results (2007-2009)

	variable	instrumental variable lag order		model NM	CV1	CV2	CV3
2007–2009 (N=35)	r1	1	β	1.002	—	—	1.004
			(S.E.)	(0.016)	(—)	(—)	(0.017)
			γ	**2.437**	—	—	**2.599**
			(S.E.)	(2.335)	(—)	(—)	(2.101)
			J-statstics	0.602	—	—	2.390
			(P-value)	(0.438)	(—)	(—)	(0.303)
			degree of freedom	1	—	—	2
		1・2	β	1.001	—	—	0.995 ***
			(S.E.)	(0.019)	(—)	(—)	(0.017)
			γ	**5.164** *	—	—	**2.738** **
			(S.E.)	(2.666)	(—)	(—)	(1.200)
			J-statstics	3.856	—	—	6.437
			(P-value)	(0.277)	(—)	(—)	(0.266)
			degree of freedom	3	—	—	5
	r2	1	β	1.012	—	—	1.014
			(S.E.)	(0.010)	(—)	(—)	(0.010)
			γ	**−2.243**	—	—	**−1.309**
			(S.E.)	(1.425)	(—)	(—)	(1.359)
			J-statstics	0.972	—	—	2.318
			(P-value)	(0.324)	(—)	(—)	(0.314)
			degree of freedom	1	—	—	2
		1・2	β	1.012	—	—	1.012
			(S.E.)	(0.010)	(—)	(—)	(0.009)
			γ	**−2.606**	—	—	**−1.169**
			(S.E.)	(1.204)	(—)	(—)	(1.219)
			J-statstics	1.957	—	—	4.740
			(P-value)	(0.581)	(—)	(—)	(0.448)
			degree of freedom	3	—	—	5
	r3	1	β	0.999 ***	—	—	0.999 ***
			(S.E.)	(0.001)	(—)	(—)	(0.001)
			γ	**−0.079**	—	—	**−0.098**
			(S.E.)	(0.091)	(—)	(—)	(0.088)
			J-statstics	2.610	—	—	2.891
			(P-value)	(0.106)	(—)	(—)	(0.236)
			degree of freedom	1	—	—	2
		1・2	β	0.999 ***	—	—	0.999 ***
			(S.E.)	(0.001)	(—)	(—)	(0.001)
			γ	**−0.105**	—	—	**−0.111**
			(S.E.)	(0.096)	(—)	(—)	(0.086)
			J-statistics	3.806	—	—	4.032
			(P-value)	(0.283)	(—)	(—)	(0.545)
			degree of freedom	3	—	—	5
	system	1	β	0.999 ***	—	—	0.999 ***
			(S.E.)	(0.000)	(—)	(—)	(0.000)
			γ	**0.066** *	—	—	**0.050**
			(S.E.)	(0.038)	(—)	(—)	(0.035)
			J-statstics	14.230	—	—	15.469
			(P-value)	(0.358)	(—)	(—)	(0.491)
			degree of freedom	13	—	—	16
		1・2	β	0.999 ***	—	—	0.999 ***
			(S.E.)	(0.000)	(—)	(—)	(0.000)
			γ	**0.077** ***	—	—	**0.089** ***
			(S.E.)	(0.028)	(—)	(—)	(0.004)
			J-statstics	26.846	—	—	29.430
			(P-value)	(0.364)	(—)	(—)	(0.547)
			degree of freedom	25	—	—	31

(Note 1) ***, **, and * mean that each variable is significant at the 1%, 5%, and 10% siginificance levels.

Table 6 estimation results (1987-2009)

	variable	instrumental variable lag order		NM	CV1	CV2	CV3
1987–2009 (N=275)	r1	1	β	0.998 ***	0.999 ***	0.999 ***	0.999 ***
			(S.E.)	(0.006)	(0.006)	(0.006)	(0.006)
			γ	**0.544**	**0.702**	**0.691**	**0.262**
			(S.E.)	(0.900)	(0.886)	(0.852)	(0.893)
			J-statstics	8.077	8.936	8.764	10.184
			(P-value)	(0.004)	(0.011)	(0.013)	(0.006)
			degree of freedom	1	2	2	2
		1・2	β	0.997 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.006)	(0.006)	(0.006)	(0.006)
			γ	**0.398**	**0.612**	**0.714**	**0.107**
			(S.E.)	(0.805)	(0.784)	(0.763)	(0.797)
			J-statstics	8.756	10.451	10.780	12.022
			(P-value)	(0.033)	(0.063)	(0.056)	(0.034)
			degree of freedom	3	5	5	5
	r2	1	β	0.999 ***	0.999 ***	1.000	0.999 ***
			(S.E.)	(0.003)	(0.003)	(0.003)	(0.003)
			γ	**0.229**	**0.243**	**0.184**	**0.230**
			(S.E.)	(0.496)	(0.494)	(0.489)	(0.502)
			J-statstics	1.803	1.873	4.407	1.806
			(P-value)	(0.179)	(0.392)	(0.110)	(0.405)
			degree of freedom	1	2	2	2
		1・2	β	0.999 ***	0.999 ***	1.000	0.999 ***
			(S.E.)	(0.003)	(0.003)	(0.003)	(0.003)
			γ	**0.255**	**0.227**	**0.262**	**0.229**
			(S.E.)	(0.413)	(0.411)	(0.410)	(0.419)
			J-statstics	1.862	3.935	4.926	2.816
			(P-value)	(0.601)	(0.559)	(0.425)	(0.728)
			degree of freedom	3	5	5	5
	r3	1	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.076** *	**0.074** *	**0.074** *	**0.076** *
			(S.E.)	(0.040)	(0.040)	(0.039)	(0.040)
			J-statstics	5.682	5.866	5.788	5.862
			(P-value)	(0.017)	(0.053)	(0.055)	(0.053)
			degree of freedom	1	2	2	2
		1・2	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.074** **	**0.071** **	**0.071** *	**0.077** **
			(S.E.)	(0.037)	(0.036)	(0.036)	(0.036)
			J-statstics	28.529	28.745	29.525	28.479
			(P-value)	(0.000)	(0.000)	(0.000)	(0.000)
			degree of freedom	3	5	5	5
	system	1	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.083** **	**0.081** **	**0.081** **	**0.082** **
			(S.E.)	(0.038)	(0.038)	(0.038)	(0.039)
			J-statstics	16.890	18.576	20.227	19.163
			(P-value)	(0.204)	(0.291)	(0.210)	(0.260)
			degree of freedom	13	16	16	16
		1・2	β	0.998 ***	0.998 ***	0.998 ***	0.998 ***
			(S.E.)	(0.000)	(0.000)	(0.000)	(0.000)
			γ	**0.085** **	**0.084** **	**0.086** **	**0.088** ***
			(S.E.)	(0.035)	(0.034)	(0.034)	(0.034)
			J-statstics	42.565	47.169	47.323	46.962
			(P-value)	(0.016)	(0.032)	(0.031)	(0.033)
			degree of freedom	25	31	31	31

(Note 1) ***, **, and * mean that each variable is significant at the 1%, 5%, and 10% siginificance levels.

r1 to r3, are estimated under one common parameter. If an estimation result is not displayed, the cause is either that the explanatory variable does not fulfill stationarity, or the standard error and "t" value are not calculated accurately due to a singular matrix error.

To summarize the movement of each estimation period, the estimated results for each of the NM and CV models with the system case, which involve the largest volume of information, are summarized in Table 7 for each estimation period.[15] From the table, estimates of the subjective discount rates for both the NM and CV models range from 0.998 to 0.999, respectively, during the entire period and have remained rather stable. This result is in contrast to Nakagawa (1998) and Tobita (1998), who reported an increase in the subjective discount rate (reduced rate of time preference) after the burst of the economic bubble. Meanwhile, with respect to relative risk aversion, the estimated value in Period I before the bubble period lies between .227 to .231. This result is similar to Hamori (1992). While the estimated value in Period II—the post-bubble period—declines to approximately half that level, between 0.105 to 0.114, the value in Period III declines to a level of –0.041 and therefore it does not meet the sign condition of the model. After the decline, the estimated value of Period IV (2007–2009) is estimated to rise to the level between .070 and .071 again. The downward trend in relative risk aversion after the burst of the economic bubble is similarly reported in Nakagawa (1998) and Tobita (1998).[16] Moreover, at the bottom of Table 7, the ratio of the standard deviation of the real consumption growth rate to the standard deviation of the real rate of return on assets is reported with a value of 100, normalized by the years 1987–1991. According to this normalized ratio, the ratio of r1 (housing) decreases after increasing to 70 percent between Periods I and II, the ratio of r2 (stocks) decreases after rising 35 percent between Periods I and III, and the ratio of r3 (government bonds) decreases after rising 68 percent between Periods I and III. This indicates widespread variation in consumption that is not based on the permanent income hypothesis between Periods I, II, and III.

The decreasing tendency of relative risk aversion after the collapse of the bubble economy can be explained by Equation (4), which represents the utility loss of households under income uncertainty and the movement of the growth rate of the income uncertainty index. Furthermore, Equation (4) is represented by $\rho(C_t, h_t) = 0.5\gamma C_t^{1-\gamma}\left(h_t / C_t\right)^2$, where C_t is real consumption in period t and h_t is the standard deviation of the movement in the consumption level that occurs with the uncertainty of income. If there is no uncertainty in income, the substitution of $h_t = 0$ into Equation (4) always holds, $\rho(C_t, h_t) = 0$, regardless of the size of relative risk aversion γ, and therefore households can select any size of relative risk aversion γ necessary to reduce the variability of the intertemporal consumption, without incurring a utility loss. On the other hand, if there is uncertainty in income, by applying $h_t > 0$ to Equation (4),

15) In the case where the validity of a model is not supported by the P value of the J statistics value under a 5% significance level, it is excluded from the calculation of the average values.

16) Nakagawa (1998) reported values for relative risk aversion of 0.24 (November 1986–February 1991), 0.11 (February 1991– October 1993), and 0.09 (October 1993– March 1998), with an estimation using stocks and short-term interest rates (repurchase yield one month) as the rate of return on assets. The estimation results of this paper are very similar.

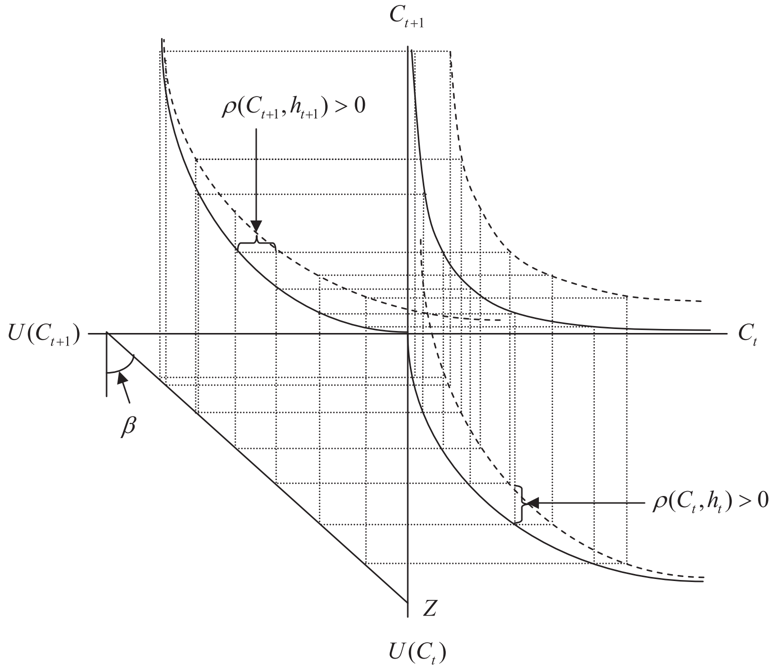

Figure 3 Rise of uncertainty and indifference curve (when $\gamma > 0$)

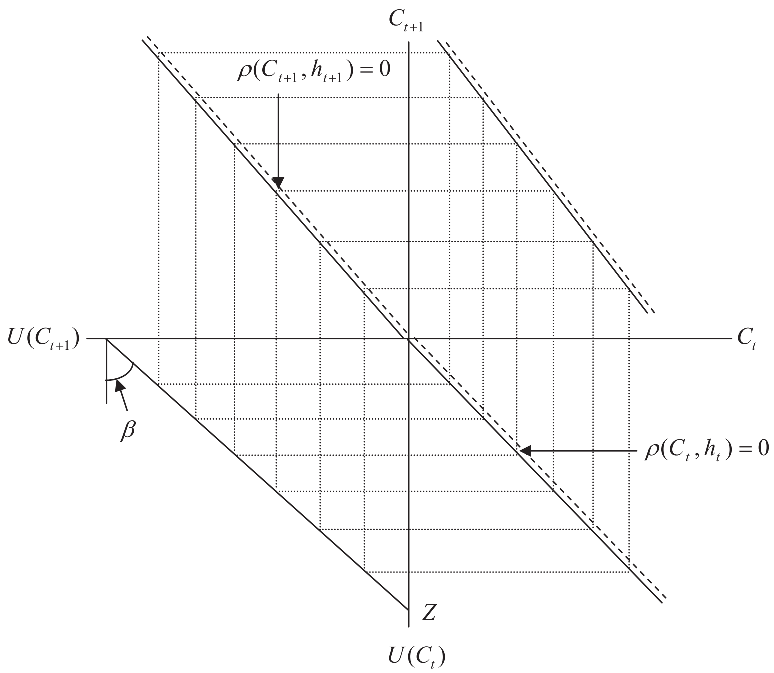

Figure 4 Rise of uncertainty and indifference curve (when $\gamma = 0$)

households suffers a utility loss of $\rho(C_t, h_t)(>0)$ proportional to the value of the square of the coefficient of variation (h_t / C_t) multiplied by relative risk aversion γ. The only way to reduce the utility loss to 0 is to decrease relative risk aversion γ to 0. In other words, this suggests that the behavior of risk aversion itself is constrained under income uncertainty.

Under Equation (12), Figures 3 and 4 show the indifference curve that binds the utility functions of the two periods (t and t + 1) under income uncertainty, of which the standard deviation of consumption in each period is identical. Figure 3 illustrates the case where the value of the relative risk aversion is positive and Figure 4 show the case where relative risk aversion is zero. In the first quadrant of Figure 3, the indifference curve that brings total utility Z during both the periods comes to be illustrated respectively at the position of the solid line, when there is no income uncertainty, and at the upper right position of the dotted line when the standard deviation of the consumption of each period h_t exists. This means that the sum of utilities derived from consumption during the two periods has been reduced under income uncertainty. In the case of positive values of relative risk aversion, households suffer a utility loss in compensation for maintaining risk a version. Meanwhile, the utility function under zero relative risk aversion becomes a linear utility function $U^*(C_t) = C_t$ through the substitution of γ = 0 into Equation (5). As such, a loss of utility does not occur, even if the standard deviation of consumption h_t exists. In the first quadrant of Figure 4, the indifference curve that brings about total utility Z during both the periods is shown as the position of the solid line when there is no income uncertainty and at the position of the dotted line when the standard deviation of the consumption of each period h_t exists. Both lines conform to each other, so households are no longer required to bear the burden of the utility loss.

According to the actual movements in the standard deviation of the growth rate of the income uncertainty index, the standard deviations of CV1 (coefficient of variation of income) and CV2 (reciprocal of jobs-to-applicants ratio) rise to about twice between Period I and Period II. The standard deviation of CV2 (reciprocal of jobs-to-applicants ratio) rises to about twice further between Period III and Period IV. Moreover, the standard deviation of CV3 (unemployment rate) rises continuously from Period I to Period IV. As the continuous rise in income uncertainty after Period II brings about a utility loss for households under the conventional level of relative risk aversion, households give priority to controlling the utility loss and become risk-neutral under income uncertainty, rather than controlling a change in the consumption of each term by risk aversion, and attain dynamic optimization. This is a major reason for the decline in relative risk aversion from Period II to Period III.

Period III, where relative risk aversion is estimated as a negative number, corresponds to zero-interest-rate policy period, when the Bank of Japan reduced the unsecured overnight call rate, and the index of the short-term yield up to 0.15%, after the IT bubble boom collapsed, and conducted quantitative monetary easing. The movement of each rate of return on assets for housing r1, equity r2, and government bonds r3 is a small rigid movement within the range of fluctuation, with the exception of equity. It is believed that this movement contributed to negative relative risk aversion, because it led to an unstable correlation between the real consumption growth rate by which the business trend is shown and the rate of return on assets,

Table 7 Estimation results for the NM model and CV model

			1987–1991	1992–2000	2001–2006	2007–2009	1987–2009
NM	β		0.998	0.998	0.998	0.999	0.998
		(S.E.)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
	γ		0.227	0.114	−0.041	0.071	0.083
		(S.E.)	(0.072)	(0.052)	(0.040)	(0.033)	(0.038)
	J−statistics		17.885	26.458	23.247	20.538	16.890
		(p−value)	(0.551)	(0.133)	(0.222)	(0.361)	(0.204)
CV	β		0.998	0.998	0.998	0.999	0.998
		(S.E.)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
	γ		0.231	0.105	−0.041	0.070	0.081
		(S.E.)	(0.068)	(0.050)	(0.038)	(0.020)	(0.038)
	J−statistics		20.173	31.643	26.308	22.449	19.322
		(p−value)	(0.580)	(0.133)	(0.319)	(0.519)	(0.254)
SD(gcp11)/SD(r1)			0.114	0.193	0.156	0.159	0.151
SD(gcp11)/SD(r2)			0.240	0.302	0.324	0.254	0.283
SD(gcp11)/SD(r3)			2.698	3.749	4.525	3.920	3.534
SD(gcp11)/SD(r1) [1987−1991=100](a)			100	170	137	140	133
SD(gcp11)/SD(r2) [1987−1991=100](b)			100	126	135	106	118
SD(gcp11)/SD(r3) [1987−1991=100](c)			100	139	168	145	131
(a)〜(c)average			100	145	147	130	127

particularly by the prolonged zero-interest-rate policy. In addition, it is believed that a large decrease in the expected rate of return of households' portfolio, which centers on safe assets, significantly reduced households' expectations for interest payments and receipts of dividends in the future. As such, they lost the advantageous feeling of attempting dynamic optimization in households' economic psychology.

3.3 Comparison of the estimation results for the NM and CV models

Next, we compare the estimation results for the NM and CV models, based on Table 7. The results illustrate that the subjective discount rate results do not differ between the NM and CV models. On the other hand, the results illustrate that the values of relative risk aversion and the estimation results for the CV model are larger in Period I and smaller in Periods II through IV, as well as during the entire period.

In addition, the estimated standard error of the CV model is smaller when excluding the entire Period.[17)]

However, the difference in relative risk aversion between the NM and CV models is very small in appearance. This means that the covariance between the rate of return on assets and the growth rate of the coefficient of variation of earnings is not sufficient to have an impact on the estimates of relative risk aversion in Japan. In other words, when considering the rate of return on assets as an index of business conditions, the income uncertainty recognized by households in Japan does not change as much in the aspects of the economy where business rises or descends. Therefore, it is suggested that the indifference curves in a multiperiod optimal consumption model is stable without significant changes in consumer preferences between the future and the present. It is believed that this is the main reason why an excellent

17) However, for Period II and the entire period, the t value of the NM model is slightly more favorable.

estimation result for CAPM has been obtained by the NM model in Japan. Thus, although various factors can be considered as reasons for why the income uncertainty recognized by households in Japan is not influenced much by business conditions, since the public pension system has been enhanced in Japan, the income uncertainty recognized by households is influenced more by institutional factors than business factors. As a result, it is believed that the weight of business factors is low compared with institutional factors.

Finally, we compare the results of a test on the over-identification restriction condition using the J statistics of the NM and CV models. Although the J statistic of the CV model exceeded that of the NM model in all the estimation periods shown in Table 7, since the number of the moment conditions corresponding to the number of lag terms increases when the growth rate of the income uncertainty index is added as an explanatory variable in the CV model, the degree of freedom of the χ^2 distribution that authorizes the J statistics value increases. Since the P value of the CV model calculated based on this condition exceeds that of the NM model for all the estimation periods, except Period II, it is confirmed that the validity of the CV model is higher than that of the NM model. Hence, the estimation result of relative risk aversion becomes more stable. This implies that the CV model can project more information on the estimation of a deep parameter than the NM model can. Therefore, the CV model has a greater effect in stabilizing estimation results

4. Conclusion

Up to the present time, precautionary savings and Euler equation estimates (C-CAPM) were discussed separately in consumption theory. The CV model integrates these estimates, thus enabling the estimation of relative risk aversion, and the consideration of a precautionary savings effect.

Estimation results of the Euler equation using the NM and CV models, based on monthly data from Japan, has clarified that the relative risk aversion of households decreased continuously from 1992 to 2006. They have also demonstrated the possibility that post-bubble Japan's continuous increase in income uncertainty prompted households to prioritize on constraining the utility loss of income uncertainty during the multiperiods, rather than acting on the dynamic optimization between different time periods by constraining the variation in consumption during each period through risk aversion, as in the definitional identity of the utility loss amount based on the uncertain utility function.

Comparing estimation results, we also demonstrated that the subjective discount rate has the same value in both the NM and CV models. As such, there is no major difference in the estimated values of the relative risk aversion coefficients. In addition, Japan's well-developed public pension scheme has reduced the covariance between the earning assets rate and the income fluctuation coefficient growth rate. We also found positive estimation results for consumption CAPM in Japan's NM model. According to the results of the model's adequacy evaluation, based on the Sargan conditions by the J statistic, the CV model was evaluated higher than the NM model throughout most of the estimation period. This result clarified that the CV model can contribute to the stability of the estimated results by reflecting as much information as possible on the parameter estimation.

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