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A THEORY OF HOUSEHOLD CONSUMPTION BEHAVIOR*

SHIGEO KURODA

I.

In case of planning over the life span, it is far most important for us to know the amount of assets which a consumer is to have both for his own consumption after retirement and for inheritance to his children.

From this point of view, our object is to derive this sum of consumption after retirement and inheritance.

We must in the first place make clear the frameworks for deriving the sum.

At the same time we have to present relations between specifications of utility function and portfolio selections for many sorts of assets, and prepare a model to combine micro-variables to macro-variables.

II.

First we see the simple case of maximizing consumer's utility under some constraints. We can usually define the following model based on a utility function consisting of the rate of consumption at every moment of time.

Consider a consumer unit and let \( T \) be its horizon [14].

\[
U = f(c_0, c_1, \ldots, c_T)
\]

The quantity \( U \), a real number, is the utility of the consumption plan \( c \).

Next, let \( c_t \) be consumption plan at time \( t \), \( y_t \) income at time \( t \), \( x_t \) saving holdings (net worth) at the end of time \( t \) and \( r_t \) interest rate. And for each time, we would have the following relation.

\[
c_t + x_t = (1 + r_{t-1}) x_{t-1} + y_t
\]

Then we extend (2) into the model including portfolio selection in every moment of time. If we assume that asset, \( x_t \), held at time \( t \) is distributed

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among many types of assets $x_{1t}, x_{2t}, \ldots, x_{mt}$, and each profit from types $r_{1t}$,
$r_{2t}, \ldots, r_{mt}$, (2) is changed in the following relation

$$c_{t} + x_{t} = \sum_{t=1}^{m} (1 + r_{t-1}) x_{t-1} + y_{t}, \quad t = 0 \ldots T$$

From the above assumption

$$x_{t} = x_{1t} + x_{2t} + \ldots x_{mt}$$

and if $U$ of (1) is maximized moving $x_{u}'$s when the special values of the
$x_{0}'$s or $x_{T}$ are given under constraints (3), (4), we could obtain the solutions
of $x_{u}'$s ($t=1, \ldots, T-1$).

But we cannot solve this by the Lagrange multiplier method. We, there­
fore, maximize mathematical expectation of utility [11, 16, 17], i.e.

$$EU = E\phi(c_{0}, c_{1}, \ldots, c_{T})$$

III.

It is important to know what $T$ is and how $x_{T}$ is to be determined. Then we assume the following assumptions;

Consumer unit refers to consumption plan over his life span. From
this point of view, $T$ and $x_{T}$ are the notions including viewpoint of con­
somer's life cycle. First we see $t$ as the time of consumer's life cycle
stages; $t=0$, present time (he is now at the age $\theta$), the time of retirement
equals $F-\theta$ (he retires at the age $F$), the time of death equals $G-\theta$ (dies
at the age $G$) [1, 2, 4, 5, 15].

Then we make a simple figure for these relations.
According to the budget constraint over the life span, it must be assumed that $x_{P-o}$, net worth at the time of retiring, equals the sum of consumption for his enjoying $G-F$ years after retirement and inheritance to his children [6, 7], so called the hump-saving [9].

Accordingly, it is very important for us to have $x_{P-o}$.

From this point, we examine some of the way of deriving $x_{P-o}$.

It is assumed that consumer receives utility only from present and prospective consumption, $c_t$ ($t=0, \cdots, G-\theta$) and from inheritance to his children, $h_{G-o}$. If we assume further that the price level of consumer goods is not expected to change appreciably over the balance of the life span, so that the volume of consumption is uniquely related to its value, than for a consumer at the age $\theta$, the utility function is given by

\[(6) \quad U = f(c_0, c_1, \cdots, c_{G-o}, h_{G-o})\]

And the hump-saving equals to (7).

\[(7) \quad x_{P-o} = \sum_{t=F+1}^{G-o} c_t + h_{G-o}\]

On the other hand, from (3), we have

\[(8) \quad c_t + x_t = \sum_{t=1}^{m} (1+r_{t,t-1}) x_{t-1} + y_t, \quad t=0, \cdots, F-\theta\]

Next we write the following form as a new utility function

\[(9) \quad U = f(c_0, \cdots, c_{P-o}, x_{P-o})\]

This function is a kind of modification of (6).

Now, in the present case it is reasonable to assume that (9) is of the form

\[(9)' \quad U = \sum_{t=0}^{P-o} \alpha_t g[c_t] + \varphi[x_{P-o}(G)]\]

Where $\alpha$ may be interpreted as a subjective discount function being a non-negative real valued function on the interval $[0, F-\theta]$ and having a continuous first derivative. $g$ is the utility associated with the rate of consumption at every moment of time and should be a concave real valued function and has two continuous derivatives the second of which is everywhere negative and the first everywhere non-negative. $\varphi$ is linear function defined on the entire real line and then, which implies that a positive $x_{P-o}(G)$ adds to utility while a negative $x_{P-o}(G)$ subtracts from utility [13, 19].

Here, we take account of the fact that he does not know how long he will live. Then $T$ is not a fixed number but a random variable with a known, probability distribution.

If (9)' is maximized under constraints (4), (7), (8), we can obtain the
values of the $x_d's$ and also, as we noted above ((5)), (9) must be written as

$$EU = Ef(c_0, \cdots, c_{p-\delta}, x_{p-\delta})$$

Then we can rewrite (9)' as

$$EU = E\left[\sum_{t=0}^{p-\delta} a_t g[c_t] + \varphi[x_{p-\delta}(G)]\right]$$

IV.

Let us assume that we find $x_{p-\delta}$ only in a model of certain macro-relationships, and this is equal to start the discussion along the lines of Meade's model [13].

He considers first the following notations;

- the rate of growth of the working population, $l$
- the rate of Harrod-neutral technical progress (i.e. of labor-expanding progress), $l'$
- the rate of growth of total output, of total consumption, of total savings, $1+1'$
- the rate of growth of output per head, of consumption per head, of the wage rate, $1'$
- the age of consumer unit, $\theta$
- time, $t$
- net worth which consumer holds at the age $\theta$, $X_\theta$
- the amount of property which consumer at the age $\theta$ will inherit to his children, $I_\theta$
- consumption of person at the age $\theta$, $C_\theta$
- the rate of wage of person at the age $\theta$, $W_\theta$
- the proportion of total national income saved, $S$
- the proportion of the national income going to profits, $R$
- the rate of interest, $i$

and if $I_\theta, C_\theta, W_\theta, X_\theta$ are written as (here, as a modification of Meade's discussion)

$$I_\theta = I e^{l(H+\frac{(1-r)(H-\theta)})}$$
$$C_\theta = C e^{l(H-\theta)} \sum_{t=0}^{\theta} e^{(s-1)t}\frac{e^{(s-1)t}}{t}$$
$$W_\theta = W \sum_{t=0}^{\theta} e^{(s-t)\theta}$$
$$X_\theta = I_\theta + C_\theta - W_\theta$$

(a budget constraint over the life span),

After all, he develops his model at the macroeconomic level in the following
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relations

(i) \[ K_0 = N e^{(\sigma + 1 - i)H} \sum_{\theta=0}^{P} e^{(\sigma - 1 - i)\theta} \]

+ \[ NC \sum_{\theta=0}^{P} \left( \sum_{t=0}^{P-\theta} e^{(\sigma - 1 - i)t} \right) e^{(\sigma - 1 - i)\theta} \]

- \[ NW \sum_{\theta=0}^{P} \left( \sum_{t=0}^{P-\theta} e^{(\sigma - 1 - i)t} \right) e^{\sigma\theta} \]

(ii) \[ \frac{iK_0}{WN \sum_{\theta=0}^{P} e^{-\theta}} = \frac{R}{1-R} \]

(iii) \[ \frac{C \sum_{\theta=0}^{P} e^{(\sigma - 1 - i)\theta}}{W \sum_{\theta=0}^{P} e^{-\theta}} = \frac{1-S}{1-R} \]

(iv) \[ W = W(i) \]

(v) \[ R = R(i) \]

(vi) \[ S = \frac{1+i}{i-i} R \]

(vii) Specification of I

Where the variables of his model are \( I, C, W, S, R, i, K_0 \) and the parameters, \( N, 1, 1', \sigma, F, G, H. \)

We can, therefore, find the equilibrium levels of all variables as the solution to a system of simultaneous equations. Finally, we must obtain the following results.

First, total assets at time \( F-\theta \) is given by

\[ K_{F-\theta} = K_0 + NW \sum_{\theta=0}^{P} \left( \sum_{t=0}^{P-\theta} e^{(\sigma - 1 - i)t} \right) e^{-\theta} \]

And the population at time \( F-\theta \) is defined

\[ \sum_{\theta=0}^{P} e^{(F-\theta) \sigma} N e^{-\theta} = \sum_{\theta=0}^{P} Ne^{(F-1-\theta)\theta} \]

\[ = N \sum_{\theta=0}^{P} e^{(F-\theta)\sigma} \]

We can thus establish that total assets at time \( F-\theta \) per head is

\[ x_{F-\theta} = K_{F-\theta} \left/ N \sum_{\theta=0}^{P} e^{(F-\theta)\sigma} \right. \]
Let us consider a specific example for our problems. We assume to specify (9)' as
\[ U = \sum_{t=0}^{\infty} \alpha_t \left( p - \frac{q}{c_t} \right) + \beta (aG + b) \]

This utility function satisfies the general assumptions of the economic theories, i.e.,
\[
\frac{\partial U}{\partial c_t} = \frac{\alpha_t q}{c_t^2} \geq 0 \\
\frac{\partial^2 U}{\partial c_t^2} = \frac{2\alpha_t q}{c_t^3} \leq 0 \\
\frac{\partial U}{\partial G} = a\beta > 0 \\
\frac{\partial^2 U}{\partial G^2} = 0
\]

And from (9)'

\[ EU = \sum_{t=1}^{\infty} \alpha_t (p - qE(c_t^{-1}) + \beta (aEG + b) \]

Here, we will use Taylor expansion on \( c_t^{-1} \) about \( Ec_t \).
\[ C^{-1} = (Ec_t)^{-1} - (c_t - Ec_t) (Ec_t)^{-2} - (c_t - Ec_t)^2 (Ec_t)^{-3} \]
\[ \approx (Ec_t)^{-1} - (c_t - Ec_t) (Ec_t)^{-2} - (c_t - Ec_t)^2 (Ec_t)^{-3} \]

As a result, we can obtain
\[ E(c_t^{-1}) = (Ec_t)^{-1} - E(c_t - Ec_t)^2 (Ec_t)^{-3} \]

On the other hand, consumption \( c_t \) at each time is from (8)
\[ c_t = y_t + \sum_{t=1}^{\infty} (1 + r_{t,t-1}) x_{t,t-1} - x_t \]

Then, if we assume the following [8]
\[ E y_t = \mu y_t \quad E r_{tt} = \mu_{tt} \]
\[ E (r_{tt} - E r_{tt}) (r_{tt} - E r_{tt}) = \sigma_{rt} \]
\[ E (y_t - \mu y_t)^2 = \sigma_{yt} \]
\[ E (y_t - \mu y_t) (r_{tt} - \mu_{tt}) = \sigma_{yt} \]

we have
\[ Ec_t = \sum_{t=1}^{\infty} (1 - \mu_{tt}) x_{t,t-1} + \mu_{yt} - x_t \]
(16) \[ E(c_t - E_c)^2 = \sum_{j=1}^{m} \sum_{i=1}^{n} \sigma_{ji} x_{t-i} x_{t-i-1} + 2 \sum_{i=1}^{m} \sigma_{yi} x_{t-i-1} + \sigma_{yt} \]

And if \( EG = \mu_g \), we have

(17) \[ E\varphi = \beta q \mu_g + b \beta \]

By substituting (15), (16), (17) into (13)', we can see

(18) \[ EU = \sum_{t=0}^{F-\theta} \alpha_t \left[ p - q \left( \sum_{i=1}^{m} (1 - \mu_{it}) x_{t-i-1} + \mu_{yt} - x_t \right) \right]^{-1} \]

\[ - \left( \sum_{j=1}^{m} \sum_{i=1}^{n} \sigma_{ji} x_{t-i-1} x_{j-t-1} + 2 \sum_{i=1}^{m} \sigma_{yi} x_{t-i-1} + \sigma_{yt} \right) \]

\[ \times \left( \sum_{t=1}^{m} (1 - \mu_{it}) x_{t-i-1} + \mu_{yt} - x_t \right)^2 \]

\[ + a \beta \mu_g + b \beta \]

Giving the expectations and variances-covariances of income \( y_t \) and rate of profit \( r_{it} \);

\[ \mu_t = \begin{pmatrix} \mu_{yt} \\ \mu_{1t} \\ \vdots \\ \mu_{mt} \end{pmatrix} \]

\[ V_t = \begin{pmatrix} \sigma_{yt} & \sigma_{yit} & \cdots & \sigma_{ymt} \\ \sigma_{1yt} & \sigma_{1yt} & \cdots & \sigma_{1mt} \\ \vdots & \vdots & \cdots & \vdots \\ \sigma_{m yt} & \sigma_{mt} & \cdots & \sigma_{mnt} \end{pmatrix} \]

And the expectation of \( G \); \( G \), \( x_0 \) or \( x_{F-\theta} \) under constraint

\[ x_t = \sum_{t=1}^{m} x_{it} \]

\[ x_{it} \geq 0 \quad i = 1 \cdots m \quad t = 0 \cdots (F-\theta-1) \]

we can determine the \( x_{it} (i=1 \cdots m, t=0 \cdots (F-\theta-1)) \) so that \( EU \) is maximized.

VI.

A whole class of the maximization problem, e.g. (18) has, in general as we pointed out before, severe difficulties for obtaining the solutions. We note, here, that dynamic programming approach (D.P.) has no procedural difficulties, i.e. D.P. may, computationally, be easier [3, 18]. And also the value of D.P. lies, in the insight it supplies concerning optimum strategies and how, in principle, they could be computed.

Now we assume that (18) can be reduced to the form

(19) \[ EU = \sum_{t=1}^{F-\theta} R_t (x_{1-t-1}, \ldots, x_{m-t-1}, x_t) \]
The manner in which (19) is obtained is as follows [10].

\[(20) \quad EU = R_1(x_{1,0}, \ldots, x_{m,0}, x_i) + R_2(x_{1,1}, \ldots, x_{m,1}, x_i) + \ldots + R_{p,0}(x_{1,p-1,0}, \ldots, x_{m,p-1,0}, x_{p,0}) \]

Where we assume that \(x_{p-1,0}\), hump-saving, has already been given by Meade’s macrorelationships. From (20), the sum of \(R_t\) over time \((s \to F-\theta)\) is given by

\[(21) \quad Z_s = \sum_{t=s}^{p-\theta} R_t(x_{1,t-1}, \ldots, x_{m,t-1}, x_t) \]

In this case, we can maximize \(Z_s\) on \(x_u\) \((i=1 \ldots m, t=s \ldots F-\theta)\) when the special value is given \(x_u\), especially, in case that \(R_t\) is a specific form.

Therefore, taking \(P_{s-1}(x_u)\) as the value of \(Z_s\) maximized, we have

\[(22) \quad P_{s-1}(x_u) = \max Z_s \]

And when \(s=F-\theta\), (22) is

\[(23) \quad P_{F-\theta-1}(x_{F-\theta}) = \max Z_{F-\theta} = \max R_{F-\theta}(x_{1,F-\theta-1}, \ldots, x_{m,F-\theta-1}, x_{F-\theta}) \]

Accordingly, we can easily obtain each value of \(x_i, p_{-1} \ldots, x_{m,F-\theta-1}\) so that \(R_{F-\theta}\) is maximized when \(x_{F-\theta}\) was given.

On the other hand, (22) is expanded in the following form.

\[(24) \quad P_{s-1}(x_u) = \max \max \ldots \max \left( \sum_{t=s}^{p-\theta} R_t(x_{1,t-1}, \ldots, x_{m,t-1}, x_t) \right)_{x_{s,0}=x_{s,0}, x_{s+1,0}=x_{s+1,0}, \ldots, x_{F-\theta-1,0}=x_{F-\theta-1,0}, x_{F-\theta,0}=x_{F-\theta,0}} = P_s(x_{s+1}) + \max \left\{ R_s(x_{1,s-1}, \ldots, x_{m,s-1}, x_s) \right\} \]

This function equals to “recurrence relation” in D.P.

Finally, we know the values of \(x_{u,i}\)’s so that \(R_i\) is maximized when \(x_i\) was given.

\[(25) \quad P_s(x_i) = P_1(x_u) + \max \left\{ R_s(x_{1,0}, \ldots, x_{m,0}, x_1) \right\} \]

References