Estimating Demand Elasticities in a Rapidly Aging Society —The Cases of Selected Fresh Fruits in Japan

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1. Introduction

It has been known for some time that the younger Japanese eat much less fresh fruit than the older generations (*White Paper*, 1995; *Declining Orange*, 2009). This difference — younger people consume perhaps 50 percent less than older people — is one of the more striking examples of age-related differences in food consumption. Japan's population structure has also undergone striking changes. For example, in 1980 the elderly (60~ years of age) accounted for 11% of the total household members covered by the government's *Family Income and Expenditure Surveys (FIES)*, whereas they accounted for more than 20% in 2000 and nearly 30% in 2010[*1] .

When individual consumption is known to vary by age and the population changes drastically in age structure over time, the demographic factors need to be introduced explicitly into demand estimation. If simple (or average) per capita consumption is used as a dependent variable in time-series econometric analyses, either price or income elasticity or both could be erroneously determined[*2].

If age-related variations in individual consumption are taken into account, we can still assume that all individuals, regardless of age, are uniformly subject to some economic influences, such as changes in income and prices. In this article, we try to compensate for the demographic variables in determining economic elasticities of demand for selected fresh fruits in Japan by applying the ordinary A/P/C cohort model, as was used by Mori et al. (Mori, ed., 2001), Mori and Saegusa (2010), and Mori and Stewart (2011).

Table 1 Vastly Differnet Individual Consumption by Age Groups in a Rapidly Aging Society, 1980 to 2010

A) Changes in Age Distribution of Population (%) B) Hypothetical Changes in Individual Consumption by Age Groups (kg/person)

age group	60~	40~59	20~39	0~19	total	60~	40~59	20~39	0~19	weighted averages
1980	11	24	30	35	100	10.00	10.00	5.09	3.00	6.05
1990	15	28	26	31	100	9.50	9.50	4.75	2.85	6.2
2000	22	28	25	25	100	9.00	9.00	4.50	2.70	6.3
2010	30	26	22	22	100	8.50	8.50	4.25	2.55	6.26

Sources: Rough estimates, calculated by the authors using *FIES* panel data, various years.

[*1] These figures represent the households covered by *FIES* but not necessarily total population. 60~ years old accounted for 30.13 % of total population in 2009 (Population Research, 2006).

[*2] Table 1B provides a constructed example that shows how complex the interaction between changes in demographic structures and demand preferences of various age groups can be. Overall average consumption of a hypothetical product increases, even though consumption by each of 4 age groups decreases, 1980~2010. The increasing proportion in the population of the age group exhibiting the highest consumption (here, the oldest age group) explains why this could happen.

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2. Framework of Cohort Model — Underlying Reasoning

Japan's government Bureau of Statistics started in 1979 to publish household purchases of various goods and services by age groups of household head (HH) in annual reports of the *Family Income and Expenditure Survey*. Table 2 provides changes in household purchases (= consumption) of fresh apples for home consumption (apples hereafter) by HH's age groups by 5 year intervals in age from 1979~1981 to 1999~2001 (3 years simply averaged) and 10 year intervals in age from 2005 to 2010. Table 2 conveys a general picture of changes in household apple consumption during the past three decades since 1980: the aggregate average household consumption of apples slightly increased in the 1980s and declined considerably after the mid 1990s; young households where HHs were under 40 years of age registered steady and drastic declines over the entire period in question, whereas old households where HHs were over 59 years of age increased consumption appreciably toward the mid 1990s and decreased somewhat in the late 1990s and the 2000s.

Every one ages up by one year, as time passes by one year. Those in their late 20s in 1980 were in their late 30s in 1990 and in their late 40s in 2000, in turn. They move in Table 2 from the cell, 4th row・2nd column in 1980 down to the cell, 8th row・6th column in 2000. Following per household consumption in the table diagonally, one may notice that on average (not to be repeated) the households where HHs were in their late 20s in 1980, cohorts born in 1951~55, increased their consumption moderately during the 1980s and reduced it slightly during the 1990s. Those households where HHs were in their late 30s in 1980, cohorts born in 1941~45, also gradually increased apple consumption to 1990 and reduced it marginally during the 1990s. It could be surmised that people tend to maintain their consumption at the level reached in their early adulthood as a core, so to speak, to be affected afterwards by their own aging and also by the outside conditions they face from time to time, such as changes in prices and income and other circumstances, including modernization in general dietary patterns, health consciousness, etc. (Tokoyama and Egaitsu, 1994).

We can speculate about reasons/underlying mechanisms for changes in apple consumption. For example, an increase of 2.42 kg from 19.52 for 50~54 year-olds in 1989~91 to 21.94 for 55~59 year-olds in 1994~96 may largely represent aging effect from one's early 50s to one's late 50s, with little influence from other (time) variables. A decrease of 1.76 kg from 14.56 for 40~44 year-olds in 1994~1996 to 12.80 for 45~49 year-olds in 1999~2001, may, on the contrary, represent declining time effect, i.e., a negative effect from prices, income, or other variables in the latter half of 1990s, with negligible aging effect from the early 40s to the late 40s. These intuitive assertions demonstrate some of the questions that can be answered by the objective tests presented in later sections.

Table 2 Changes in Household Consumption of Apples by HH Age Groups (kg/household)

	1979~81	1984~86	1989~91	1994~96	1999~001		2004~006	2009~010
Average	18.24	18.12	18.52	17.67	14.28	Average	12.90	13.17
under 25	7.55	6.09	5.08	5.32	2.03	under 30	3.61	3.17
25~29	12.74	10.35	7.24	5.60	3.49			
30~34	16.37	14.60	11.08	8.34	5.25	30~39	5.21	4.80
35~39	18.97	17.50	15.43	11.62	7.86			
40~44	19.43	20.27	18.46	14.56	10.41	40~49	8.55	7.56
45~49	19.78	19.91	20.60	17.87	12.80			
50~54	18.53	17.83	19.52	19.44	14.39	50~59	12.54	11.60
55~59	18.10	19.21	21.29	21.94	16.91			
60~64	18.61	19.28	20.83	22.81	18.69	60~69	17.98	18.02
over 64	19.73	19.61	22.47	23.07	20.36	over 69	19.83	20.96

Sources: *FIES*, various issues.

3. Deriving per capita Adult's Consumption by Age from Household Data

Consumption provided in Table 2 is measured in terms of household, the size of which varies by age groups in any given year and declined moderately overall during the 30 year period from 1980 to 2010. For example, the youngest age group, under 25 years old, averaged 2.73 in person per household, compared to 4.25 and 3.59 for the middle aged households where HHs were 40~44 and 50~54 years old, respectively in 1990. The total households covered by the *FIES* averaged 3.82 persons in 1980, 3.56 in 1990, 3.24 in 2000, and 3.09 in 2010, respectively. The data given in Table 2 should better be converted to per capita basis, at the least.

Deriving per capita data is straightforward: simply divide household consumption by the number of persons contained in the respective household. Table 3 corresponds to Table 2, with the household consumption converted to per capita data, based on the average size of the respective household. The ordinary households covered by the *FIES* comprise a household head and his/her spouse and their children, usually zero to three in number in present-day Japan. The household consumers are thus parents and children, who usually differ in age by 25~35 years.

Japan also surveys individual food consumption directly. Official surveys of food intakes by individuals, in place of households, started in 1995. A few researchers have obtained individual consumption by age[*3] from the *FIES* panel data, by means of "behaviour equations" approach (Prais, 1953), as used by Morishima (1984) and Ishibashi (1997; 2006; 2007)[*4].

However, Mori and Inaba (1997) proposed an alternative approach, using HH data (referred to below as macro data) from the *FIES* annual reports, to derive individual consumption by age of household members by means of equations which incorporate exact household age compositions by HH's age groups. Use of the HH data provides a longer time horizon (1979~2010) and richer product detail than can be obtained from the individual consumption surveys. Mori and Inaba's model was statistically fortified later by Tanaka, Mori and Inaba (2004). In this article, we will follow their lead to derive individual consumption by age from macro data, household consumption classified by the age groups of household head in the *FIES* annual reports.

Individual consumption of fresh apples by 5 year age intervals is estimated for every year from 1979 to 2010, using the Tanaka, Mori and Inaba model (TMI) and the estimates for the age groups of 15~19, 20~25 to 70~74, and 75 ~ years old[*5] are provided in Appendix Table 1 (the comparable data for fresh bananas in Appendix Table

Table 3 Changes in per capita Household Consumption of Apples by HH Age Groups (kg/person)

	1979~81	1984~86	1989~91	1994~96	1999~001		2004~006	2009~010
Average	4.78	4.89	5.17	5.18	4.33	Average	4.07	4.25
under 25	2.67	2.15	1.79	1.84	0.71			
25~29	3.80	3.18	2.32	1.88	1.17	under 30	1.17	1.04
30~34	4.17	3.79	2.97	2.39	1.55			
35~39	4.47	4.12	3.72	2.90	2.02	30~39	1.45	1.33
40~44	4.53	4.72	4.33	3.48	2.54			
45~49	4.92	4.88	5.17	4.52	3.21	40~49	2.19	1.99
50~54	5.16	4.98	5.44	5.51	4.00			
55~59	5.41	5.97	6.63	7.02	5.36	50~59	3.76	3.53
60~64	5.80	6.49	7.21	8.08	6.60	60~69	6.68	6.75
over 64	6.26	6.94	8.27	8.98	8.04	over 69	8.19	8.70

Sources: Calculated by the authors, using *FIES*, various issues.

2), respectively. For easier, visual comprehension, these general cohort tables, every 5 years in age × 32 years, are condensed to standard cohort tables, 5 years in age by 5 year intervals from 1979~81 to 2009~10 and shown in Table 4 for apples and Table 5 for bananas, respectively.

Table 4 Changes in Individual Consumption of Apples by Age, 1979~81 to 2009~10 (kg/year)

age	79~81	84~86	89~91	94~96	99~001	004~006	009~10
20~24	3.70	2.97	2.38	1.92	0.95	1.08	0.74
25~29	3.82	3.23	2.71	2.49	1.45	1.57	1.25
30~34	4.80	4.50	3.97	3.54	2.34	1.85	1.68
35~39	5.26	5.23	5.47	4.60	3.30	2.27	2.14
40~44	5.45	6.05	6.50	5.63	4.23	2.86	2.63
45~49	5.91	6.21	7.29	6.92	5.02	3.57	3.29
50~54	6.08	6.38	7.59	7.98	6.15	4.43	4.16
55~59	6.27	7.51	8.69	9.40	7.28	5.87	5.69
60~64	6.79	7.96	9.15	10.17	8.54	8.05	8.22
65~69	7.14	8.17	9.77	10.50	9.28	8.90	9.25
70~74	7.27	8.28	10.08	10.68	9.67	9.55	9.96

Source: Appendix Table 1.

Table 5 Changes in Individual Consumption of Bananas by Age, 1979~91 to 2009~10 (kg/year)

age	79~81	84~86	89~91	94~96	99~001	004~006	009~10
20~24	3.82	3.08	2.69	2.67	2.87	2.88	3.32
25~29	4.17	3.56	3.08	2.92	3.21	3.47	4.08
30~34	4.08	3.72	3.48	3.26	3.67	3.91	4.59
35~39	3.44	3.09	3.31	3.40	4.16	4.25	5.01
40~44	3.33	2.80	3.20	3.58	4.75	4.55	5.46
45~49	3.65	3.07	3.50	3.82	5.14	5.23	6.45
50~54	4.04	3.65	4.31	4.32	5.73	6.23	8.25
55~59	4.53	4.55	5.48	5.92	7.06	7.63	9.56
60~64	4.90	5.37	6.46	7.59	9.37	9.48	10.74
65~69	4.86	5.69	6.69	8.41	10.62	10.48	11.82
70~74	4.82	5.79	6.77	8.59	11.24	11.22	12.72

Source: Appendix Table 2.

*3 Japanese government's Ministry of Health and Welfare started to collect individual food intakes by age including young children in 1995, based on one day surveys in November every year. These *Nutrition Surveys* classify food intakes by broad categories, such as meats and fruit, including juices.

*4 It was until recently and can still be time-consuming and difficult (and impossible for researchers without the public assignments) to obtain access to the individual panel data (personal enquiry at Bureau of Statistics, September, 2011). Ishibashi would complain that it was not unusual to take six months or so after application to obtain the *FIES* panel data from Bureau of Statistics, even when she worked at the National Center for Agricultural Research until 2009 (Ishibashi, 1998−2007).

*5 Age groups by 5 year intervals from 0~4 to 75 ~ were covered in our analysis. However, estimates of four youngest groups, from 0~4 to 15~19 years of age have proved not quite stable and the oldest age group, over 74 years of age contains more than a single cohort in each cell. For these reasons, they are not covered by our cohort decompositions to follow.

4. Decomposing per capita Individual Consumption by Age into Age, Period and Cohort Effects

A typical cohort model in additive form is expressed as follows (Glenn, 1977),

$$Y_{ij} = B + A_i + P_j + C_k + \epsilon_{ij} \qquad (1)$$

where:

Y_{ij} : per capita consumption by individuals i years of age in time j
B : grand mean effect
A_i : age effect attributable to age i years old
P_j : period or time effect attributable to time j
C_k : cohort effect attributable to birth cohort k
ϵ_{ij} : random errors

To center the parameters, we set a re-parameterization (2) below:

$$\sum A_i = \sum P_j = \sum C_k = 0 \qquad (2)$$

Model (1) can be written in the conventional matrix form of a least-squares regression:

$$Y = Xb + \epsilon \qquad (3)$$

In order to avoid or overcome the "identification problem" inherent in the additive cohort model*6, conventionally "equality constraints" of any chosen parameters are commonly imposed, such as: $A_{42} = A_{47}$ (individuals of 42 years old on average have the equal age effect as ones of 47 years old), or $P_{1984} = P_{1985}$ (the year 1984 has the equal period effect as the year 1985), for example.

Rejecting "arbitrary choice" of identifying constraints, Nakamura introduced the "intuitively more natural" assumptions of zenshintekihenka (gradual changes of successive parameters) over the entire ranges of all three factors of age, period and cohort (Nakamura, 1982; Nakamura, 1986). Asano proposed, in the appendix to evaluation of Nakamura's Bayesian cohort model, a unique approach to overcome the identification difficulty, by means of the Moore-Penrose generalized inverse matrix (Asano, 2001), on a purely mathematical basis free from any parameter-related assumptions. Along a similar line of deductions, Yang et al. developed in a more comprehensive way a purely algebraic (and geometrical) model, the "intrinsic estimator" (IE) and compared their model with the conventional generalized model in a cohort analysis of U.S. female mortality rates over the period of 1960~64 to 1995~99 (Yang, Fu, and Land, 2004; Yang et al., 2008). Asano's proposal was applied by Tanaka to the actual rice and fresh fish consumption in Japan from 1979 to 2005 and produced results, similar to the parameters estimated both by Nakamura's Bayesian model (BE) and IE, conducted by Mori and Saegusa, on the same data set (Tanaka, et al., 2007) *7.

In this article, we will apply BE on two sets of data: general cohort tables of individual consumption of apples and bananas by age from 1979 to 2010 (Appendix Table 1 and Appendix Table 2). Based on the authors' experience, BE appears to perform better than IE on general cohort tables, whereas the opposite is the case with standard cohort tables, in which the number of period effects, the number of the years observed, is substantially smaller than age and cohort effects*8. The results of our cohort analyses on apples by BE are provided in Table 6. The corresponding results for bananas are provided in Table 7.

*6 The indices of the three effects, age (i years old), period (the survey year j) and birth years (k) are interdependent: $j = i + k$ (4). Therefore, the ordinary least square estimator of the matrix regression model (3) does not exist, due to the fact that the design matrix X is singular with one less than full column rank (See Mason and Fienberg, 1985 for the identification problem in cohort analysis).

*7 The subsequent investigations have revealed that almost identical results should be produced by both BE and IE on some types of products, either actual or simulated data but different, if not of substantial degree, parameter estimates would accrue on other types, which can not be foretold (Mori, Saegusa, and Kawaguchi, 2008; Mori, Kawaguchi, and Saegusa, 2009; Mori, Kawaguchi, and Saegusa, 2010; Mori and Stewart, 2011, etc.).

*8 When individual consumption is classified by 5 year intervals from 20~24 up to70~74 years of age over the period of 1980 to 2000, for example, the number of years is only 5, as compared to 11 age groups and 15 cohorts. Nakamura's basic assumption: "gradual changes between successive parameters" should not hold on the period parameters (Mori, Kawaguchi, and Saegusa, 2010).

5. Period Effects: Pure Time Effects with Age and Cohort Effects Accounted for

A) Pure Time Effects

For a first example to illustrate period effects, suppose that individuals in their late 40s (47 years old) in 1980 consumed on average (not to be repeated) 4.5 kg/person. They would consume 5.0 kg in 1985, *ceteris paribus*, if it is known a priori that the age effect for those in their early 50s (52 in years) is greater by 0.5 than that for the late 40s: $A_{52} - A_{47} = 0.5$. If they actually consumed 5.3 kg in 1985, the environmental influences, such as prices and/or income, might have worked positively to boost consumption by 0.3. On the contrary, if the actual

Table 6 Individual Apple Consumption Decomposed by Age, Period, and Cohort Effects: Bayesian Estimator Model

Grand Mean Effect= 1.444 (0.016) (in natural log)

Age Effects			Period Effects			Cohort Effects		
(age group)		(SD)	(year)		(SD)	(born in)		(SD)
20~24	−.067	(.047)	1979	−.314	(.039)	1905~09	.734	(.076)
25~29	−.075	(.048)	1980	−.213	(.037)	1910~14	.621	(.090)
30~34	−.011	(.049)	1981	−.222	(.037)	1915~19	.630	(.083)
35~39	−.007	(.052)	1982	−.193	(.037)	1920~24	.656	(.120)
40~44	−.040	(.057)	1983	−.115	(.037)	1925~29	.671	(.145)
45~49	−.076	(.060)	1984	−.122	(.036)	1930~34	.680	(.115)
50~54	−.071	(.057)	1985	−.149	(.037)	1935~39	.661	(.093)
55~59	−.009	(.052)	1986	−.111	(.037)	1940~44	.611	(.094)
60~64	.088	(.049)	1987	−.035	(.038)	1945~49	.562	(.105)
65~69	.116	(.048)	1988	.032	(.039)	1950~54	.423	(.123)
70~74	.132	(.047)	1989	.013	(.040)	1955~59	.206	(.093)
			1990	.023	(.041)	1960~64	−.005	(.094)
			1991	.055	(.042)	1965~69	−.299	(.097)
			1992	.037	(.042)	1970~74	−.590	(.100)
			1993	.120	(.042)	1975~79	−.891	(.094)
			1994	.134	(.042)	1980~84	−1.211	(.085)
			1995	.119	(.042)	1985~89	−1.473	(.077)
			1996	.129	(.042)	1990~	−1.986	(.085)
			1997	.075	(.042)			
			1998	.054	(.042)			
			1999	−.033	(.041)			
			2000	.022	(.040)			
			2001	.015	(.039)			
			2002	.111	(.038)			
			2003	.068	(.037)			
			2004	.002	(.037)			
			2005	.004	(.036)			
			2006	.062	(.037)			
			2007	.064	(.037)			
			2008	.095	(.037)			
			2009	.171	(.037)			
			2010	.102	(.039)			

Note: Figures in parentheses denote SD.

Table 7 Individual Banana Consumption Decomposed by Age, Period, and Cohort Effects: Bayesian Estimator Model

Grand Mean Effect= 1.435 (0.012) (in natural log)

Age Effects			Period Effects			Cohort Effects		
(age group)		(SD)	(year)		(SD)	(born in)		(SD)
20~24	−.162	(.062)	1979	−.108	(.042)	1905~09	−.196	(.094)
25~29	−.146	(.063)	1980	−.211	(.042)	1910~14	−.161	(.101)
30~34	−.166	(.065)	1981	−.239	(.042)	1915~19	−.007	(.103)
35~39	−.246	(.069)	1982	−.238	(.042)	1920~24	.107	(.114)
40~44	−.291	(.078)	1983	−.444	(.041)	1925~29	.213	(.124)
45~49	−.245	(.083)	1984	−.318	(.041)	1930~34	.284	(.121)
50~54	−.101	(.078)	1985	−.284	(.041)	1935~39	.282	(.119)
55~59	.114	(.069)	1986	−.188	(.042)	1940~44	.234	(.122)
60~64	.315	(.065)	1987	−.199	(.043)	1945~49	.193	(.125)
65~69	.422	(.063)	1988	−.202	(.045)	1950~54	.210	(.126)
70~74	.506	(.062)	1989	−.183	(.048)	1955~59	.243	(.122)
			1990	−.190	(.049)	1960~64	.203	(.121)
			1991	−.152	(.050)	1965~69	.062	(.121)
			1992	−.177	(.050)	1970~74	−.093	(.122)
			1993	−.043	(.051)	1975~79	−.224	(.115)
			1994	−.029	(.051)	1980~84	−.344	(.103)
			1995	−.084	(.051)	1985~89	−.442	(.097)
			1996	−.090	(.051)	1990~	−.566	(.096)
			1997	−.003	(.050)			
			1998	.004	(.050)			
			1999	.148	(.049)			
			2000	.225	(.048)			
			2001	.165	(.045)			
			2002	.134	(.043)			
			2003	.191	(.042)			
			2004	.250	(.041)			
			2005	.284	(.041)			
			2006	.287	(.041)			
			2007	.247	(.042)			
			2008	.422	(.042)			
			2009	.562	(.042)			
			2010	.461	(.042)			

Note: Figures in parentheses denote SD.

consumption stayed the same at 4.5 kg in 1985 as in 1980, then it can be inferred that the external circumstances prevailing in 1985 might have depressed consumption by 0.5.

For a second example, with regard to cohort effects, suppose that individuals in their late 50s, cohorts born in 1926~30, consumed 6.0 kg in 1985 and those in the same age group, cohorts born in 1931~34, 6.7 kg in 1990. If we can assume using side-evidence that cohort effects for these two groups should be very close: $C_{26\text{-}30} \fallingdotseq C_{31\text{-}35}$, then environmental influences, the period effect for 1990, P_{90}, should be greater by 0.7 than that for 1985, P_{85} : $P_{90} - P_{85} \simeq 0.7$.

Period effects provided in the second column of Tables 6 and 7 represent the pure time effects with age and cohort effects controlled over the period of 1979 to 2010, with the ordinary sum to zero constraints imposed on each factor. These "pure" time effects should involve various environmental influences on individual consumption prevailing in the respective time periods. These influences may include prices, income and possibly non-economic forces other than demographic variables, such as increased health-consciousness, the "PET-bottle culture", etc. (Mori et al., *Declining Orange*, 2009, p.16).

B) The Case of Apples As an Example

Following the elementary time-series econometric analysis of per capita consumption of a single food product, apples here, we first regress per capita household consumption(in kg), $capQ_j$ from 1979 to 2010 against real average paid prices[*9](yen per 100g), RP_j over the same period, as shown in equation (5) below.

$$\begin{aligned} \log(capQ_j) &= a + b\log(RP_j) + \epsilon_j \qquad (5) \\ &= 1.080 + 0.131\log(RP_j) \\ &\quad (1.62)\ \ (0.72) \qquad \text{Adj.}R^2 = -0.016 \end{aligned}$$

We then replace $\log(capQ_j)$ in equation (5) by (grand mean + period effect for the year j) from our cohort analysis provided in Table 6, which can be interpreted as "pure time effects" with demographic factors accounted for, as follows.

$$\begin{aligned} (GM + PE_j)^{*10} &= a + b\log(RP_j) + \epsilon_j \qquad (6) \\ &= 4.617 - 0.865\log(RP_j) \\ &\quad (6.93)\ \ (4.76) \qquad \text{Adj.}R^2 = 0.412 \end{aligned}$$

It appears apparent that the pure time effects derived from our cohort analysis should represent the realities more reasonably than the simple per capita consumption, in respect to price elasticity, which is normally expected to be negative in sign and not far below 1.0 in absolute value, except for the necessities like rice and fresh vegetables.

The *FIES* provides household purchases of various goods and services for 16/18 annual household income classes of approximately 8,000 households, excluding single person households, every year[*11]. Based on these cross-sectional data, we can readily estimate income elasticities of household consumption of selected products, as shown in equation (7) below. In doing so, we exclude both the top (approximately 10~15%) and lowest (approximately 10~15%) of households on the income scale from our investigations. We also adjust household income for household size, using "equivalence scales,"[*12] in recognition of the presence of economies of scale in overall household consumption (Ferreira et al., 1998; *OECD Project on Income Distribution*, 2009, etc.). Both income and consumption are converted into natural logs, so that the parameters estimated directly relate average elasticities.

$$\log(capQ_i) = a + b\log Y_i + \epsilon_i \qquad (7)$$

where:

$capQ_i$ = average per capita consumption of apples in kg by i^{th} household on income scale

Y_i = average household income of i^{th} household in million yen,adjusted by OECD-modified equivalence scales

ϵ_i = random errors

Our estimates of income elasticities for apple consumption are provided in Table 8.

The average income elasticities for household apple consumption shown in Table 8 suggest that household income influenced apple consumption positively to some extent for the first half of the survey period of 1979 to 2010 but, on the contrary, slightly negatively during the latter half of the period in question, when examined by the cross-section data. In fact, retired elderly people, most of whom belong to the lower income groups (however, not necessarily lower in terms of living expenditures) have come to account for an increasingly larger share of the total *FIES* population. Steadily decreasing income elasticities of demand for fresh apples in the above cross-sections might partly reflect the positive age and cohort effects of the older population as shown in Table 6[*13].

*9 As shown in Fig. 1, the average prices paid by households are very closely related in the movement to CPI for apples.

*10 Estimated in natural log.

*11 The data are not carried in the *FIES* annual reports after 1979 and only available from microfiche films or CDs at the Library of Bureau of Statistics.

*12 Various measures have been put forth, of which we employ "OECD-modified scales" for overall consumption. Since food is regarded as "entirely private good" (Deaton and Paxson, 1998, p. 899), we use simple per capita consumption for our dependent variables.

*13 For further elucidations, refer to Mori et al., "Age-free Income Elasticities of Demand" (2006).

Table 8 Estimates of Average Income Elasticities of Household Apple Consumption from *FIES* Cross-Sectional Data, Selected Years: 1979, 1985, 1990, 1995, 2000, 2005, and 2010

Year	a: intercept	b: average elasticity	Adjusted R^2
1979	1.34 (45.7)	0.21 (4.35)	0.666
1985	1.21 (22.2)	0.36 (6.26)	0.793
1990	1.28 (14.3)	0.32 (4.00)	0.577
1995	1.50 (10.8)	0.08 (0.69)	−0.050
2000	1.81 (11.8)	−0.29 (2.29)	0.261
2005	1.92 (12.9)	−0.50 (3.91)	0.565
2010	2.05 (13.1)	−0.65 (4.88)	0.675

Note: numbers in parentheses denote t-values.
Model: $\log(capQ_i) = a + b \log Y_i + \epsilon_i$
where:
$capQ_i$ = average per capita consumption of apples in kg by i^{th} household on income scale
Y_i = average household income of i^{th} household in million yen, adjusted by OECD-modified equivalence scales

We will regress per capita household consumption, $capQ_j$ from 1979 to 2010 against real average household living expenditures (in 1,000 yen per month) adjusted by OECD-modified equivalence scales, REX_j, as a proxy for household well-being or income, over the same period of time, as shown in equation (8) below[*14].

$$\begin{aligned} \log(capQ_j) &= a + b\log(REX_j) + \epsilon_j \qquad (8)\\ &= \underset{(0.21)}{0.0364} + \underset{(0.69)}{0.236}\log(REX_j) \qquad \text{Adj.}R^2 = -0.017 \end{aligned}$$

We then replace $\log(capQ_j)$ in equation (8) by (grand mean + period effects) from our cohort analysis provided in Table 6, as was done in equation (6) above.

$$\begin{aligned} (GM + PE_j) &= a + b\log(REX_j) + \epsilon_j \qquad (9)\\ &= \underset{(7.01)}{-8.971} + \underset{(8.15)}{2.037}\log(REX_j) \qquad \text{Adj.}R^2 = 0.678 \end{aligned}$$

Time series analysis of simple per capita data (equation 8) led to a conclusion that household consumption of apples was not significantly income responsive. As observed above, cross-section analyses of nearly 8,000 households each year over the thirty year period of 1979 to 2010 suggest that household incomes might have played a significant role in determining household consumption of apples, positively in the first half of the survey period and somewhat negatively in the latest decade. When the period effects derived from our cohort analysis are regressed against household living expenditures per equivalence scale (equation 9), we obtained an extremely high positive elasticity, with good statistics, both in terms of t-value and R^2, which needs further scrutiny.

*14 The average size of households covered by the *FIES* declined steadily from 3.83 persons per household in 1979 to 3.08 in 2010, approximately by 20%. This may need to be taken into account to measure changes in the household well-being. Due to conceivable economies of scale in overall consumption, the nominal size of the household should be adjusted by "equivalence scales", which registered an 11% decrease, from 2.049 to 1.824 over the same period ("OECD-modified" scales).

Fig. 1 Apple Prices: Comparison of Real *FIES* Paid Prices and Real CPI

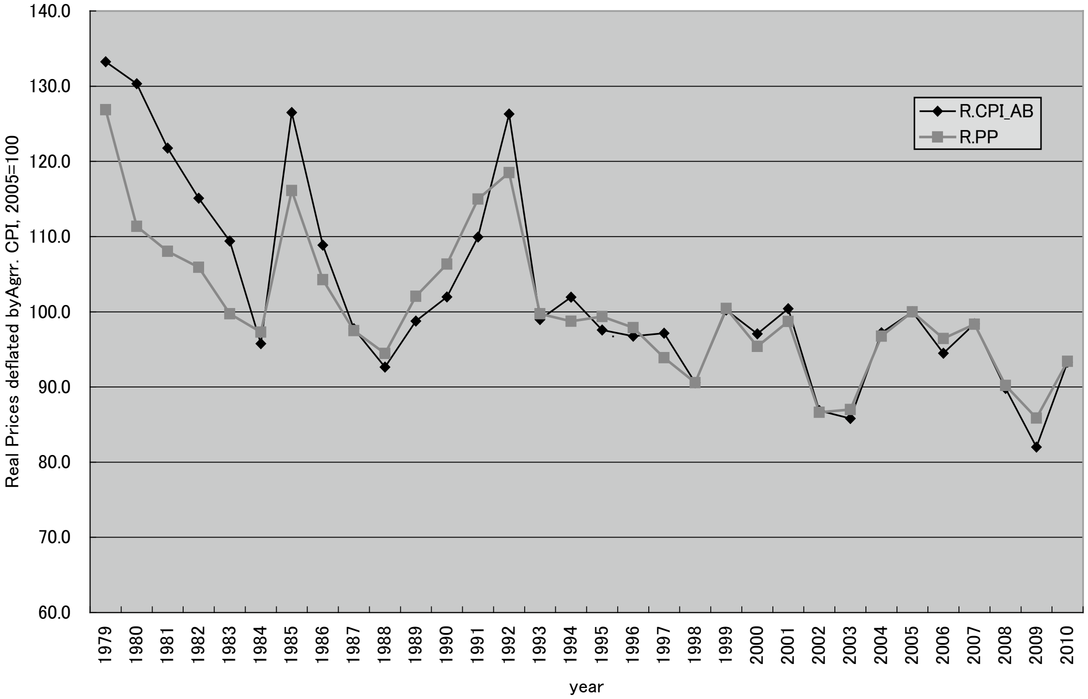

Fig. 2 Banana Prices: Comparison of Real *FIES* Paid Prices and Real CPI

6. Determining More Realistic Demand Elasticities

A) The Case of Apples

First, simple per capita consumption is regressed against real average paid prices and real household living expenditures, adjusted by the “equivalence scales” over the period of 1979 to 2010. Estimated price and income elasticities are given below in equation (10).

$$\begin{aligned} \log(capQ_j) &= a + b\log(RP_j) + c\log(REX_j) \\ &\quad + \epsilon_j \qquad (10) \\ &= -0.818 + 0.184\log(RP_j) + 0.335\log(REX_j) \\ &\quad\ (0.39)\quad (0.96) \qquad\qquad (0.94) \qquad\qquad \text{Adj.}R^2 = -0.019 \end{aligned}$$

The multiple regression, including both price and income, has produced no better results than equations (5) and (8), where simple per capita data were also used.

As already tried in equations(6) and (9), we will then regress (grand mean + period effects) estimated in natural log against the same set of independent variables in the above equation over the same period, the result of which is provided in equation (11) below.

$$\begin{aligned} (GM + PE_j) &= a + b\log(RP_j) + c\log(REX_j) + \epsilon_j \qquad (11) \\ &= -5.077 - 0.597\log(RP_j) + 1.713\log(REX_j) \\ &\quad\ (5.08)\quad (6.65) \qquad\qquad (10.24) \qquad\qquad \text{Adj.}R^2 = 0.868 \end{aligned}$$

Judging from the signs of both price and income parameters and the accompanying statistics, t-values and adjusted R^2, the data appear to fit the model very well. However, in view of our estimates of income elasticities obtained from the annual cross-section data from 1979 to 2010 (Table 8), which declined from +0.2~3 to −0.5 over time, average income elasticity of 1.7 appears too high, although the positive sign may be reasonable. If so, the price elasticity, −0.597 needs to be scrutinized accordingly.

Equation (11) can be rewritten as shown below in equation (12).

$$(GM + PE_j) - c\log(REX_j) = a + b\log(RP_j) + \epsilon_j \qquad (12)$$

The question here is that c is unknown in the left hand side of equation (12). If we arbitrarily assign 0.10 uniformly[*15] to c for the entire period of 1979 to 2010, we will have an estimate of average price elasticity as presented in equation (13) below.

c = 0.10:

$$\begin{aligned} (GM + PE_j) - \underline{0.10}\log(REX_j) &= 4.01 - 0.85\log(RP_j) \qquad (13) \\ &\quad\ (6.37)\ (4.90) \qquad \text{Adj.}R^2 = 0.426 \end{aligned}$$

We will then increase c gradually as follows,

c = 0.50:

$$\begin{aligned} (GM + PE_j) - \underline{0.50}\log(REX_j) &= 1.79 - 0.79\log(RP_j) \qquad (14) \\ &\quad\ (3.44)\ (5.55) \qquad \text{Adj.}R^2 = 0.490 \end{aligned}$$

c = 1.0:

$$\begin{aligned} (GM + PE_j) - \underline{1.0}\log(REX_j) &= -1.04 - 0.71\log(RP_j) \qquad (15) \\ &\quad\ (2.63)\ (6.57) \qquad \text{Adj.}R^2 = 0.577 \end{aligned}$$

c = 1.50:

$$(GM + PE_j) - \underline{1.50}\,\log(REX_j) = -3.87 - 0.63\,\log(RP_j) \qquad (16)$$

$$(12.14)\ (7.26) \qquad \text{Adj.}R^2 = 0.625$$

c = 1.7:

$$(GM + PE_j) - \underline{1.70}\,\log(REX_j) = -4.15 - 0.62\,\log(RP_j) \qquad (17)$$

$$(13.18)\ (7.25) \qquad \text{Adj.}R^2 = 0.624$$

By the test of sheer statistics, the data appears to fit the model slightly better, as we assign the larger income elasticities to the model up to 1.50. However, we are not ready to accept that the income elasticity of household demand for fresh apples should be as large as 1.5, judging from our estimates obtained from cross-sectional analyses of the *FIES* data classified by household income groups from 1979 to 2010, as presented in equation (7) and summarized in Table 8. Surprisingly, the price elasticity determined in the experiments above stays around −0.7, regardless of the values assigned to c (average income elasticity) ranging from 0.1 to 1.70. It may be safe to surmise that the average price elasticity of household demand for fresh apples should be around −0.7, with the income elasticity left in open question.

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*15 It is suspected with sound economic reasons that the average income elasticities, or the elasticities at the median income should have declined slightly over the some 30 year period of 1979 to 2010.

B) The Case of Bananas

We first regress per capita household (banana) consumption (in kg), $capQ_j$ from 1979 to 2010 against real average paid prices (yen per 100g), RP_j over the same period, as follows,

$$\log(capQ_j) = a + b\,\log(RP_j) + \epsilon_j \qquad (18)$$

$$= 4.675 - 1.010\,\log(RP_j)$$

$$(5.13)\quad (3.49) \qquad \text{Adj. } R^2 = 0.264$$

We then replace $\log(capQ_j)$ in equation (18) by $(GM + PE_j)$ from our cohort analysis provided in Table 7.

$$(GM + PE_j) = a + b\,\log(RP_j) + \epsilon_j \qquad (19)$$

$$= 4.495 - 0.974\,\log(RP_j)$$

$$(4.50)\quad (3.07) \qquad \text{Adj.}R^2 = 0.214$$

Quite unlike the case of apples observed in the previous sub-section, both simple per capita data and period effects derived from our cohort analysis have produced similar results, in terms of price elasticity, around unity, with significant t-values and fair adj. R^2.

We next move to the estimation of income elasticities. As in the case of apples, real household living expenditures (in 1,000 yen per month), adjusted by equivalence scales, are used here.

$$\log(capQ_j) = a + b\,\log(REX_j) + \epsilon_j \qquad (20)$$

$$= -5.227 + 1.324\,\log(REX_j)$$

$$(1.21)\quad (1.55) \qquad \text{Adj.}R^2 = 0.044$$

We then replace $\log(capQ_j)$ in equation (20) by $(GM + PE_j)$ from our cohort analysis provided in Table 7, as was done just above.

$$(GM + PE_j) = a + b\,\log(REX_j) + \epsilon_j \qquad (21)$$

$$= -4.982 + 1.262\,\log(REX_j)$$

$$(1.08)\quad (1.39) \qquad \text{Adj.}R^2 = 0.029$$

As we have seen in the case of price elasticities for bananas above, both simple per capita data and period effects, supposedly free from demographic factors, have produced similar estimates of income elasticities, positively as high as 1.3, with very poor statistical indicators in both cases. We will examine the plausibility of these figures by analyzing the cross-sectional data from the *FIES*, as we did before with apples.

$$\log(\mathrm{capQ}_i) = a + b\log Y_i + \epsilon_i \qquad (22)$$

where:

capQ$_i$ = average per capita consumption of bananas in kg by ith household on income scale

Y$_i$ = average household income of ith household in million yen, adjusted by OECD-modified equivalence scales

ϵ_i = random errors

The results are provided in Table 9.

Table 9 Estimates of Average Income Elasticities of Household Banana Consumption from *FIES* Cross-Sectional Data, Selected Years: 1979, 1985, 1990, 1995, 2000, 2005, and 2010

Year	a: intercept	b: average elasticity	Adjusted R^2
1979	1.46 (84.9)	−0.05 (1.74)	0.183
1985	1.28 (25.9)	−0.08 (1.61)	0.138
1990	1.38 (34.3)	−0.10 (2.81)	0.385
1995	1.67 (20.52)	−0.23 (3.45)	0.498
2000	2.16 (19.5)	−0.36 (3.92)	0.545
2005	1.71 (16.6)	−0.51 (5.83)	0.750
2010	1.86 (14.3)	−0.48 (4.31)	0.615

Note: numbers in parentheses denote t-values.

Model: $\log(\mathrm{capQ}_i) = a + b\log Y_i + \epsilon_i$

where:

capQ$_i$ = average per capita consumption of bananas in kg by ith household on income scale

Y$_i$ = average household income of ith household in million yen, adjusted by OECD-modified equivalence scales

Judging from the estimates of income elasticities obtained from the cross-sectional data of nearly 8,000 households each year from 1979 to 2010, fresh bananas for household consumption appear to be slightly income negative, in the neighborhood of −0.3~0.4 but by no means as large as +1.3, as determined in equations (20) and (21) above.

We will then repeat the same procedure as taken in the case of apples in equations (10) and (11) and then go over the statistical experiments, or simulation, the same as equations (13) through (17).

$$\begin{aligned} \log(\mathrm{capQ}_j) &= a + b\log(\mathrm{RP}_j) + c\log(\mathrm{REX}_j) + \epsilon_j \qquad (23) \\ &= \underset{(1.40)}{8.237} - \underset{(3.03)}{1.162}\log(\mathrm{RP}_j) - \underset{(0.61)}{0.607}\log(\mathrm{REX}_j) \qquad \mathrm{Adj.R^2} = 0.249 \end{aligned}$$

When a simple per capita consumption is used, the multiple regression has produced no better results than equation (20), in respect to income parameter. We will then replace capQ$_j$ by the period effects derived from our cohort analysis in Table 7.

$$\begin{aligned} (\mathrm{GM} + \mathrm{PE}_j) &= a + b\log(\mathrm{RP}_j) + c\log(\mathrm{REX}_j) + \epsilon_t \qquad (24) \\ &= \underset{(1.25)}{8.07} - \underset{(2.68)}{1.127}\log(\mathrm{RP}_j) - \underset{(0.56)}{0.610}\log(\mathrm{REX}_j) \qquad \mathrm{Adj.R^2} = 0.195 \end{aligned}$$

The data used, the period effects derived from our cohort analysis, do not appear to fit the model better than a simple per capita consumption, in equation (23). Both are almost identical in respect to parameter estimates, i.e., −1.1, significantly different from zero for price elasticity and −0.6, not significantly different from zero for income elasticity. We are thus to conclude that income may have played no important role in changes in household consumption of bananas over the period from 1979 to 2010. For the sake of safety, or curiosity in casual expression, we repeat the same experimental procedure, undertaken with apples in the previous sub-section (A).

Equation (24) can be rewritten as shown below in equation (25)

$$(GM + PE_j) - c \log(REX_j) = a + b \log(RP_j) + \epsilon_j \qquad (25)$$

The question here is again that c is unknown in the left hand side of equation (25). If we arbitrarily assign 0.00 uniformly to c for the entire period of 1979 to 2010, we will have an estimate of average price elasticity as presented in equation (26) below.

$c = 0.00$:

$$(GM + PE_j) - \underline{0.00} \log(REX_j) = 4.49 - 0.97 \log(RP_j) \qquad (26)$$
$$(4.50) \quad (3.07) \qquad \text{Adj.}R^2 = 0.214$$

We will then increase c in negative value gradually as follows,

$c = -0.10$:

$$(GM + PE_j) \underline{+0.1} \log(REX_j) = 5.08 - 1.00 \log(RP_j) \qquad (27)$$
$$(5.10) \quad (3.15) \qquad \text{Adj.}R^2 = 0.224$$

$c = -0.50$:

$$(GM + PE_j) \underline{+0.50} \log(REX_j) = 7.43 - 1.10 \log(RP_j) \qquad (28)$$
$$(7.48) \quad (3.48) \qquad \text{Adj.}R^2 = 0.264$$

$c = -1.0$:

$$(GM + PE_j) \underline{+1.0} \log(REX_j) = 10.36 - 1.22 \log(RP_j) \qquad (29)$$
$$(10.42) \quad (3.87) \qquad \text{Adj.}R^2 = 0.311$$

$c = -2.0$:

$$(GM + PE_j) \underline{+2.0} \log(REX_j) = 16.23 - 1.47 \log(RP_j) \qquad (30)$$
$$(15.91) \quad (4.54 \qquad \text{Adj.}R^2 = 0.388$$

As we assigned the negatively higher values to c from 0 to −2.0, we obtained better statistical fits. On the other hand, as we assign the higher positive values to c from 0 to 0.1, the statistical fits tend to be the poorer, as shown below.

$c = 0.1$:

$$(GM + PE_j) - \underline{0.1} \log(REX_j) = 3.91 - 0.95 \log(RP_j) \qquad (31)$$
$$(3.91) \quad (2.98) \qquad \text{Adj.}R^2 = 0.203$$

From the stand point of sheer statistics, it may appear that the income elasticity of household banana consumption should be over 2.0 in negative value, in the realm of highly inferior goods. Bananas are so inexpensive in Japan (a bunch of 4~5 pieces retailed for a US dollar or two) that even the poor can afford to purchase them. As the household income advances, consumers will buy more strawberries, musk melons, the more expensive fruits. The income elasticity for fresh fruit as a whole is found quite high, nearly 1.5 (Mori and Stewart, 2011, p.165). As household income increases, Japanese consumers will buy more fruit, including strawberries and musk melons, perhaps not at the appreciable sacrifice of bananas. We are not ready to accept that bananas are so much "inferior" in consumption. Our intuition seems to be supported by the cross-sectional analysis of 8,000 households, each year covered by the *FIES* from 1979 to 2010, as demonstrated by Table 9. The price elasticity should be taken around unity, regardless of the values assigned to income elasticity.

7. Summary and Discussion

The influences of discernible demographic variables, age and/or cohort effects, need to be accounted for when present in individual consumption, by some way or another, to conduct reasonable time-series econometric analyses of demand. Tachibana and Ueji (2004a; 2004b) introduced time variables, intercept-shifting as well as slope-shifting, in their analyses of household demand for various food products, in recognition of the steady changes in age structure of Japanese households, with substantial improvements in model fit. Possible impacts of population aging, however, involve both aging in a narrow sense and generational replacements, combinations of which might exert compound, nonlinear influences on aggregate future consumption. Denton, Mountain and Spencer (1999) introduced more sophisticated, dummy variables, "age/ cohort effects," "trend/cohort effects" and "additional cohort effects" in explaining changes in Canadian expenditure patterns. As Mori and Stewart pointed out, these dummy variables are of little use in forecasting future changes in demand[*16] (Mori and Stewart, 2011, p.166).

[*16] No one is certain if the past trend will continue into the future (Mori and Stewart, 2011, pp.169-170).

The future age structure of population, in respect of both age in a narrow sense and birth cohorts, is predicted with certainty (National Institute of Population, 2006). Once age and cohort effects are identified in individual consumption of selected products, and elasticities of economic variables are determined to be free from the demographic variables, it would be feasible to predict future consumption under different scenarios: if the economy grows annually at 2%, for example, and the price declines by say 20%, to the year 2020.

We have attempted to estimate the price and income elasticities of household consumption for fresh apples and fresh bananas, based on the *FIES* macro data, from 1979 to 2010. We first derived individual consumption by adult age groups from data classified by age of household head (HH), which was decomposed into age, time (survey years) and cohort effects. In lieu of simple per capita data, we regressed period effects against real average paid prices and real household expenditures, as proxies for income, from 1979 to 2010.

We obtained the price elasticity around −0.8 and the income elasticity significantly larger than +1.0 for fresh apples, and the price elasticity around unity and the income elasticity significantly under −2.0 for fresh bananas, respectively. Judging from the cross-sectional data of approximately 8,000 households each year from 1979 to 2010, apples can not be regarded so much income positive and on the other hand, bananas can not be regarded so inferior in household demand. We applied a sort of simulation, by assigning various degrees of income elasticity, experimentally ranging from 0.10 to 1.7, to apple consumption, with the accruing price elasticities remaining around −0.8 for apples. We repeated the same procedures, assigning 0.1 to −2.0 as experimental income elasticities for bananas, with the price elasticities virtually intact around unity.

Our estimated income elasticity for apples of as large as 1.7 (equation (11)) and that for bananas as low as −2.0 (equation (30)) remain doubtful. Regardless of the values of income elasticity, however, it appears reasonable to assume that the price elasticity for fresh apples and bananas should be around unity.

In the Technical Supplement which follows, we will attempt to introduce prices and household income into the traditional cohort model, equation (1), or "augment the cohort model" with these economic variables, after the fashion of Stewart and Blisard (2008) and Yakushiji (2010). The tentative conclusions obtained from our new ventures appear to support the statements in the above paragraphs, in regard to economic demand elasticities.

Technical Supplement —
An Attempt to Augment the Traditional A/P/C Model with Economic Variables

A) Introduction

In the previous sections of the text, we followed a two-step approach. First, we derived individual consumption (by age) of apples and bananas from the macro data — household data classified by the age groups of household head in the *FIES* annual reports — every year from 1979 to 2010.We then decomposed it by age, period and cohort effects, using the Nakamura's Bayesian cohort model. We next regressed the period effects so obtained against prices and household income (adjusted for household size), to determine own price and income elasticities of the respective products. In this supplement, we demonstrate a one-step approach, introducing the economic variables, prices and income directly into the traditional A/P/C model. We simply add first one variable, prices and then two variables, prices and income, to the existing cohort model, following the lead of Stewart and Blisard (2008)[*17].

[*17] It may require a in-depth statistical re-examination, or a complete reshuffle of the estimation structure, to augment the A/P/C cohort model with additional variables. Statistically more rigorous models, with each effect separated into a "linear component" and a "curvature component" (Yanagimoto and Yanagimoto, 1987) are under consideration, to be put forth shortly.

B) Tentative Results from a One-Step Approach

We add two economic variables, real prices paid and real household expenditures adjusted by equivalence scales in natural logs, as follows.

$$Z_1(j)=\log(RP_j),\ Z_2(j)=\log(REX_j)$$

$$\log Y_{ij}=\mu+Z_1(j)\beta+Z_2(j)\eta+A(i)+\overline{P(j)}+X_c(i,j)C+\epsilon_{ij} \qquad (32)$$

where Y_{ij} represents individual consumption by adult i years old in the year j from Appendix Tables1-2; μ corresponds to B, A(i) to A_i, and $X_c(i,j)C$ to C_k, respectively in equation(1) in the text, whereas $\overline{P(j)}$ represents time effects other than influences from price and income changes over the period in question.

In solving equation (32), the ordinary effects, age, time and cohort, are subject to Nakamura's assumption of "gradual changes between successive parameters". The results are provided in Sup-Tables 1 and 2 below.

As shown in Sup-Table 1, ABIC decreases appreciably when price is added to the model, with the price elasticity for apples estimated at −0.73. When income is added on top of A/P/C and the price variable, ABIC decreases even further, with the price and income elasticities estimated at −0.74 and 1.68, respectively, both significantly different from zero.

As shown in Sup-Table 2, in the case of bananas, ABIC decreases appreciably when price is added to the model, with the price elasticity for bananas estimated at −0.49. with a reasonable t-value. When income is added on top of A/P/C and the price variable, ABIC decreases a little further, with the price and income elasticities estimated at −0.49, significantly different from zero and −1.11, not significantly different from zero, respectively.

Sup-Table 1 Estimates of Price and Income Elasticities by the One-Step Approach: Apples

	(a)	(b)	(c)
μ	1.444 (.016)	4.133 (.499)	−4.401 (2.618)
β		−0.733 (0.136)	−0.736 (0.117)
η			1.682 (0.514)
ABIC	677.7	654.7	645.8

Notes: 1. (a) stands for A/P/C model, as used in the text, (b) A/P/C model with price variable and (c) A/P/C model with price and income variables; 2. figures in parentheses denote standard errors.

Sup-Table 2 Estimates of Price and Income Elasticities by the One-Step Approach: Bananas

	(a)	(b)	(c)
μ	1.435 (.012)	2.973 (.500)	8.618 (5.868)
β		−0.490 (0.159)	−0.493 (0.159)
η			−1.108 (1.148)
ABIC	468.7	458.9	455.3

Notes: 1. (a) stands for A/P/C model, as used in the text, (b) A/P/C model with price variable and (c) A/P/C model with price and income variables; 2. figures in parentheses denote standard errors.

C) Comparison of Cohort Parameters Estimated by Different Models and Implications

In solving equation (1), the additive A/P/C cohort model, by means of the Nakamura's Bayesian estimator, substantially varying estimates are produced by different combinations[*18] of hyper-parameters assigned to the assumption of "gradual changes between successive parameters"(Asano, 2001; Mori, Saegusa, and Kawaguchi, 2008; etc.). It is also conceivable that different estimates of cohort parameters should accrue, when other variables, price and income, are added to the model, as in equation (32).

Cohort parameters estimated by three different models are provided in Sup-Table 3 for apples and Sup-Table 4 for bananas, respectively. As expected, both age and cohort effects estimated by our new models, incorporating the economic variables (the third and fourth columns of (a) and (c) of Sup-Tables 3 and 4) have proved very little different from those estimated by the traditional cohort model, as shown in Table 6 for apples and Table 7 for bananas[*19]. This might imply that adding the economic variables, price and income, to the A/P/C model should not alter both age and cohort effects in overall structure, which could justify our two-step approach in

Sup-Table 3 Comparisons of Cohort Parameters for Apples by Different Models

a) Age Effects (in natural log)

Age Group	A/P/C	A/P/C+Price	A/P/C+Price +Income
20~24	−.067 (.047)	−.074 (.046)	−.056 (.042)
25~29	−.075 (.048)	−.081 (.046)	−.065 (.043)
30~34	−.011 (.049)	−.015 (.047)	−.004 (.044)
35~39	−.007 (.052)	−.010 (.050)	−.002 (.046)
40~44	−.040 (.057)	−.042 (.055)	−.038 (.051)
45~49	−.076 (.060)	−.076 (.058)	−.075 (.054)
50~54	−.071 (.057)	−.069 (.055)	−.072 (.051)
55~59	−.009 (.052)	−.012 (.050)	−.005 (.046)
60~64	.088 (.049)	.093 (.047)	.081 (.044)
65~69	.116 (.048)	.122 (.046)	.107 (.043)
70~74	.132 (.047)	.140 (.046)	.121 (.043)
ABIC	677.7	654.7	645.8

Note: figures in parentheses denote SD.

c) Cohort Effects (in natural log)

Cohorts (bornin)	A/P/C	A/P/C+Price	A/P/C+Price +Income
1905~09	.734 (.076)	.733 (.074)	.763 (.070)
1910~14	.621 (.090)	.608 (.087)	.640 (.084)
1915~19	.630 (.083)	.618 (.080)	.645 (.076)
1920~24	.656 (.120)	.647 (.118)	.668 (.115)
1925~29	.671 (.145)	.665 (.142)	.682 (.140)
1930~34	.680 (.115)	.674 (.112)	.686 (.108)
1935~39	.661 (.093)	.656 (.089)	.664 (.084)
1940~44	.611 (.094)	.608 (.090)	.613 (.084)
1945~49	.562 (.105)	.561 (.102)	.561 (.096)
1950~54	.423 (.123)	.423 (.120)	.420 (.116)
1955~59	.206 (.093)	.208 (.089)	.201 (.083)
1960~64	−.005 (.094)	−.001 (.090)	−.011 (.084)
1965~69	−.299 (.097)	−.294 (.094)	−.308 (.088)
1970~74	−.590 (.100)	−.583 (.097)	−.602 (.091)
1975~79	−.891 (.094)	−.884 (.091)	−.905 (.085)
1980~84	−1.211 (.085)	−1.203 (.082)	−1.228 (.077)
1985~89	−1.473 (.077)	−1.462 (.074)	−1.489 (.070)
1990~	−1.986 (.085)	−1.975 (.082)	-2.001 (.079)

Note: figures in parentheses denote SD.

b) Period Effects (in natural log)

Year	A/P/C	A/P/C+Price	A/P/C+Price +Income
1979	−.314 (.039)	−.149 (.036)	.000 (.044)
1980	−.213 (.037)	−.128 (.034)	.012 (.041)
1981	−.222 (.037)	−.151 (.037)	−.007 (.043)
1982	−.193 (.037)	−.143 (.035)	−.021 (.044)
1983	−.115 (.037)	−.111 (.034)	−.014 (.045)
1984	−.122 (.036)	−.110 (.033)	−.023 (.043)
1985	−.149 (.037)	−.075 (.033)	−.010 (.042)
1986	−.111 (.037)	−.071 (.034)	−.018 (.042)
1987	−.035 (.038)	−.040 (.035)	−.017 (.041)
1988	.032 (.039)	.004 (.037)	−.013 (.041)
1989	.013 (.040)	.032 (.038)	−.008 (.041)
1990	.023 (.041)	.075 (.039)	.009 (.041)
1991	.055 (.042)	.134 (.040)	.036 (.041)
1992	.037 (.042)	.134 (.039)	.031 (.040)
1993	.120 (.042)	.134 (.039)	.030 (.039)
1994	.134 (.042)	.127 (.039)	.028 (.037)
1995	.119 (.042)	.110 (.039)	.017 (.036)
1996	.129 (.042)	.097 (.040)	−.001 (.036)
1997	.075 (.042)	.036 (.041)	−.042 (.036)
1998	.054 (.042)	.000 (.039)	−.058 (.035)
1999	−.033 (.041)	−.033 (.038)	−.069 (.034)
2000	.022 (.040)	−.012 (.037)	−.047 (.033)
2001	.015 (.039)	−.010 (.036)	−.031 (.032)
2002	.111 (.038)	.009 (.035)	−.013 (.032)
2003	.068 (.037)	−.018 (.034)	−.022 (.032)
2004	.002 (.037)	−.025 (.033)	−.025 (.033)
2005	.004 (.036)	−.005 (.033)	−.004 (.035)
2006	.062 (.037)	.028 (.034)	.033 (.038)
2007	.064 (.037)	.034 (.036)	.044 (.039)
2008	.095 (.037)	.028 (.036)	.055 (.040)
2009	.171 (.037)	.060 (.035)	.080 (.042)
2010	.102 (.039)	.041 (.038)	.068 (.045)
$\sum$ (|Pj|)[*1]	3.014	2.164	0.886

Note:*1 Sum of period effects in absolute values; figures in parentheses denote SD.

the text, i.e., first try to estimate age, time and cohort effects and then regress time effects against the economic variables. Actually, both price and income elasticities determined in the foregoing text are not substantially different from those obtained by the one-step approach in this supplement.

*18 The best combination is sought according to the principle of ABIC minimization (Mori, et al., 2001, 321-324).
*19 Reproduced in the second column, (a) and (c) of Sup-Tables 3 and 4, respectively.

As conceptually clear from equation (32), however, the period effects from the new models should vary from those from the ordinary A/P/C model, reproduced in the second column of (b), Sup-Tables 3 and 4, respectively. What interests us is how they differ. The period effects, provided in the third and fourth columns, respectively of (b), Sup-Tables 3 - 4, exhibit the time effects in individual consumption, with the influences from economic variables accounted for. Visually inspected, time effects appear to have shrunk in absolute magnitude over the entire period from 1979 to 2010. Particularly in the case of apples, variations in time effects have shrunk appreciably when the price variable is added and they have become almost flat along the X axis, when the income

Sup-Table 4 Comparisons of Cohort Parameters for Bananas by Different Models

a) Age Effects (in natural log)

Age Group	A/P/C	A/P/C+Price	A/P/C+Price +Income
20~24	-.162 (.062)	-.169 (.061)	-.179 (.061)
25~29	-.146 (.063)	-.151 (.062)	-.159 (.062)
30~34	-.166 (.065)	-.170 (.064)	-.176 (.064)
35~39	-.246 (.069)	-.249 (.068)	-.253 (.068)
40~44	-.291 (.078)	-.292 (.077)	-.294 (.077)
45~49	-.245 (.083)	-.245 (.082)	-.245 (.082)
50~54	-.101 (.078)	-.100 (.077)	-.098 (.077)
55~59	.114 (.069)	.116 (.068)	.120 (.068)
60~64	.315 (.065)	.319 (.064)	.325 (.064)
65~69	.422 (.063)	.427 (.062)	.435 (.062)
70~74	.506 (.062)	.513 (.061)	.522 (.061)
ABIC	468.7	458.9	455.3

Note: figures in parentheses denote SD.

c) Cohort Effects (in natural log)

Cohorts (bornin)	A/P/C	A/P/C+Price	A/P/C+Price +Income
1905~09	-.196 (.094)	-.206 (.093)	-.220 (.093)
1910~14	-.161 (.101)	-.172 (.100)	-.186 (.100)
1915~19	-.007 (.103)	-.016 (.102)	-.029 (.102)
1920~24	.107 (.114)	.100 (.113)	.089 (.113)
1925~29	.213 (.124)	.206 (.122)	.197 (.122)
1930~34	.284 (.121)	.279 (.119)	.272 (.119)
1935~39	.282 (.119)	.278 (.118)	.273 (.118)
1940~44	.234 (.122)	.232 (.120)	.229 (.121)
1945~49	.193 (.125)	.192 (.124)	.191 (.124)
1950~54	.210 (.126)	.211 (.124)	.212 (.124)
1955~59	.243 (.122)	.245 (.120)	.248 (.120)
1960~64	.203 (.121)	.207 (.120)	.211 (.120)
1965~69	.062 (.121)	.067 (.119)	.074 (.119)
1970~74	-.093 (.122)	-.087 (.120)	-.078 (.121)
1975~79	-.224 (.115)	-.216 (.114)	-.206 (.114)
1980~84	-.344 (.103)	-.335 (.102)	-.322 (.102)
1985~89	-.442 (.097)	-.431 (.096)	-.417 (.096)
1990~	-.566 (.096)	-.554 (.095)	-.538 (.095)

Note: figures in parentheses denote SD.

b) Period Effects (in natural log)

Year	A/P/C	A/P/C+Price	A/P/C+Price +Income
1979	-.108 (.042)	-.065 (.053)	-.164 (.092)
1980	-.211 (.042)	-.147 (.048)	-.248 (.076)
1981	-.239 (.042)	-.159 (.050)	-.261 (.083)
1982	-.238 (.042)	-.191 (.049)	-.267 (.092)
1983	-.444 (.041)	-.311 (.055)	-.376 (.101)
1984	-.318 (.041)	-.236 (.045)	-.290 (.093)
1985	-.284 (.041)	-.167 (.050)	-.215 (.089)
1986	-.188 (.042)	-.146 (.042)	-.183 (.083)
1987	-.199 (.043)	-.206 (.043)	-.224 (.078)
1988	-.202 (.045)	-.190 (.053)	-.173 (.084)
1989	-.183 (.048)	-.159 (.056)	-.130 (.077)
1990	-.190 (.049)	-.156 (.050)	-.110 (.078)
1991	-.152 (.050)	-.117 (.051)	-.056 (.073)
1992	-.177 (.050)	-.140 (.050)	-.068 (.075)
1993	-.043 (.051)	-.114 (.051)	-.045 (.074)
1994	-.029 (.051)	-.152 (.051)	-.091 (.059)
1995	-.084 (.051)	-.196 (.056)	-.140 (.061)
1996	-.090 (.051)	-.161 (.056)	-.096 (.059)
1997	-.003 (.050)	-.053 (.056)	-.006 (.059)
1998	.004 (.050)	.002 (.049)	.044 (.055)
1999	.148 (.049)	.132 (.049)	.162 (.052)
2000	.225 (.048)	.155 (.047)	.181 (.047)
2001	.165 (.045)	.091 (.045)	.100 (.045)
2002	.134 (.043)	.133 (.043)	.145 (.044)
2003	.191 (.042)	.183 (.041)	.185 (.045)
2004	.250 (.041)	.229 (.042)	.238 (.056)
2005	.284 (.041)	.239 (.040)	.245 (.056)
2006	.287 (.041)	.238 (.041)	.229 (.069)
2007	.247 (.042)	.242 (.042)	.239 (.067)
2008	.422 (.042)	.437 (.042)	.418 (.065)
2009	.562 (.042)	.554 (.042)	.533 (.076)
2010	.461 (.042)	.431 (.045)	.415 (.084)
$\sum (\lvert P_j \rvert)$[*1]	6.762	6.132	6.277

Note:*1 Sum of period effects in absolute values; figures in parentheses denote SD.

variable is further added, as demonstrated by Sup-Fig. 1. In the case of bananas, on the contrary, the variations appear to have become even a little wider, when the income variable is added on top of the price variable, as shown by Sup-Fig. 2. Actually, the sum of period effects in absolute values for the entire period from 1979 to 2010 decreased from 3.014 to 2.164 and 0.886, as one and two economic variables were added to the model, in the case of apples. In the case of bananas, however, the sum decreased from 6.762 to 6.132 but increased to 6.277, in turn (bottom row, b) of Sup-Tables 3 and 4.

It appears statistically solid to conclude that income may not have exercised meaningful impacts on changes in individual consumption of bananas over the period of 1979~2010, whereas individual consumption of apples may have been affected positively by income to a great extent, with the average elasticity estimated at 1.7. In respect to the impact of prices, the price elasticity of apples is estimated at −0.73~74, very close to the one reached in the preceding text by the two-step approach and that for bananas at −0.49, considerably smaller than the one reached there.

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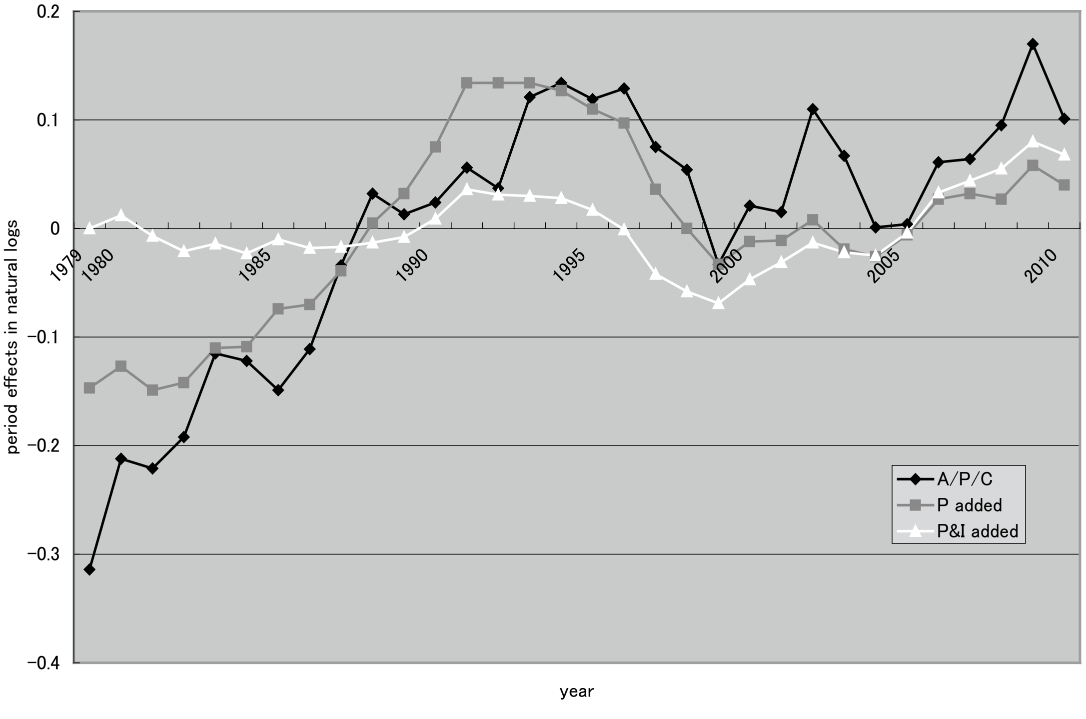
Sup-Fig. 1 Period effects estimated by differnet models for apple consumption, 1979 to 2010



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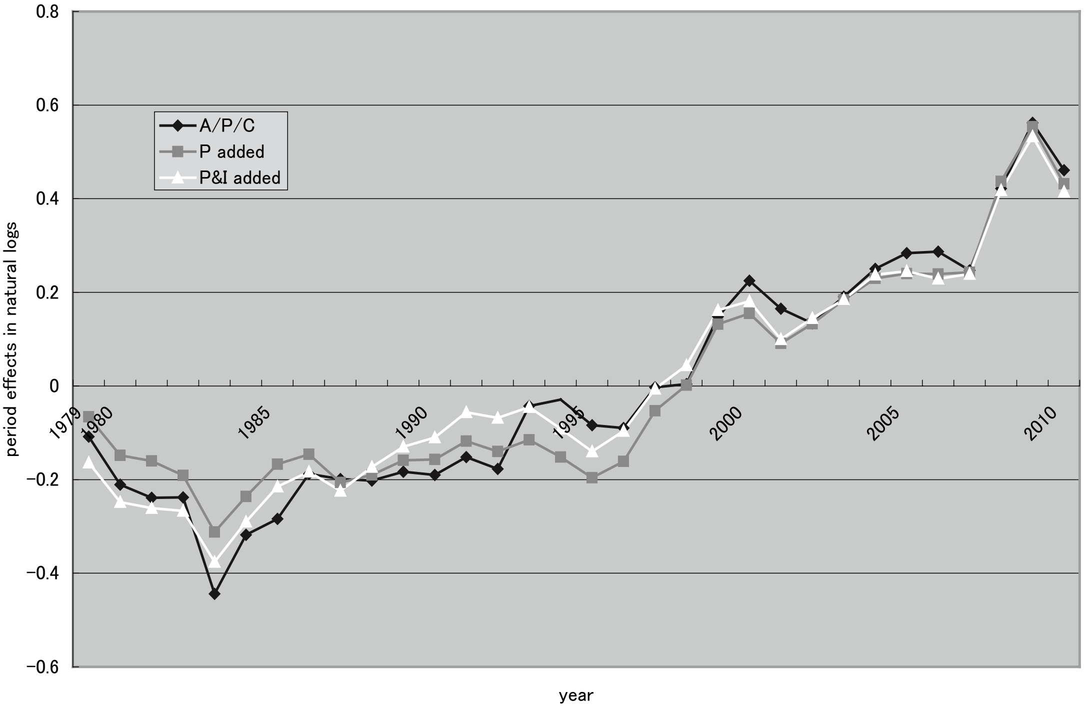
Sup-Fig. 2 Period effects estimated by different models for banana consumption, 1979 to 2010



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Appendix Table 1 Estimates of Inddividual Consumption of Apples by Age Groups, 1979 to 2010 (kg/person)

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
15~19	3.61	3.48	3.95	4.07	3.40	4.01	2.55	2.71	2.48	2.59	3.06	2.21	1.71	1.98	2.07	1.39
20~24	3.63	3.49	3.99	3.96	3.42	3.67	2.61	2.63	2.60	2.77	2.87	2.15	2.12	2.11	2.14	1.78
25~29	3.70	3.71	4.04	4.09	3.78	3.80	2.91	2.98	3.08	3.17	2.98	2.51	2.64	2.35	2.57	2.40
30~34	4.29	5.64	4.48	4.49	4.88	4.69	4.64	4.18	4.65	4.70	4.22	3.89	3.79	3.50	3.60	3.96
35~39	4.40	6.08	5.29	5.20	5.82	5.08	5.43	5.17	5.93	5.67	5.14	5.28	5.99	5.01	5.33	4.86
40~44	4.72	6.32	5.30	5.66	6.32	5.99	5.88	6.29	6.64	7.84	6.41	6.66	6.43	6.33	6.75	6.03
45~49	5.38	6.68	5.69	6.00	6.27	6.53	5.94	6.14	6.50	7.95	7.42	7.23	7.23	6.89	7.43	7.22
50~54	5.53	6.75	5.96	5.85	6.98	6.09	6.40	6.64	7.28	8.33	7.17	7.53	8.07	7.87	7.91	8.33
55~59	5.53	7.34	5.93	7.52	8.38	7.16	6.91	8.47	8.41	8.98	7.78	9.36	8.95	8.04	9.38	9.30
60~64	6.09	7.25	7.03	7.46	8.80	7.83	7.61	8.42	8.92	9.28	8.45	9.55	9.46	9.07	10.53	11.28
65~69	7.17	6.94	7.31	6.62	8.28	8.34	8.12	8.05	8.91	9.14	9.34	9.71	10.27	8.87	11.03	11.20
70~74	7.56	6.81	7.44	6.21	8.03	8.58	8.36	7.89	8.91	9.08	9.79	9.82	10.65	8.80	11.26	11.16
75~	7.30	6.45	7.13	5.80	7.58	8.21	8.03	7.47	8.49	8.64	9.49	9.40	10.30	8.37	10.80	10.64

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
15~19	1.69	1.24	0.77	0.59	0.55	0.70	0.59	0.58	0.41	0.39	0.96	0.85	0.17	0.25	0.47	0.33
20~24	2.01	1.95	1.20	1.04	0.89	1.10	0.87	1.06	0.76	0.76	1.23	1.26	0.54	0.50	0.82	0.66
25~29	2.48	2.60	1.81	1.66	1.40	1.64	1.30	1.65	1.43	1.33	1.67	1.72	1.11	1.00	1.28	1.21
30~34	3.21	3.44	2.89	2.76	2.28	2.47	2.27	2.60	2.19	1.86	1.76	1.92	1.91	1.79	1.84	1.53
35~39	4.43	4.51	4.54	4.45	3.26	3.35	3.27	3.46	2.90	2.46	2.07	2.28	2.44	2.38	2.41	1.87
40~44	5.52	5.36	5.31	5.27	4.17	4.25	4.26	4.25	3.64	3.15	2.62	2.82	2.75	2.81	2.97	2.28
45~49	6.83	6.69	5.97	6.31	4.75	5.16	5.14	5.20	4.64	4.03	3.21	3.45	3.49	3.40	3.65	2.94
50~54	7.52	8.09	7.60	7.68	6.38	6.12	5.97	6.43	6.07	5.18	3.92	4.20	4.62	4.22	4.46	3.85
55~59	9.40	9.51	8.70	8.57	7.45	7.43	6.96	8.27	7.75	6.54	5.52	5.53	6.44	6.75	6.23	5.15
60~64	10.13	9.09	9.42	9.38	8.28	9.04	8.29	9.94	9.53	8.12	8.05	7.98	8.67	9.65	9.17	7.28
65~69	10.32	9.97	10.03	9.80	9.03	9.89	8.92	10.30	10.20	8.90	8.92	8.87	9.62	9.95	9.76	8.75
70~74	10.43	10.45	10.32	10.02	9.39	10.39	9.24	10.31	10.58	9.47	9.62	9.56	10.30	9.77	10.17	9.75
75~	9.99	10.20	9.95	9.65	9.07	10.61	9.39	10.34	10.76	9.73	9.90	9.84	10.59	9.66	10.34	10.17

Source: Calculated by the authors from *FIES* annual data, using TMI model.

Appendix Table 2 Individual Consumption of Bananas by Age Groups, 1979 to 2010 (kg/person)

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
15~19	3.93	3.27	3.09	3.32	2.36	2.86	2.62	2.52	2.71	2.80	2.46	2.38	2.41	2.63	2.64	2.66
20~24	4.23	3.59	3.66	3.71	2.78	3.14	3.14	2.94	3.08	3.17	2.87	2.57	2.63	2.85	2.79	2.79
25~29	4.57	3.86	4.08	4.09	3.15	3.56	3.61	3.49	3.54	3.53	3.39	2.89	2.96	3.12	3.06	3.05
30~34	4.51	3.94	3.80	3.74	3.00	3.66	3.56	3.93	3.69	3.43	3.70	3.30	3.43	3.14	3.39	3.38
35~39	3.70	3.43	3.18	3.09	2.51	2.91	2.99	3.37	3.37	3.21	3.16	3.23	3.52	3.10	3.73	3.58
40~44	3.84	3.28	2.86	3.20	2.29	2.57	2.60	3.22	3.15	3.07	2.99	3.20	3.41	3.26	3.83	3.86
45~49	4.01	3.63	3.31	3.33	2.40	2.83	2.92	3.45	3.07	3.24	3.21	3.66	3.64	3.27	4.01	4.09
50~54	4.24	4.00	3.88	3.67	3.04	3.11	3.59	4.26	4.09	4.15	4.14	3.96	4.84	3.82	4.52	4.50
55~59	4.88	4.31	4.40	4.43	3.85	4.17	4.28	5.19	5.10	4.86	5.82	5.33	5.30	5.00	6.55	6.37
60~64	5.34	4.55	4.82	5.06	4.15	5.36	4.82	5.92	5.70	6.02	6.20	6.48	6.70	6.12	7.29	7.71
65~69	5.02	4.76	4.80	5.16	4.10	5.33	5.66	6.09	6.06	6.08	6.49	6.79	6.78	7.05	8.76	8.95
70~74	4.84	4.85	4.77	5.18	4.06	5.27	5.98	6.13	6.20	6.07	6.59	6.92	6.79	7.26	8.97	9.15
75~	4.56	4.65	4.54	4.93	3.85	4.98	5.78	5.85	5.94	5.78	6.31	6.64	6.47	6.98	8.60	8.77

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
15~19	2.52	2.48	2.26	2.10	2.83	2.76	2.45	2.01	2.49	2.42	2.59	2.04	2.56	2.42	2.85	2.26
20~24	2.72	2.51	2.47	2.33	2.94	3.03	2.64	2.34	2.78	2.99	3.15	2.50	3.40	3.09	3.68	2.96
25~29	2.99	2.73	2.82	2.67	3.24	3.42	2.97	2.80	3.16	3.59	3.71	3.12	4.13	3.74	4.47	3.68
30~34	3.25	3.16	3.28	3.03	3.62	3.91	3.48	3.47	3.60	3.76	3.93	4.05	3.86	4.34	4.91	4.27
35~39	3.27	3.36	3.90	3.55	4.04	4.40	4.04	3.92	4.04	3.95	4.16	4.63	3.61	4.75	5.31	4.72
40~44	3.40	3.50	3.76	3.62	4.75	4.87	4.63	4.16	4.48	4.26	4.52	4.89	3.61	5.09	5.82	5.11
45~49	3.61	3.76	4.05	4.26	4.84	5.43	5.15	4.69	5.04	4.92	5.20	5.57	4.25	6.05	6.88	6.03
50~54	4.48	3.99	4.80	4.77	5.40	6.11	5.68	5.48	5.72	5.91	6.17	6.62	5.45	8.11	8.85	7.65
55~59	5.53	5.87	6.45	6.19	6.94	7.31	6.93	6.78	6.90	7.36	7.63	7.88	6.84	9.04	10.21	8.92
60~64	7.79	7.26	8.29	8.36	9.19	9.63	9.29	9.18	9.09	9.68	9.53	9.24	8.40	9.75	11.41	10.07
65~69	8.12	8.17	9.11	9.57	10.42	11.17	10.27	10.00	9.91	10.96	10.41	10.07	9.44	10.60	12.48	11.15
70~74	8.25	8.37	9.39	9.93	10.77	12.06	10.88	10.61	10.55	11.90	11.13	10.62	10.26	11.46	13.37	12.08
75~	7.89	8.03	9.03	9.58	10.35	12.43	11.12	10.88	10.81	12.31	11.45	10.87	10.62	11.87	13.78	12.50

Source: Calculated by the authors from *FIES* annual data, using TMI model.