Cohort Analysis: Ability to Predict Future Consumption —The Cases of Fresh Fruit in Japan and Rice in Korea

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1. Introduction

Since the second half of the Twentieth Century, there have been substantial changes in food marketing in Japan and in many other countries. Members of younger generations have been exposed to an increasingly wide variety of foods at supermarkets and restaurants. They may also be more accustomed to using convenience foods. It is possible that people's tastes and preferences are shaped by such aspects of the food environment at the time when they grow up. If so, it is further possible that people born around the same point in history (a "birth cohort") have shared more similar experiences as young children and teenagers and exhibit more similar patterns of food demand than people born farther apart in time. A growing body of research on food demand allows for such effects attributable to cohort. Recent studies in countries outside of Japan and Asia to allow for cohort effects include Utz (2005), Stewart and Blisard (2008), Aristei, Perali, and Pieroni (2008), Gustavsen and Rickertsen (2009) and Zan and Fan (2010).

Japan is a country where major changes are occurring in the food marketing system, and where researchers need to consider the possibility that demand is being influenced by differences in tastes and preferences across birth cohorts. Early studies of food demand in Japan to account for birth cohorts include Mori *et al*. (2001). Tanaka and Mori (2003) soon afterwards used data on household fruit consumption classified by the head of household's age in annual reports of the *Family Income and Expenditure Survey* (*FIES*), 1979 to 2001. Specifically, they decompose fruit consumption reported in the *FIES* into the individual household members' age, birth cohort, and time (period) effects. In order to highlight the conceivable impacts of generational changes or cohort replacements on fresh fruit consumption in Japan's rapidly aging society, they further predict levels of consumption over the period of 2010 and 2020. Mori and Clason (2004) and recently Yakushiji at PRIMAFF (2010) undertook a similar investigation with fish and meat and household expenditures for various food products, respectively, in an aging society of Japan .

At the time of Tanaka and Mori's (2003) study, it was already known that average per capita household consumption of fresh fruit per year had fallen from 41.85 kg in 1979-81 to 31.47 kg in 1999-01, a decrease of 10.38 kg per person. However, when consumption was examined by age and cohort groups, it was found that still larger decreases had to be expected. The results are summarized below in Fig.1. Consider, for example, Japanese born in the years 1921-30. In 1980, when members of this birth cohort were in their 50s, they consumed approximately 60 kg of fruit per person. In 2000, when members of this same cohort were in their 70s, they still ate about 60 kg of fruit. By contrast, Japanese in their 50s in 2000, who were born in the years 1941-50, consumed just about 50 kg per person per year. Thus, Japanese in their 50s in 2000 ate about 10 kg less fresh fruit

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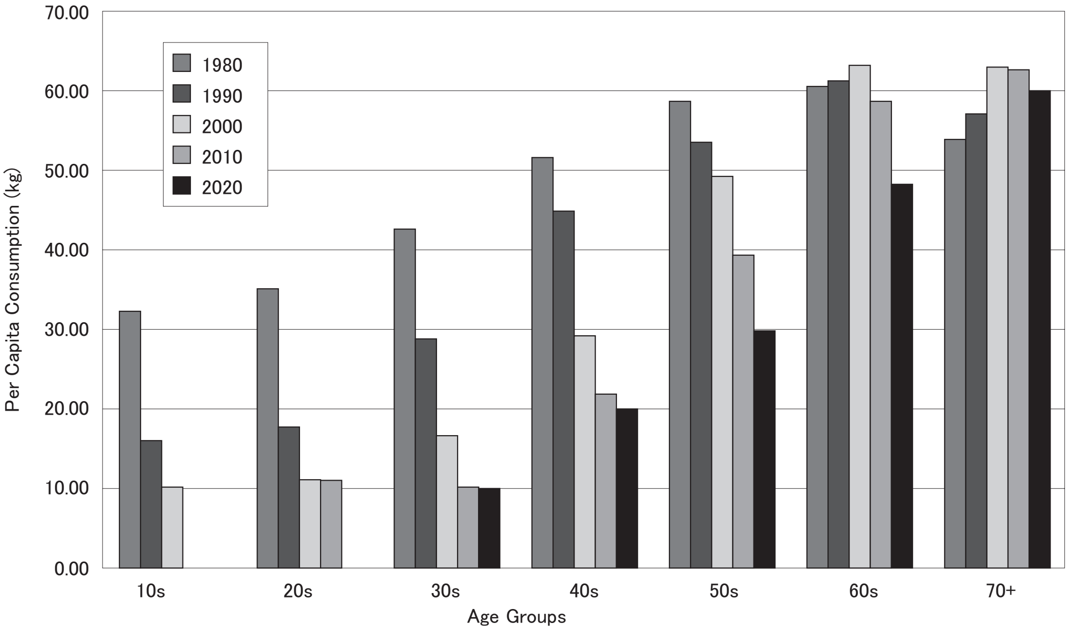
Fig. 1 Per Capita Individual Consumption of Fresh Fruit, by Age Groups, 1980 to 2020



Source: Tanaka and Mori, 2003.

per person as compared with Japanese in their 50s in 1980. Overall, younger cohorts, or newer cohorts to be exact, are likely to exhibit dramatically lower levels of consumption in the coming decades. For example, in 2010 and 2020, Tanaka and Mori predict that Japanese who will be in their 20s and 30s will consume as little as 10 kg which is less than one-fifth of the level of consumption of those who will be in their 60s and 70s then.

When changes in the age-cohort structure of a population are overlooked, researchers risk obtaining severely biased estimates of economic factors, such as income and price elasticities. Evidence of this risk was presented by Mori *et al*. for a few selected food products, including beef and oranges (Mori *et al*., 2006; Mori, Clason, and Lillywhite, 2006; Mori *et al*., 2009).

However, early studies of food demand allowing for cohort effects were met with skepticism. As discussed by Mori (2003), it was not conceivable to industry experts by casual observation or intuition that, in 2010, adults in their 20s and 30s would be consuming only 20 % of the level of consumption exhibited by those aged 70 years or older.

Since actual consumption data are now available up to the year 2009, if not 2010, we think it is interesting to determine whether Tanaka and Mori's (2003) predictions have been realized and to what extent. In this paper, we replicate their analysis, basically with the same data set and the same statistical methodology with some refinements. That is, we will predict 2009 consumption by age groups, using the data from 1979 to 2001. In the past few years, deriving individual consumption by age from household data classified by the head of household's age has improved technically. New analytical tools, known as the "intrinsic estimator" (IE) model, have also become available for age-period-cohort decomposition (Yang, Fu, and Land, 2004; Yang *et al*., 2008). For the sake of comparison, we further analyze the same household data from 1960 to 2001 by means of a "traditional" time-series approach.

To check that the ability of a cohort analysis to predict future consumption is not unique to the case of fresh fruit consumption in Japan, but more broadly based, we also consider rice consumption in Korea in the Appendix. Consumption of rice has decreased dramatically in Korea over the past two decades, with average per capita consumption declining from 121.8 kg in 1982 to 76.9 kg in 2007. Korean society has been aging more rapidly than has Japanese society. The larger percentage of older people in the Korean population may have a positive impact on average total consumption, because today's older people tend to stick to the traditional rice-centered diet, thus eating more rice, if not more cereals than younger people. At the same time, however, the eventual replacement of rice-eating older generations by newer generations who are not as dependent on rice in their diet may exercise a significant downward influence on average total rice consumption. It was suggested by Han *et al*. that, without due considerations of changes in the age-cohort structure of population, it might be an open question whether rice has become an inferior good (Han *et al*., 2010). In the Appendix, we predict rice consumption in 2005-12 by means of a cohort analysis, using the household consumption data classified by the head of household's age groups from 1982 to 2002.

2. Deriving Individual Consumption by Age from Household Data Classified by the Head of Household's Age Group

The Japanese government's Statistics Bureau has been publishing data on household purchases (= consumption) of various goods and services classified by the household head's (HH) age group in annual reports of the *Family Income and Expenditure Survey* (*FIES*), since 1979. The age groups are classified by 5 year intervals, ≤24, 25-29, ---, 60-64 and 65+. The case of fresh fruit consumption from 1980 to 2000 is summarized in Table 1, where the age groups are condensed to 10 year intervals, ≤29, 30-39, 40-49, 50-59, and 60+.

Table 1 Changes in Household Purchases of Fresh Fruit by HH Age Groups, 1979-81 to 1999-2001 (kg/year)

year/age	~29	30~39	40~49	50~59	60~	average
1979-1981	105.11	149.04	173.42	169.34	166.79	159.63
1989-1991	49.11	86.44	126.56	134.57	138.38	119.99
1999-2001	31.26	51.66	86.27	116.07	133.89	102.36

Note: Original data classified annually and by 5 year intervals are simply averaged.
Sources: *FIES*, various issues.

Table 1 clearly demonstrates a few distinct tendencies in household fruit consumption: (1) household consumption was declining steadily over the period of 1980 to 2000, (2) the younger households reduced their consumption much more rapidly than older households, with the result that households with a HH under 30 years of age consumed less than one-fourth of the quantity of fresh fruit consumed by households with a HH above 60 years of age in 2000. As stated by *White Paper on Agriculture, 1994*, "the young have been leaving behind fresh fruit" (wakamono no kudamono-banara) lately.

Japan's households have consistently become smaller in size. Specifically, the number of people living in a Japanese household has declined from 3.82 in 1980 to 3.24 in 2000, on average, and this trend can be observed across all HH age groups. It follows that the data in Table 1 needs, at least, to be converted to a per capita basis. However, simply dividing total household consumption by household size ignores the fact that each age cell contains consumption by at least two different age groups, parents and their children, typically 30 to 40 years apart in present-day Japan. For example, the value 149.04 (kg) in Table 1 in the age cell for HH age group 30-39 in 1980 may represent consumption by two adults in their 30s and two infants. Ten years later in 1990, members of this cell had moved diagonally to the age cell for HH age group 40-49 and reported 126.56 kg of fresh fruit, which may represent consumption by two adults in their 40s and also by two teenagers. After another 10 years in 2000, 116.07 kg in the next age cell may represent consumption by two adults in their 50s and very likely consumption by one young adult in their 20s.

In order to track down changes in individual consumption by the same cohorts diagonally in Table 1, one needs to remove consumption attributable to family members other than the HH and his/her spouse in each age cell. For example, taking rounded numbers from the third row, 1989-91 in Table 1, we have 4 equations to solve:

$H_{25}(3) = 50$; $H_{35}(4) = 90$; $H_{45}(4) = 130$; $H_{55}(3) = 135$, where

H_j denotes household consumption by HH j years old and number in parentheses represents number of family members.

First, we consider per capita household consumption using the simple approach of dividing total household consumption by household size which will yield the following estimates:

$X_{25} = 50/3 = 16.7$; $X_{35} = 90/4 = 22.5$; $X_{45} = 130/4 = 32.5$; $X_{55} = 135/3 = 45$, where

X_i denotes average individual consumption by a person of i years of age. This approach is, however, based on the unlikely assumption that all family members fall in the same age category as the household head.

Alternatively, one may think of the more realistic, pragmatic approach that accounts for differences in the family member age structure of households as follows:

$H_{25} = 2X_{25} + 1X_0$ --------- (1)
$H_{35} = 2X_{35} + 2X_5$ --------- (2)
$H_{45} = 2X_{45} + 2X_{15}$ -------- (3)
$H_{55} = 2X_{55} + 1X_{25}$ -------- (4)

where equation (1) states that households with a HH aged 20 to 29 years old include two adults and one infant, on average. If we can further assume, based on some outside information such as *National Nutrition Surveys*, which are regrettably not as consistent as *FIES* with respect to the coverage of periods and food items, or even by intuition that $X_0 \approx 0.5X_5$ ---- (5); $X_5 \approx 0.4X_{15}$ ---- (6); $X_{15} \approx X_{25}$ ---- (7),

then we will have approximate solutions as presented below:

$X_{25} \approx 22.7$; $X_{35} \approx 35.9$; $X_{45} \approx 42.3$; $X_{55} \approx 56.2$; and additionally $X_0 \approx 4.5$; $X_5 \approx 9.1$; $X_{15} \approx 22.7$.

Data on the actual family member structures of households headed by people of different age groups, though very complex, are available from various sources. Among other sources, these data can be found in (1) appendix tables attached to *FIES* annual reports; (2) Volume 4, *Distribution of Households*, *National Survey of Family Income and Expenditure*, which takes place every five years, various issues; (3) *National Census*, various issues.

Altogether, *FIES* provides 10 equations for HH age groups, ≤ 24, 25-29, ---, 60-64, and 65+, as presented below in equations (8),---,(17). Instead of assuming exact equality, as we did for (1) to (4), above, we introduce an error term, E_j for each equation. Individual consumption by age can then be estimated by minimizing the sum of squared errors for the final solution. Also, instead of imposing assumptions like $X_{15} \approx X_{25}$ above, we further introduce the assumption of gradual changes between successive parameters (parameta no zenshinteki henka) per advice from Y. Saegusa. That is, we assume the difference in consumption between people adjacent in age group, $X_i - X_{i+1}$, will be small. We then minimize the sum of residuals squared, $\sum(X_i - X_{i+1})^2$, as supplementary constraints. This statistical procedure has been repeatedly elucidated and is not produced here (Mori and Inaba, 1997; Tanaka, Mori, and Inaba, 2004; Mori *et al*., 2009).

$H_{22} = \sum C_{i22}X_i + E_{22}$ -------(8)

$H_{67} = \sum C_{i67}X_i + E_{67}$ -------(17)

Where

H_j = average household consumption by j[th] HH age group (from *FIES* annual report)

C_{ij} = average number of persons in the i[th] age group in the j[th] HH age group household

Estimates of per capita individual consumption of fresh fruit by age, 0-4, 5-9,--, 70-74, and 75+ from 1979 to 2001 are presented in Table 2. Throughout the entire period, we obtain t-values for the parameters larger than 10.0 for the age groups above 50 years old, indicating that our estimates of individual consumption for the older age groups should be very robust. On the other hand, we obtain t-values for the young children groups, 0-4, and 5-9, in particular, that are less than 1.0 for the period 1994 and afterwards, indicating that our estimates for non-

Table 2 Individual per Capita At-home Consumption of Fresh Fruit by Age, 1979-2001

	0~4	5~9	10~14	15~19	20~24	25~29	30~34	35~39	40~44	45~49	50~54	55~59	60~64	65~69	70~74	75~
1979	26.71	30.72	32.97	35.76	37.13	38.06	46.82	48.07	54.61	59.13	63.99	61.24	67.62	63.65	62.01	56.17
1980	20.41	24.74	25.46	27.63	29.71	30.73	44.57	53.93	53.40	58.01	63.29	60.03	60.15	56.34	54.75	49.63
1981	20.89	25.51	27.80	29.86	30.18	30.60	36.27	42.35	46.32	51.60	54.64	53.80	61.04	56.48	54.53	49.22
1982	20.38	25.48	28.53	29.69	28.84	29.87	35.63	44.12	48.95	53.38	52.51	62.39	60.95	53.90	51.15	45.86
1983	18.19	23.19	25.70	25.35	26.39	29.21	37.58	46.67	53.56	53.89	59.41	66.75	65.22	59.62	57.09	51.43
1984	20.17	23.14	24.59	25.17	25.60	27.34	35.38	37.02	49.93	50.63	51.82	61.75	65.03	60.40	59.01	53.27
1985	11.98	16.17	19.53	21.34	21.57	23.84	34.90	40.78	46.90	51.83	53.16	60.55	64.81	61.18	59.56	53.78
1986	12.98	16.29	18.14	18.21	20.02	23.65	34.86	38.55	51.67	50.29	54.81	61.93	63.83	59.98	58.12	52.35
1987	12.55	17.04	20.10	20.81	21.63	24.07	30.85	42.30	49.05	50.43	52.73	68.07	63.22	62.36	62.18	57.13
1988	12.03	15.54	17.86	18.03	18.51	20.92	28.62	37.48	52.66	51.83	52.91	62.04	64.32	62.65	61.83	55.94
1989	8.70	12.46	16.10	18.76	19.02	21.00	30.22	36.37	43.31	50.05	49.69	56.96	58.11	59.78	60.80	56.73
1990	3.85	7.87	12.00	14.82	14.50	17.09	29.06	37.69	43.77	51.14	49.17	58.71	62.99	62.34	62.26	56.58
1991	3.65	6.84	10.35	13.41	14.69	17.34	24.62	35.54	41.19	49.62	51.35	56.26	61.25	60.15	59.80	54.82
1992	4.29	7.45	10.21	12.00	13.96	16.37	24.93	32.40	43.40	46.00	53.97	54.67	60.69	60.67	60.71	57.39
1993	5.64	8.40	11.08	13.20	14.07	16.58	22.43	32.38	37.91	45.20	46.95	55.04	60.51	62.57	63.58	62.71
1994	5.86	6.86	7.75	9.41	11.57	14.45	23.52	27.36	37.77	44.95	54.52	57.99	62.48	66.64	68.79	69.89
1995	3.38	5.31	8.31	11.56	14.30	17.43	21.25	26.51	33.86	42.38	46.95	53.58	57.97	61.59	63.43	64.26
1996	2.38	4.47	6.89	9.75	12.80	15.84	20.56	27.28	33.13	40.13	46.93	55.06	56.00	60.06	62.31	63.47
1997	1.42	2.61	4.76	7.36	10.66	14.25	19.37	30.35	34.85	40.60	49.41	55.73	58.37	62.40	64.49	65.50
1998	1.06	1.63	4.10	6.75	9.90	13.31	17.77	27.73	32.80	37.94	48.67	53.50	61.33	61.21	61.15	60.63
1999	1.98	3.58	5.30	6.66	9.02	12.82	18.94	23.68	33.22	35.69	44.28	50.85	61.28	63.18	63.97	64.24
2000	3.12	5.02	6.38	7.01	9.25	12.54	16.41	23.29	30.59	32.36	45.94	52.95	59.10	64.68	67.27	67.49
2001	1.29	2.38	4.42	6.52	9.31	12.61	17.29	23.37	29.71	35.04	43.37	57.36	58.43	62.08	64.05	64.96

Source: Estimated by the authors, using Tanaka, Mori and Inaba model, based on *FIES* data, various years.

adults should not be robust. T-values for the young adult-groups, particularly 20-24, and 25-29 are less than 3.0 in the last few years of the survey period, whereas these values far exceed 3.0 until 1990 or so. Different weights on the supplementary constraints, $(X_i - X_{i+1})^2$, would produce very similar estimates of individual consumption for the age groups above 40 years old (see Tanaka, Mori, and Inaba, 2004 for statistical verifications).

In view of these statistical evaluations, the data presented in Table 2 should be dependable for the age/cohort-related analyses except for the first 3 columns, 0-4, 5-9, and 10-14. For the sake of safety, data pertaining to next 3 columns, 15-19, 20-24 and 25-29 during the last few years of the survey period should be viewed with caution.

A sketchy inspection of the data arrayed by age and period in Table 2 reveals a few distinct features of changes in fresh fruit consumption in Japan. Thirty years ago, around 1980, the young under 30 years of age would consume substantially less fruit, say 50 % less than those in their 50s and 60s and they reduced their fruit consumption very drastically, say more than 70 % within the next two decades toward 2000. By contrast, Japanese in their mid-50s and older have kept their fruit consumption near the previous high levels to the effect that the older people above their mid-50s consumed nearly five times more fruit than those in their 20s and even ten times more than non-adult young people around 2000. Middle-aged people in their 40s consumed 55 kg thirty years ago around 1980, on average, not substantially less than the older people. However, middle-aged people reduced their consumption to some 30 kg in 2000, about one half the level of those in their 60s and 70s then.

In recognition of the indisputable fact that those in their 40s in 2000 were in their 20s in 1980, who consumed on average 30 kg of fruit then, we can conclude that these cohorts who were born in the 1950s did not change their consumption much, maintaining the previous level as they aged from their 20s in 1980 to 40s in 2000. Likewise, those in their early 50s consumed 63 kg, the largest amount of fruit in 1979 to 1980 and this cohort, which reached the age of early 70s in 2000, consumed 65 kg then, the largest of all age groups. Similarly, those in the early 50s in 2000 consumed 45 kg, which coincides with the 45 kg consumed by those aged in their early 30s in 1979-80.

When tracing the data in Table 2 diagonally with the interval of 5 years, i.e., starting in 1979 down to 1984, then to 1989, ---, one can notice the apparent presence of cohort effects in individual fruit consumption over the period in question. The aspect of birth cohorts, or generations, needs to be taken into account to correctly interpret per capita consumption data arrayed by age/period in Table 2.

3. Decomposing Individual Consumption by Age from 1979 to 2001 by Age, Period and Cohort Effects

Few would disagree with the need for adding the cohort factor in explaining individual consumption by people of different ages in certain periods of time in a way such as: $X_{it} = f(A_i, P_t, C_k)$, regardless of functional forms. In dealing with events in epidemiology such as cancer mortality rates, or sociological events such as arrest rates of cardinal crimes, the linear additive model, equation (18) has been commonly applied (Holford,1983; Mason and Smith,1985; Clayton and Schiffers, 1987; Fu, 2008, etc.)

$$X_{it} = B + A_i + P_t + C_k + E_{it} \text{ -------(18)}$$

where

B: grand mean effect

A_i: effects attributable to age i years old

P_t: effects attributable to period t

C_k: effects attributable to cohort k

E_{it}: random errors

Estimation of the additive A/P/C model is complicated by an identification problem associated with the exact linear relation between the three factors of age, period and (birth) cohort, i.e., i + k = t. For example, when a person belonging to a birth cohort born in 1980 is 20 years old, the time period must be no other than 2000. "Conventionally"(Yang, Fu, and Land, 2004) equality constraints on any chosen parameters, such as $A_i = A_{i+1}$, $P_t = P_{t+m}$, or $C_k = C_{k+n}$, have been imposed on top of the sum-to- zero side constraints of these parameters. In dislike of the arbitrary choice of the identifying constraint, Nakamura introduced an intuitively more natural assumptions of gradual changes between successive parameters over the entire ranges of age, period, and cohort attributes (Bayesian cohort models: Nakamura, 1982 and 1986). Asano proposed, on a purely mathematical basis free from any parameter-related assumptions, a unique approach to overcome the difficulty, by means of the Moore-Penrose's general inverse matrix (Asano, 2001, pp. 362-64). Yang *et al*. developed in a more comprehensive manner a purely algebraic (and geometrical) model, called the "intrinsic estimator" and compared their model with the conventional generalized linear model based on the equality constraint in a cohort analysis of U.S. female mortality rates (Yang, Fu, and Land, 2004; Yang *et al*., 2008).

We have applied both Nakamura's Bayesian estimator (BE) and intrinsic estimator (IE) models to consumption of various food products arrayed by age and period and attempted to examine the workability of these two models and also the conventional linear models with equality constraints by simulation (Mori and Gorman, 2001; Mori *et al*., 2001; Mori, Saegusa and Kawaguchi, 2008; Mori *et al*., 2009; Mori, Kawaguchi and Saegusa, 2009; Mori and Saegusa, 2010; Mori, Kawaguchi and Saegusa, 2010; and several others). The theoretical structures of these models in statistical mathematics are not given in this paper.

The results of cohort analyses of the data in Table 2 by both BE and IE models are presented in Tables 3a and 3b, respectively. As is often the case for unknown reasons, BE tends to yield a sharper slope in cohort effects and conversely milder slope in age effects than IE. Which is more truthful (closer to the "true" values), we cannot decide. In fitting the data in Table 2, individual consumption by age groups from 0-4 to 75+ to the cohort equation (18), we face an important choice of what age groups to cover. If we start from the youngest age group, 0-4, we are assuming that the eating habits of fresh fruit, or cohort effects are firmly formed early in this stage and should be carried over the remaining lifecycle (Birch, 1999; Benton, 2004). However, eating habits for fresh fruit may be affected by experiences in primary school

Table 3a Estimates of Cohort Parameters of Individual Fresh Fruit Consumption by Age Groups from 15-19 up, 1979 to 2001, by Means of Bayesian Estimator Model

Grand Mean=39.70(0.30) (kg)

Age effects Age	(SD)	Period Effects Year	(SD)	Cohort Effects Born in	(SD)
15−19	0.13(3.2)	1979	4.68(1.3)	~1904	4.69(5.4)
20−24	−3.57(2.7)	1980	1.61(1.2)	1905−09	3.48(4.2)
25−29	−6.38(2.2)	1981	−1.10 (1.1)	1910−14	8.73(3.6)
30−34	−4.79(1.7)	1982	−0.92 (1.0)	1915−19	13.32(3.0)
35−39	−3.70(1.2)	1983	1.13 (0.9)	1920−24	18.06(2.5)
40−44	−1.89(0.7)	1984	0.04 (0.8)	1925−29	18.51(2.0)
45−49	−2.13(0.5)	1985	−0.40 (0.7)	1930−34	19.45(1.5)
50−54	−1.38(0.7)	1986	−0.36 (0.7)	1935−39	15.77(1.1)
55−59	2.34(1.2)	1987	0.84 (0.6)	1940−44	13.06(0.7)
60−64	4.52(1.7)	1988	0.25 (0.6)	1945−49	11.71(0.7)
65−69	4.41(2.2)	1989	−0.96 (0.5)	1950−54	4.22(1.0)
70−74	6.09(2.7)	1990	−0.91 (0.5)	1955−59	−2.36(1.5)
75~	6.35(9.6)	1991	−1.62 (0.5)	1960−64	−7.950(2.0)
		1992	−1.33 (0.6)	1965−69	−13.68(2.5)
		1993	−0.86 (0.6)	1970−74	−19.07(3.0)
		1994	0.41(0.7)	1975−79	−23.59(3.5)
		1995	−0.87(0.7)	1980−84	−29.77(4.1)
		1996	−1.08(0.8)	1985~	−34.56(4.7)
		1997	−0.01(0.9)		
		1998	−0.38(1.0)		
		1999	−0.01(1.1)		
		2000	0.75(1.2)		
		2001	1.17(1.3)		

Sources: Calculated by the authors, using the program designed by Saegusa in the language of Visual Basics.

Table 3b Estimates of Cohort Parameters of Individual Fresh Fruit Consumption by Age Groups from 15-19 up, 1979 to 2001, by Means of Intrinsic Estimator Model

Grand Mean=39.20(0.33) (kg)

Ageeffects Age	(SD)	PeriodEffects Year	(SD)	CohortEffects Born in	(SD)
15−19	−9.06(0.7)	1979	8.76(0.6)	~1904	−7.67(5.1)
20−24	−11.52(0.6)	1980	4.73(0.6)	1905−09	−9.14(1.9)
25−29	−12.94(0.6)	1981	1.23(0.6)	1910−14	−1.57(1.1)
30−34	−9.58(0.5)	1982	1.28(0.6)	1915−19	4.51(1.0)
35−39	−6.99(0.5)	1983	3.98(0.6)	1920−24	10.96(0.9)
40−44	−3.47(0.5)	1984	1.71(0.6)	1925−29	12.87(0.8)
45−49	−2.24(0.5)	1985	1.10(0.6)	1930−34	15.60(0.8)
50−54	0.01(0.5)	1986	0.66(0.6)	1935−39	13.45(0.8)
55−59	5.55(0.5)	1987	2.12(0.6)	1940−44	12.30(0.8)
60−64	9.38(0.5)	1988	0.98(0.6)	1945−49	12.72(0.7)
65−69	10.69(0.6)	1989	−0.91(0.6)	1950−54	6.68(0.7)
70−74	14.14(0.6)	1990	−0.78(0.6)	1955−59	1.72(0.7)
75~	16.03(0.6)	1991	−2.15(0.6)	1960−64	−2.28(0.7)
		1992	−2.02(0.6)	1965−69	−6.50(0.6)
		1993	−1.98(0.6)	1970−74	−10.36(0.7)
		1994	−0.39(0.6)	1975−79	−13.26(0.8)
		1995	−2.68(0.6)	1980−84	−18.07(1.0)
		1996	−3.24(0.6)	1985~	−21.95(1.5)
		1997	−1.96(0.6)		
		1998	−3.04(0.6)		
		1999	−2.91(0.6)		
		2000	−2.32(0.6)		
		2001	−2.18(0.6)		

Sources: Calculated by the authors, using the program designed by Saegusa in the language of Visual Basics.

(school-lunch programs, for example) apart from individual parental influences. Intuitively, it seems realistic to take the eating habits formed by the period of early adolescence as representing cohort effects in fruit consumption. As mentioned earlier, the first three columns from the left in Table 2 are statistically not dependable. We will then start from the age group, 15-19, as the youngest, without objective background to support it, though.

In the case of the standard cohort table, which selects the period in accordance with the age classification, one can trace the same cohort by following the table diagonally. Table 2 arrays the data by 5-year intervals in age for every year from 1979 to 2001. The cohort in one age cell moves to the next age cell only after 5 years, instead of every survey year. On the recognition that successive ages in population should be very close in size, we are assuming that approximately one fifth of the cohort in any age cell moves to the next age cell next year, with four fifths remaining in the same age cell. The entire cohort completely moves to the next age cell every 5 years. The following illustrations might help to understand our assumptions:

In year t: $X_{it} = B + A_i + P_t + C_k + E_{it}$ ------(19)

In the following year, t+1:

$$X_{it+1} = B + A_i + P_{t+1} + 0.8C_k + 0.2C_{k+1} + E_{it+1} \quad \text{------(20)}$$

Tables 3a and 3b demonstrate that the parameters estimates by IE (3b) carry substantially narrower ranges of deviation than BE (3a). However, this should not be interpreted to suggest that IE has decomposed the data in Table 2 more efficiently than BE, or that the estimates in Table 3b might be closer to the “true” values of age, period and cohort effects, compared to Table 3a. We have so far learned, especially in conducting simulation that standard deviations attached to the parameter estimates have very little to do with the recovery performance of simulated data, either in BE, IE or OLS with equality constraints (Mori, Kawaguchi, and Saegusa, 2010).

4. Projecting Future Individual Consumption by Age Groups, Following a Specific Cohort into the Next Age and Period

Those in their early 40s (40-44 years old) in 1994 were born in 1950-54 and belong to 11th cohort in the third column of Table 3(a/b). This cohort moves to the next age cell of 45-49 years old in 1999. Now that we have the estimates for specific age, period and cohort effects available from Table 3(a/b), we can construct per capita individual consumption by this cohort, say in 1999 as the grand mean effect + age effects for the late 40s (45-49) + period effect for 1999 + cohort effect of those born in 1950-54.

Table 3a (BE) gives: 39.70 + (-)2.13 + (-)0.01 + 4.22 = 41.78.

Table 3b (IE) gives: 39.20 + (-)2.24 + (-)2.91 + 6.68= 40.73.

Projecting consumption by birth cohorts for years beyond the range of the analytical sample (past the year 2001 in our study) raises questions about what value to assign to the period effect. Consider, for example, those in their early 30s (30-34) in 2004 who were born in 1970-74, the 15th cohort in the third column of Table 3(a/b). Their average per capita consumption can be projected as:
39.70 + (-)4.79 + P_{2004} + (-)19.07 from 3a (BE) and 39.20 + (-)9.58 + P_{2004} + (-)10.36 from 3b (IE), respectively, where the period effect for the year 2004 is unknown. If the first year of the survey period, 1979, is deleted from the second column of Table 3a, the overall slope (Holford, 1985, pp.833-34) is nearly flat, or slightly ascending for the period category. One may therefore assume that the period effects would oscillate around the baseline of zero or, say two year average of 2000-2001 at +0.96 for the coming decade or so, when we depend for our projection on the parameters estimated by BE. On the other hand, the overall slope for the period effects is slightly declining in the second column of Table 3b. However, the slope for the last 11 years since 1991 is nearly flat around the base line at -2.26. If we take, as a proxy for the period effects for the coming decade, +0.96 for the BE projection and -2.26 for the IE projection, respectively[*1], probable per capita average consumption by those in their early 30s in 2004 can be:

BE projection: 39.70 + (-)4.79 + 0.96 + (-)19.07 = 16.80.

IE projection: 39.20 + (-)9.58 + (-)2.26 + (-)10.36 = 17.00.

Despite substantial differences in the parameter estimates yielded by both BE and IE, projected individual consumption for a specific cohort in selected age groups in certain years has proved amazingly close to each other. When different weights, hyper-parameters are allotted on the identifying constraints of “gradual changes between successive parameters” in running Nakamura’s Bayesian model, significantly different parameters, particularly the slope of age and cohort attributes would often result, although the predicted consumption by age and period, synthesized values of grand mean, age, period, and cohort effects tend to be almost identical in most cases. In running the BE approach for this paper, we relied on ABIC (minimization) in selecting the best combination of hyper-parameters.

Projecting future consumption also raises questions about what values to assign to the cohort effect for people too young to be included in the analytical sample. In 2009, those in the age group, 15-19 years old, who were born in 1990-94, are too young to be covered by the current analyses, either BE or IE, and an estimate of cohort effect is likewise not empirically available. One may guess the likely effects for this new cohort by extrapolating the declining trend observed in the bottom part of the third column of Table 3(a) or (b), or by simply assuming that the new cohort would carry the same attribute as the last one, the 18th cohort in the column. In this paper, we just leave this age cell in our projection blank.

Table 4 provides projected per capita individual

Table 4 Projected per Capita Individual Consumption of Fresh Fruit by Age Groups, 2004 and 2009, by Bayesian Estimator (BE) and Intinsic Estimator (IE) Approaches (kg/person)

	BE	IE	FIES		BE	IE	FIES	Tanaka
Age	2004	2004	2004	Age	2009	2009	2009	2010
15~19	6.23	5.94	3.90	15~19			5.17	
20~24	7.31	7.35	7.95	20~24	2.52	3.47	8.66	
25~29	10.69	10.74	12.62	25~29	4.51	5.93	12.78	10.09
30~34	16.80	17.01	17.97	30~34	12.28	14.11	16.47	8.80
35~39	23.28	23.45	21.94	35~39	17.89	19.60	19.14	11.61
40~44	30.82	31.19	25.16	40~44	25.08	26.97	21.42	18.62
45~49	36.18	36.42	31.01	45~49	30.59	32.42	25.95	25.18
50~54	43.50	43.63	39.06	50~54	36.92	38.68	33.35	33.85
55~59	54.71	55.21	49.47	55~59	47.21	49.17	46.28	44.69
60~64	58.24	58.62	57.92	60~64	56.89	59.05	56.77	54.91
65~69	60.83	61.09	62.08	65~69	58.12	59.93	60.07	62.03
70~74	66.20	66.68	63.76	70~74	62.52	64.53	61.11	62.81
75~	65.52	65.86	64.62	75~	66.45	68.57	61.57	62.20

consumption of fresh fruit by age groups in 2004 and 2009, synthesizing cohort parameters estimated by both BE and IE, Table 3a and Table 3b, respectively. For reference, individual consumption by age derived directly from *FIES*, annual reports of 2004 and 2009 and the projected individual consumption by age for the year 2010, attempted by Tanaka and Mori in 2003 are also provided.

If we presume that the estimates of individual consumption by age derived from *FIES* annual reports represent the "true" values, our projections for the year 2004 either by BE or IE replicate actual consumption by age extremely well, except for the youngest age group of 15-19 years old. Those for the year 2009, however, proved to be not so successful, particularly for the three youngest groups from 20-24 to 30-34 years old, and the oldest group of 75+ years old, substantially under-projecting individual consumption for these young groups, and slightly over-projecting for the oldest. Per capita consumption by young adults in their 20s is projected to be under 10 % of the level of the elderly in their 70s in 2009, whereas these young adults are estimated to have consumed nearly 20 % of the level consumed by the elderly according to the annual report, *FIES*, 2009[*2].

As discussed earlier, estimates of individual consumption by age derived from *FIES* are less dependable for the youngest age groups, under 20 years old and, additionally, eating habits for fresh fruit might be further affected by events during one's late adolescence, 15-19 years of age. On these premises, we repeated exactly the same procedures to re-conduct our cohort analysis, using the data from 1979 to 2001, with all age groups of under 20-24 years old in the cohort Table 2 deleted. Tables 5a and 5b and Table 6 correspond to Tables 3a and 3b and Table 4, respectively. Apparent underestimates for the younger age groups, under 30 years old in 2009 by the first trial provided in Table 4 are somewhat mitigated. On the other hand, future consumption by the oldest group, 75+, remains overestimated by nearly 10 %, particularly by IE, as compared with individual consumption derived directly from *FIES* for 2009. Following the lead of Tanaka and Mori (2003), we depict our projections in Table 6 graphically in Fig. 2 by 10-year intervals in age, along with the estimates derived directly from *FIES*, 2004 and 2009, and also the projections by Tanaka and Mori in 2003.

One specific issue in age-period-cohort modeling is the choice to transform rates in question, per capita individual quantity of consumption in this study (Holford, 1985). We have learned intuitively and empirically that the functional form, $\log(X_{it})$ should often better fit the economic variables, which tend to

Table 5a Estimates of Cohort Parameters of Individual Fresh Fruit Consumption by Age Groups from 20-24 up, 1979 to 2001, by Means of Bayesian Estimator Model

Grand Mean=42.04(0.30) (kg)

Age effects Age	(SD)	Period Effects Year	(SD)	Cohort Effects Born in	(SD)
20−24	−0.94(2.4)	1979	3.32(1.1)	~1904	6.98(4.7)
25−29	−3.59(2.0)	1980	0.44(1.0)	1905−09	5.68(3.4)
30−34	−2.55(1.6)	1981	−2.60 (1.0)	1910−14	10.20(2.8)
35−39	−2.04(1.2)	1982	−2.30 (0.9)	1915−19	14.10(2.4)
40−44	−0.98(0.8)	1983	0.34 (0.8)	1920−24	18.26(1.9)
45−49	−1.70(0.5)	1984	−0.86 (0.8)	1925−29	18.14(1.5)
50−54	−1.51(0.5)	1985	−0.93 (0.7)	1930−34	18.44(1.1)
55−59	1.45(0.8)	1986	−0.63 (0.6)	1935−39	14.13(0.8)
60−64	3.00(1.2)	1987	0.64 (0.6)	1940−44	10.84(0.7)
65−69	2.40(1.6)	1988	0.18 (0.6)	1945−49	8.85(0.8)
70−74	3.37(2.0)	1989	−1.11 (0.5)	1950−54	0.74(1.1)
75~	3.08(7.6)	1990	−0.72 (0.5)	1955−59	−6.45(1.5)
		1991	−1.35 (0.5)	1960−64	−12.30(1.9)
		1992	−0.92 (0.6)	1965−69	−19.71(2.3)
		1993	−0.45 (0.6)	1970−74	−24.55(2.7)
		1994	1.19(0.6)	1975−79	−28.99(3.2)
		1995	−0.34(0.7)	1980~	−34.35(3.7)
		1996	−0.44(0.8)		
		1997	0.93(0.8)		
		1998	0.56(0.9)		
		1999	0.98(1.0)		
		2000	1.79(1.0)		
		2001	2.28(1.1)		

Sources: Calculated by the authors, using the program designed by Saegusa in the language of Visual Basics.

Table 5b Estimates of Cohort Parameters of Individual Fresh Fruit Consumption by Age Groups from 20-24 up, 1979 to 2001, by Means of Intrinsic Estimator Model

Grand Mean=41.44(0.34) (kg)

Ageeffects Age	(SD)	Period Effects Year	(SD)	Cohort Effects Born in	(SD)
20−24	−11.18(0.6)	1979	8.04(0.6)	~1904	−7.30(5.0)
25−29	−12.54(0.6)	1980	4.33(0.6)	1905−09	−8.35(1.9)
30−34	−9.26(0.5)	1981	0.32(0.6)	1910−14	−1.34(1.1)
35−39	−6.95(0.5)	1982	0.39(0.6)	1915−19	4.42(1.0)
40−44	−3.79(0.5)	1983	3.70(0.6)	1920−24	10.60(0.9)
45−49	−2.80(0.5)	1984	1.26(0.6)	1925−29	12.27(0.8)
50−54	−0.83(0.5)	1985	0.92(0.6)	1930−34	14.70(0.8)
55−59	4.42(0.5)	1986	0.72(0.6)	1935−39	12.27(0.8)
60−64	7.98(0.5)	1987	2.08(0.6)	1940−44	10.85(0.7)
65−69	9.02(0.5)	1988	1.08(0.6)	1945−49	10.98(0.7)
70−74	12.18(0.6)	1989	−1.03(0.6)	1950−54	4.66(0.7)
75~	13.75(0.6)	1990	−0.56(0.6)	1955−59	−0.60(0.6)
		1991	−1.93(0.6)	1960−64	−4.55(0.6)
		1992	−1.72(0.6)	1965−69	−10.12(0.7)
		1993	−1.82(0.6)	1970−74	−13.01(0.8)
		1994	0.18(0.6)	1975−79	−15.49(1.0)
		1995	−2.52(0.6)	1980~	−19.97(1.5)
		1996	−3.02(0.6)		
		1997	−1.48(0.6)		
		1998	−2.64(0.6)		
		1999	−2.53(0.6)		
		2000	−1.96(0.6)		
		2001	−1.81(0.6)		

Sources: Calculated by the authors, using the program designed by Saegusa in the language of Visual Basics.

Fig. 2 Projections of Individual Fruit Consumption by Age to 2004 and 2009 by BE and IE

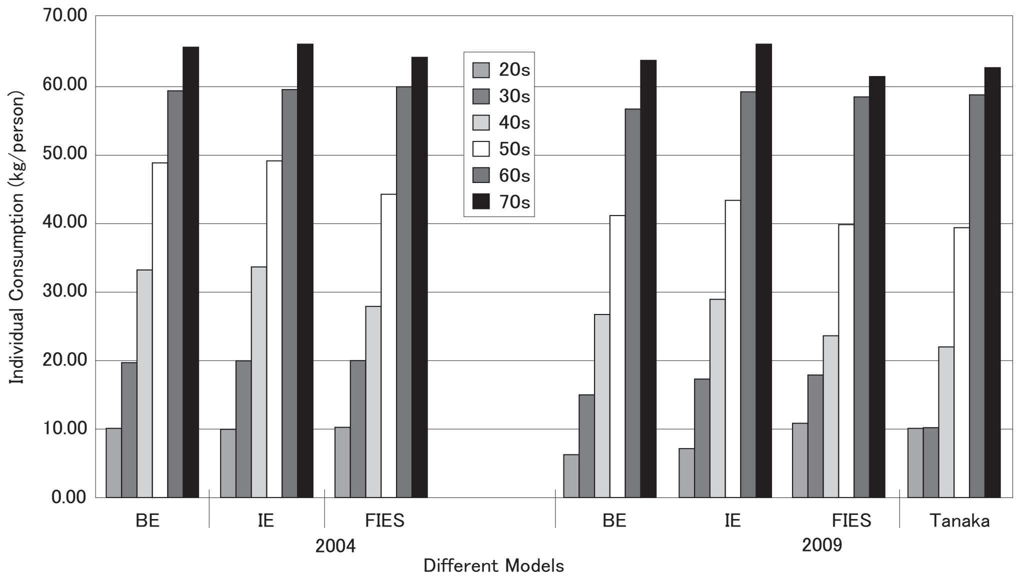


Table 6 Projected per Capita Individual Consumption of Fresh Fruit by Age Groups, 2004 and 2009, by Bayesian Estimator (BE) and Intinsic Estimator (IE) Approaches: the Age Group, 15-19 Deleted (kg/person)

	BE	IE	FIES		BE	IE	FIES	Tanaka
Age	2004	2004	2004	Age	2009	2009	2009	2010
20~24	8.78	8.41	7.95	20~24			8.66	
25~29	11.49	11.52	12.62	25~29	6.13	7.04	12.78	10.09
30~34	16.98	17.28	17.97	30~34	12.53	14.81	16.47	8.80
35~39	22.32	22.49	21.94	35~39	17.48	19.59	19.14	11.61
40~44	30.79	31.22	25.16	40~44	23.38	25.65	21.42	18.62
45~49	35.92	36.16	31.01	45~49	30.07	32.21	25.95	25.18
50~54	43.31	43.38	39.06	50~54	36.11	38.13	33.35	33.85
55~59	54.38	54.97	49.47	55~59	46.27	48.64	46.28	44.69
60~64	57.91	58.39	57.92	60~64	55.93	58.51	56.77	54.91
65~69	60.60	60.85	62.08	65~69	57.30	59.43	60.07	62.03
70~74	65.89	66.43	63.76	70~74	61.58	64.00	61.11	62.81
75~	65.29	65.57	64.62	75~	65.59	68.01	61.57	62.20

vary proportionately rather than by absolute amounts by year/age. We also have learned that an additive A/P/C model fits the log-transformed rates better, where per capita consumption by age ranges so widely from 10 kg for the younger groups to 60 kg for the older age groups in recent years as shown in Table 2, for example (Mori *et al*., 2009).

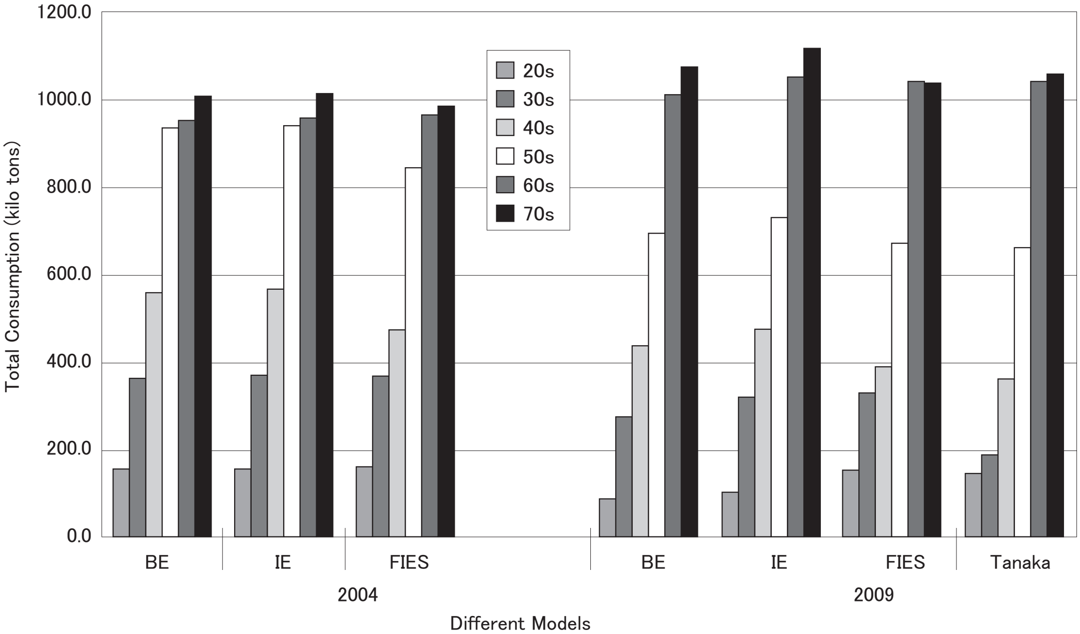
We have applied the same additive A/P/C model, both BE and IE, to log-transformed individual consumption by age groups, from 15-19 to 75+, over the period of 1979 to 2001, and obtained projections by age to 2004 and 2009. These results are summarized in Table 7. We feel that, following the logarithmic transformation, our projections may have improved to a slightly recognizable extent in the case of BE, but seems to substantially overestimate per capita individual consumption for the older age groups in the cohort decomposition by the IE model.

The National Institute of Population and Social Security has published projections of Japanese population by age from 2005 to 2055 (Institute of Population, 2006). We can predict total consumption of fresh fruits by age in the future years, multiplying

Table 7 Projected per Capita Individual Consumption of Fresh Fruit by Age Groups, 2004 and 2009, by Bayesian Estimator (BE) and Intinsic Estimator (IE) Approaches, in log Transformation (kg/person)

	BE	IE	FIES		BE	IE	FIES	Tanaka
Age	2004	2004	2004	Age	2009	2009	2009	2010
15~19	5.99	6.04	3.90	15~19			5.17	
20~24	7.81	7.95	7.95	20~24	4.96	5.23	8.66	
25~29	11.20	11.36	12.62	25~29	7.03	7.55	12.78	10.09
30~34	16.23	16.47	17.97	30~34	12.26	13.25	16.47	8.80
35~39	22.22	22.48	21.94	35~39	17.10	18.39	19.14	11.61
40~44	30.17	30.65	25.16	40~44	23.38	25.20	21.42	18.62
45~49	36.20	36.70	31.01	45~49	30.23	32.61	25.95	25.18
50~54	43.73	44.20	39.06	50~54	37.30	40.19	33.35	33.85
55~59	55.37	56.13	49.47	55~59	47.51	51.15	46.28	44.69
60~64	59.20	59.66	57.92	60~64	53.38	62.72	56.77	54.91
65~69	62.12	62.59	62.08	65~69	59.74	63.99	60.07	62.03
70~74	67.83	68.63	63.76	70~74	64.59	69.59	61.11	62.81
75~	66.69	67.54	64.62	75~	68.92	74.34	61.57	62.20

Fig. 3 Projections of Total Fruit Consumption by Age to 2004 and 2009 by BE and IE



our projections of per capita consumption by age in Table 6, for example, by total population estimates by age for specific years. Fig. 3 demonstrates projections of total fresh fruit consumption by age from different sources, excluding population under 20 years old, in 2004 and 2009, respectively.

*1: These assumptions are in no way other than arbitrary.
*2: Dyck finds it interesting that the youngest cohorts in Tables 4 and 6 increased consumption between 2004 and 2009 (based on *FIES* columns). He suspects that "perhaps abandonment of at-home fruit consumption (by the young) is finally ending". It seems probable that cohort effects attributable to the newest comers born after 1980-84 should not be significantly smaller or larger in negative values than the 17th cohort in the third column of Tables 3a and 3b (Dyck, July 2010).

5. A More "Traditional" Time Series Analysis

Having demonstrated the ability of demand models that include age, period, and cohort effects to forecast food consumption, we think it is further interesting to briefly compare these results with those from a more traditional analysis that does not explicitly account for differences in consumption across birth cohorts. If a researcher is interested in estimating price and income elasticities, he or she may regress measures of consumption on measures of income, prices, and, perhaps, other control variables. Tachibana and Ueji (2004), for one, include a time variable in their demand analyses of household consumption from 1965 to 2001 of various food products, including fresh fruit and meats.

For the sake of comparison with the results of our A/P/C model, we consider a simple demand model in which household fresh fruit consumption depends on prices and household consumption expenditures. Data for this portion of our study are also from annual reports of the *Family Income and Expenditure Survey*. Though the Japanese government's Statistics Bureau has only been publishing household purchase data disaggregated by age groups of the HH since 1979, more aggregated data are available for earlier years. Here, we use data from 1960 through 2001.

A preliminary examination of the data revealed that household fresh fruit consumption was generally increasing until 1973 and decreasing thereafter. We then conducted Perron's (1989) test to determine whether the natural logarithm of consumption was trend stationary or exhibited a unit root. Since Nelson and Plosser (1982) first identified the potential for "spurious" results, when working with time series data that do not have a constant mean and variance, it has been customary to first investigate the time series properties of the variables before undertaking any further analysis. Perron's (1989) test for a unit root allows for a one-time change in the level and/or slope of the trend function. Allowing for a one-time change in the slope of the trend function in 1973, we could reject the null hypothesis of a unit root and found that the natural logarithm of consumption was trend stationary. Thus, we must also consider including a time trend in our demand model to account for factors besides income and prices that might affect consumption. Such a time trend may capture changes in the population-average level of consumption over time due to the aging of the population and also the replacement of older cohorts with newer ones. Of course, a time trend will also capture other phenomena like changes in diet and health awareness, or, perhaps, the introduction of substitute products by marketers.

We further converted our income and price variables into real, inflation-adjusted values. Our estimated model (t-values based on Newey-West standard errors in parentheses) is:

$$\begin{aligned}\log Q_t = &-3.372 + 1.438 \log Y_t - 0.603 \log P_t \\ &(-1.47) \quad (6.61) \quad (-3.03) \\ &- 0.011T - 0.018 D_t T \text{ ---------------(21)} \\ &(-1.28) \quad (-3.77)\end{aligned}$$

Where

Q_t: average household fresh fruit consumption in period t

P_t: 100 x (CPI for fruit/aggregate CPI)

Y_t: 100 x (household total expenditures/aggregate CPI)

T: time trend equal to 1 for 1960, 2 for 1961, 3 for 1962,…

D_t: indicator variable equal to 1 if year > 1973, 0 otherwise

Overall, the data appear to fit the model well (adjusted $R^2 = 0.86$). The residuals associated with the final model did exhibit autocorrelation and, having examined these residuals, we decided to report robust Newey-West standard errors allowing for a one period lag in the autocorrelation structure.

Our estimated price and income elasticities further appear to be reasonable. We can use these results to examine how changes in prices and income have likely affected household fresh fruit consumption in Japan in the 2000 to 2009 decade. We note that household real living expenditures and prices were 6.1 % less and 2.1 % lower, respectively in 2009, compared to 1999-2001. It follows that

- A 2.1 % decrease in real fresh fruit prices over the past decade should have increased the quantity of fruit demanded by households by 1.3 %, all else constant.
- Similarly, a 6.1 % decrease in household consumption expenditures should have reduced the quantity demanded by 8.8 %, all else constant.
- Actually, average household consumption of fresh fruit decreased by 8.6 % from 1999-2001 to 2009, as is shown in Table 8 below.

Overall changes in prices and household consumption expenditures explain part of the change in Japanese fresh fruit consumption over the

Table 8 Average Household Purchases of Fresh Fruit and Related Statistics, 2000, 2004 and 2009

	Average Q. Purchased (kg/household)	Living Exp. 1,000 Real yen[1]	Average P. Paid Real yen[1]/kg	CPI: Aggregate	CPI: Fresh Fruit
1999-2001	102.7	3,716	408.5	102.2	103.0
2004	95.9	3,625	397.9	100.3	100.7
2009	93.9	3,491	373.6	100.3	98.9

Note: 1. Base year = 2005.
Sources: Statistics Bureau, *CPI* and *FIES*, various issues.

2000-09 decade. However, the importance of the time trend in our estimated model demonstrates that demand determinants other than prices and income are also important.

Moreover, if we are interested in forecasting future changes in demand, our estimated model is of little use. The importance of the time trend prevents us from predicting consumption past 2001 because we do not know all the factors underlying this time trend. As noted above, these factors could include age effects, cohort effects, changes in diet and health awareness, or, perhaps, even the introduction of substitute products by marketers. It is thus hard to say whether the trend will abate or continue unabated. And it is likewise not customary to extrapolate; rather we should probably assume all time effects to be unchanged from the immediate past[*3].

*3 When the number of 50 is assigned to T in equation (21) above for the year 2009, the average household consumption is predicted to be 62.86 kg, substantially lower than the actual consumption of 93.9 in Table 8. If T is assumed unchanged from the immediate past, say 2000 at 41, however, the consumption is predicted at 81.61 kg.

Notably, we could have also augmented our A/P/C model presented earlier in this paper to include income and price variables as, for example, in Mori, Clason, and Lillywhite (2006). However, the goals of this study do not include estimating income and price elasticities nor do we think that changes in prices and income explain much of the long-run, ongoing change in Japanese fresh fruit consumption.

6. Summary and Discussion

A growing body of literature allows for the possibility that members of the same birth cohort may exhibit a more similar demand for some foods than do people born farther apart in time. Differences in demand between birth cohorts have been further hypothesized to reflect the evolution of the food environment with the tastes and preferences of particular cohorts being shaped by the foods they consumed during their formative years. Moreover, there is little doubt that the food environment in Japan and other countries around the world has been changing. Members of younger generations are being exposed to an increasingly wide variety of foods at supermarkets and restaurants. They may also be more accustomed to using convenience foods.

As more studies employ A/P/C models that explicitly account for cohort effects, we believe it is interesting to investigate the ability of these models to predict future changes in consumption as compared with a more traditional time series analysis. To make our analysis realistic, we limit our analytical sample to include only the set of information available to a forecaster in the very early 2000s. We then use these data for estimation and the prediction of consumption in the most recent years for which data are now available.

Fresh fruit consumption in Japan is a natural case study. There has been a substantial decrease in average household consumption from over the past 30 years. Tanaka and Mori (2003) first analyzed this phenomenon using *FIES* data to decompose household consumption into age, birth cohort, and time effects. However, as discussed by Mori (2003), their results were met with skepticism. It was not conceivable to industry experts that, in 2010, young adults in their 20s and 30s would be consuming only 20 % of the level of consumption exhibited by those aged 70 years or older. Predicting future trends in fresh fruit consumption is important to food marketers, including both Japanese producers and exporters of fresh fruit to Japan. It is further important to anyone concerned about diet and health. Fruit consumption is important to a balanced, healthful diet. Substituting other foods for fruit could negatively impact the well-being of future generations.

The A/P/C model estimated for this study, which incorporates technical refinements not available at the time of Tanaka and Mori's (2003) analysis, can reasonably predict recent levels of individual fresh fruit consumption by age groups and cohorts using only data available in the early 2000s. The traditional time series model also does a reasonable job of explaining consumption trends up to 2001. However, the explanatory power of the model rests on the inclusion of a time trend. Without better information about the economic factors underlying that time trend, it is not clear how a researcher could use estimation results for predicting consumption at later points in time. Notably, after accounting for cohort effects, our A/P/C model revealed no evidence of consumption trending consistently upwards or downwards over the survey period. This suggests that variation in demand between members of different birth cohorts explains much of the time trend identified in the traditional time series analysis.

To check that the ability of a cohort analysis to predict future consumption is not unique to the case of fresh fruit consumption in Japan, but more broadly based, we further applied the same model to rice consumption in Korea. These results are reported in the Appendix. The same A/P/C model is again found to perform well. However, unlike the case of fresh fruit consumption in Japan, we identify a significant time trend even after accounting for age and cohort effects. This suggests that other developments in the population or economy of Korea are also important. Differences in demand between birth cohorts are one of the primary determinants of long-run trends.

Overall, our results underscore the importance of accounting for cohort effects in demand models that seek to predict future changes in consumption. Failing to explicitly include an important variable in a forward-looking analysis comprises the efficacy of that analysis. Evidence presented in this study that cohort effects are important to predicting both fresh fruit consumption in Japan and rice consumption in Korea suggests that researcher should consider the same possibility in studies of other food products in other countries. The small but growing body of research cited in this study demonstrates that researchers are just now beginning to do so.

APPENDIX:
Projecting 2005 to 2012 Korean Rice Consumption by Age Groups, Using the *FIES* Data from 1982 to 2002[*4]

*4 The analysis for this appendix has been made possible with the data provided in the article, "Household Rice Consumption Behavior in Korea: A Cohort Analysis," by Doo Bong Han, Hiroshi Mori and others, submitted to *Korean Journal of Agricultural Economies* in the summer 2010.

Through the Korea National Statistical Office (renamed Statistics Korea (KNSO) on July 6, 2009), the South Korean government has been publishing

Appendix Table 1 Estimates of Individual Rice Consumption by Age (1982~2002) (kg/person)

	10-19	20-29	30-39	40-49	50-59	60-69
1982	112.08	115.86	119.51	120.72	123.14	113.99
1983	110.26	116.17	122.06	127.45	132.23	108.54
1984	110.06	110.17	108.35	120.73	124.74	103.94
1985	104.40	101.08	103.73	118.68	133.52	120.20
1986	98.83	92.00	99.54	111.46	127.11	132.47
1987	102.93	86.37	91.27	111.95	128.28	125.53
1988	92.71	89.78	101.83	117.33	127.60	113.15
1989	81.36	89.13	102.92	114.51	120.34	116.93
1990	91.22	81.96	87.96	100.49	114.76	111.46
1991	67.89	80.51	96.61	113.41	121.35	106.11
1992	79.69	69.19	81.59	97.44	110.46	101.79
1993	72.47	64.54	75.94	90.20	104.37	117.26
1994	66.65	62.78	76.01	93.55	105.98	111.01
1995	57.91	57.41	73.12	92.04	103.35	105.45
1996	62.69	58.15	71.56	90.18	102.17	108.23
1997	53.65	49.89	65.64	85.91	97.11	105.94
1998	38.13	35.56	52.88	77.85	91.74	90.34
1999	44.52	50.48	66.82	79.20	92.22	90.72
2000	46.65	46.59	59.19	71.74	87.51	88.58
2001	49.01	46.71	56.64	66.07	86.59	89.07
2002	52.03	42.60	49.73	59.09	73.49	85.71

Source: Estimated by Han *et al*., using Tanaka, Mori and Inaba model, based on *FIES* data, various years.

household income and expenditures by major categories, classified by the age groups of household head (HH), since 1982. Following exactly the same procedures as presented in Section 2 in the foregoing text, we estimated per capita individual at-home consumption of rice by age groups from 1982 to 2002, which is shown in Appendix Table 1. On the tacit assumption that the cohort effects in rice consumption should be formed in adolescence, the age groups under 10 years old are not provided.

A visual inspection of the individual consumption data in Appendix Table 1 arrayed by 10 year-intervals in age, 10-19, 20-29, ---, 60-69 years old, every year from 1982 to 2002 is revealing. A few distinct features of changes in household consumption of rice in the past two decades include: (1) in the early 1980s, the young and the old ate about the same amount of rice, consuming approximately 110 kg, regardless of age; (2) in the early 1990s, the young Koreans in their teens and 20s ate approximately 10 kg less than the middle aged people in their 30s and 40s, who consumed another 10 kg less in turn than older Koreans in their 50s and 60s; (3) after the turn of the century in the early 2000s, the disparity between age groups further widened, i.e., the young in their teens and 20s ate 15 kg less than the middle aged, who consumed 15-20 kg less than the old; (4) across all age groups, per capita individual consumption declined drastically and consistently over the entire period in question.

The data in Appendix Table 1 was decomposed by age, period (calendar year), and cohort effects, using the same Bayesian estimator (BE) and intrinsic estimator (IE) models which were applied to fresh

Appendix Table 2a
Estimates of Cohort Parameters of Individual Rice Consumption by Age, 10-19 to 60-69 Years Old, 1982 to 2002, by Means of Bayesian Estimator Model
Grand Mean = 87.70 (0.69) (kg)

Age Effects		Period Effects		Cohort Effects	
Age	(SD)	Year	(SD)	Birth Years	(SD)
10~19	9.17(6.9)	1982	20.97(3.3)	~1922	2.64(9.8)
20~29	−5.34(4.3)	1983	21.48(3.0)	1923~1932	19.94(7.1)
30~39	−7.80(2.0)	1984	18.14(2.9)	1933~1942	20.08(4.5)
40~49	−3.24(2.0)	1985	17.45(2.6)	1943~1952	14.84(2.5)
50~59	3.40(4.3)	1986	15.29(2.4)	1953~1962	5.24(2.5)
60~	3.82(12.1)	1987	13.35(2.3)	1963~1972	−8.15(4.5)
		1988	12.21(2.1)	1973~1982	−22.51(7.1)
		1989	9.65(2.0)	1983~1992	−32.07(9.8)
		1990	5.44(1.9)		
		1991	3.42(1.8)		
		1992	−1.51(1.8)		
		1993	−3.88(1.8)		
		1994	−5.30(1.9)		
		1995	−7.41(2.0)		
		1996	−8.47(2.1)		
		1997	−12.83(2.2)		
		1998	−19.40(2.4)		
		1999	−17.33(2.6)		
		2000	−18.78(2.8)		
		2001	−19.79(3.0)		
		2002	−22.40(3.3)		
ABIC = 871.57					

Note: Each effect is subject to the zero sum constraint.
Source : Calculated by the authors, using the BE model designed by Saegusa in the language of Visual Basics.

Appendix Table 2b
Estimates of Cohort Parameters of Individual Rice Consumption by Age, 10-19 to 60-69 Years Old, 1982 to 2002, by Means of Intrinsic Estimator Model
Grand Mean = 87.34 (0.73) (kg)

Age Effects		Period Effects		Cohort Effects	
Age	(SD)	Year	(SD)	Birth Years	(SD)
10~19	9.95(1.6)	1982	20.96(2.3)	~1922	0.56(2.78)
20~29	−5.86(1.4)	1983	23.25(3.4)	1923~1932	20.32(2.3)
30~39	−8.51(1.5)	1984	17.18(2.4)	1933~1942	15.64(2.2)
40~49	−3.64(1.6)	1985	18.16(2.4)	1943~1952	6.33(2.1)
50~59	3.53(1.4)	1986	15.25(2.4)	1953~1962	5.24(2.5)
60~	4.52(3.3)	1987	13.05(2.4)	1963~1972	−7.54(1.8)
		1988	12.78(2.4)	1973~1982	−22.46(1.9)
		1989	10.30(2.4)	1983~1992	−33.08(3.3)
		1990	4.46(2.4)		
		1991	4.51(2.4)		
		1992	−2.73(2.4)		
		1993	−4.40(2.4)		
		1994	−4.98(2.4)		
		1995	−8.54(2.4)		
		1996	−7.03(2.4)		
		1997	−11.95(2.4)		
		1998	−23.00(2.4)		
		1999	−15.87(2.4)		
		2000	−18.93(2.4)		
		2001	−19.06(2.4)		
		2002	−23.42(2.4)		
AIC = 837.65					

Note: Each effect is subject to the zero sum constraint.
Source : Calculated by the authors, using the IE model designed by Saegusa in the language of Visual Basics.

fruit consumption in Japan (Section 3 in the text). The results are presented in Appendix Table 2a for BE and Appendix Table 2b for IE, respectively. Unlike the case of fresh fruit consumption in Japan, both BE and IE yield quite similar estimates of the age and cohort effects, resulting in almost identical estimates of period effects for the survey years, 1982 to 2002. Distinct cohort effects, with the newer generations exhibiting a diminishing propensity to consume rice, are evident. Also evident are (pure) period effects which, controlling for age and cohort effects, show a consistent downward trend in rice consumption among all Koreans over the 20-year period after the early 1980s.

Now that we have determined the parameters of our A/P/C model of rice consumption in Korea, we can further predict individual rice consumption by age (and cohort) in future years, as we conducted in the foregoing sections, particularly Section 4. However, in the case of fresh fruit consumption, the (pure) period effects were neither trending consistently upwards nor downwards over the survey period. Thus, we plausibly assumed that the period effects in the near future years would stay the same as the average of the latest few years. With period effects for rice consumption in Korea suggesting a consistently declining trend, it is more natural to assume that the period effects will be increasingly negative in the future, unless, say, future trends in the Korean economy disrupts this trend. The only remaining question is "falling at what speed?"

First we predicted future consumption by extrapolating our estimated 1982 to 2002 period effects in order to assign probable levels to the period effects in 2002 to 2012. Appendix Table 3a and Appendix Table3b report projections for per capita individual

Appendix Table 3a Projections of Individual Korean Rice Consumption by Age by BE-I (kg)

Reference: Per Capita Rice Consumption by Age, Derived Directly from *FIES* (kg)

	10s	20s	30s	40s	50s	60s	P. Effects		10s	20s	30s	40s	50s	60s
2002	40.82	35.87	47.77	65.72	81.96	87.62	−23.98	2002	52.03	42.60	49.73	59.09	73.49	85.71
2003		32.52	43.94	61.99	78.60	84.70	−26.38	2003	NA	NA	NA	NA	NA	NA
2004		29.16	40.10	58.25	75.25	81.78	−28.77	2004	NA	NA	NA	NA	NA	NA
2005		25.81	36.27	54.51	71.89	78.86	−31.17	2005	50.04	32.22	32.48	38.61	59.51	75.21
2006		22.46	32.44	50.77	68.53	75.93	−33.57	2006	33.39	25.22	33.77	40.82	54.47	71.83
2007		19.10	28.60	47.04	65.17	73.01	−35.97	2007	14.97	26.08	37.90	44.29	53.39	65.79
2008		15.75	24.77	43.30	61.81	70.09	−38.37	2008	NA	NA	NA	NA	NA	NA
2009		12.39	20.93	39.56	58.46	67.17	−40.76	2009	NA	NA	NA	NA	NA	NA
2010		9.04	17.10	35.83	55.10	64.25	−43.16	2010						
2011		5.69	13.27	32.09	51.74	61.32	−45.56	2011						
2012		2.33	9.43	28.35	48.38	58.40	−47.96	2012						

Notes: Period effects = trend extrapolated from 1982 to 2002.

Appendix Table 3b Projections of Individual Korean Rice Consumption by Age by IE-I (kg)

Reference: Per Capita Rice Consumption by Age, Derived Directly from *FIES* (kg)

	10s	20s	30s	40s	50s	60s	P. Effects		10s	20s	30s	40s	50s	60s
2002	39.95	34.74	47.01	65.75	82.23	87.79	−24.28	2002	52.03	42.60	49.73	59.09	73.49	85.71
2003		31.25	43.09	61.93	78.87	84.90	−26.71	2003	NA	NA	NA	NA	NA	NA
2004		27.77	39.18	58.13	75.52	82.03	−29.13	2004	NA	NA	NA	NA	NA	NA
2005		24.28	35.25	54.31	72.16	79.14	−31.56	2005	50.04	32.22	32.48	38.61	59.51	75.21
2006		20.79	31.33	50.49	68.80	76.25	−33.99	2006	33.39	25.22	33.77	40.82	54.47	71.83
2007		17.30	27.41	46.68	65.44	73.37	−36.42	2007	14.97	26.08	37.90	44.29	53.39	65.79
2008		13.81	23.49	42.86	62.07	70.48	−38.85	2008	NA	NA	NA	NA	NA	NA
2009		10.33	19.58	39.05	58.72	67.60	−41.27	2009	NA	NA	NA	NA	NA	NA
2010		6.84	15.65	35.23	55.36	64.71	−43.70	2010						
2011		3.35	11.73	31.42	52.00	61.83	−46.13	2011						
2012		−0.14	7.81	27.60	48.64	58.94	−48.56	2012						

Notes: Period effects = trend extrapolated from 1982 to 2002.

consumption by age groups for the years 2002 to 2012, synthesizing the extrapolated period effects with our estimates of age and cohort effects derived by means of BE and IE, respectively. The youngest cohort group covered by our study was 10-19 years old in 2002, born in 1983-92. Thus, we have no estimates of the cohort effects for the youngest age group which reached 10-19 years old after 2002. The first age column in the table is likewise left blank after the year, 2002*5.

*5 For example, the age group, 10-19 years old in 2005 comprises approximately 50 % of the cohort born in 1983-92 and another 50 % of those born in 1993-2002.

How do predicted rates of consumption compare with actual rates of consumption? For reference, we attach estimates of per capita individual consumption by age groups for the years of 2005, 2006 and 2007, derived from *FIES* (Han *et al*., 2010).

Both BE and IE yield quite similar predictions of individual consumption by age for the future years up to 2012. As compared with actual consumption by age derived directly from *FIES* , our projections for the years of 2005, 2006 and 2007 look fair, except that the predicted consumption by the youngest group, 20-29 years old, could be slightly too low and that for the group aged 50-59 years old appears a little too high. However, extending our projections further into the future produces a fatal flaw. Using the results of our model estimates by means of IE, we project individual consumption by young adults in their 20s at minus 0.14 kg/person, on average, in 2012 (Appendix Table 3b). Similarly, using the results of our model estimated by means of BE, we project individual consumption among these same people in 2012 at 2.33 kg, on average, which is lower than 5 % of the level of those over 50 years of age in the same year (Appendix Table 3a).

As an alternative, "bold-guts" approach, we next assigned probable levels to the period effects in 2002 to 2012 by extrapolating only from the last half of the period by our estimation sample, 1992 to 2002, instead of the full period, 1982 to 2002. For our results based on both the BE and IE, we obtained probable levels for the period effects that are slightly milder in slope as compared with the first trial above. We thereafter assigned these extrapolated figures to the period effects of the years 2002 to 2012, following the same procedures to calculate our projections as conducted above. The results are shown in Appendix Table 4a (BE) and Appendix Table 4b (IE). We obtained no negative values and/or incredibly low predictions for individual consumption but, on the other hand, we find that the predicted levels of consumption for the older age groups have slightly floated-up.

Finally, as discussed already in Section 4 of the text, researchers have learned over the years that a logarithmic transformation of the economic variables, $\log(X_{it})$, may improve model fit. The question of

Appendix Table 4a
Projections of Individual Korean Rice Consumption by Age by BE−II

	10s	20s	30s	40s	50s	60s	P Effects
2002	41.46	36.51	48.41	66.36	82.60	88.26	−23.34
2003		33.39	44.81	62.86	79.48	85.57	−25.51
2004		30.26	41.20	59.35	76.35	82.88	−27.67
2005		27.14	37.60	55.84	73.22	80.19	−29.84
2006		24.01	33.99	52.33	70.09	77.49	−32.01
2007		20.89	30.39	48.82	66.96	74.80	−34.18
2008		17.76	26.78	45.32	63.83	72.11	−36.35
2009		14.64	23.18	41.81	60.70	69.41	−38.52
2010		11.51	19.57	38.30	57.57	66.72	−40.69
2011		8.39	15.97	34.79	54.44	64.03	−42.86
2012		5.26	12.36	31.28	51.31	61.33	−45.03

Notes: Period effects = trend from 1992 to 2002 extrapolated.

Appendix Table 4b
Projections of Individual Korean Rice Consumption by Age by IE−II

	10s	20s	30s	40s	50s	60s	P Effects
2002	40.85	35.64	47.91	66.65	83.13	88.69	−23.38
2003		32.45	44.29	63.14	80.07	86.11	−25.51
2004		29.26	40.67	59.62	77.01	83.52	−27.64
2005		26.07	37.04	56.10	73.95	80.93	−29.77
2006		22.88	33.42	52.58	70.88	78.34	−31.90
2007		19.68	29.79	49.06	67.82	75.75	−34.04
2008		16.49	26.17	45.54	64.76	73.16	−36.17
2009		13.30	22.55	42.02	61.69	70.57	−38.30
2010		10.11	18.92	38.50	58.63	67.98	−40.43
2011		6.92	15.30	34.98	55.57	65.39	−42.56
2012		3.72	11.67	31.46	52.50	62.80	−44.70

Notes: Period effects = trend from 1992 to 2002 extrapolated.

Appendix Table 5a
Projecting Korean Rice Consumption by Age in log by BE

	10s	20s	30s	40s	50s	60s
2002	43.25	40.41	50.25	66.36	81.62	87.02
2003		38.46	47.50	63.01	78.43	84.37
2004		36.59	44.89	59.83	75.36	81.80
2005		34.82	42.43	56.81	72.41	79.31
2006		33.14	40.10	53.94	69.58	76.90
2007		31.54	37.91	51.22	66.86	74.56
2008		30.01	35.83	48.63	64.24	72.29
2009		28.56	33.86	46.18	61.73	70.09
2010		27.18	32.01	43.85	59.32	67.96
2011		25.86	30.25	41.63	57.00	65.89
2012		24.61	28.59	39.53	54.77	63.89

Notes: Period effects = trend from 1982 to 2002 extrapolated.

Appendix Table 5b
Projecting Korean Rice Consumption by Age in log by IE

	10s	20s	30s	40s	50s	60s
2002	42.81	39.99	49.93	66.53	82.00	87.59
2003		38.02	47.17	63.14	78.82	85.00
2004		36.14	44.56	59.93	75.77	82.48
2005		34.35	42.10	56.87	72.84	80.03
2006		32.65	39.77	53.97	70.01	77.66
2007		31.04	37.57	51.22	67.30	75.35
2008		29.50	35.49	48.61	64.70	73.12
2009		28.04	33.53	46.14	62.19	70.95
2010		26.66	31.67	43.79	59.78	68.85
2011		25.34	29.92	41.55	57.47	66.81
2012		24.09	28.27	39.44	55.24	64.83

Notes: Period effects = trend from 1982 to 2002 extrapolated.

functional form is one of the key issues when working with an A/P/C model in general. Given that the period effects are large in size, relative to the age and cohort effects (Appendix Tables 2a and 2b) and compared with the results for other products, say fresh fruit in Japan (Table 3a and Table 3b), we considered whether a logarithmic transformation of individual consumption by age groups might lead to more realistic projections. Thus, we undertook exactly the same procedures as described in the foregoing paragraphs in order to predict individual consumption by age groups from 2005 to 2012. Our results are shown in Appendix Table 5a (BE) and Appendix Table 5b (IE), assigning the trend extrapolated from 1982 to 2002[*6] to the period effects of the respective years. Both BE and IE seem to yield quite similar predictions across all age groups. Also, apparent "under"-predictions for the younger adults, at least for the last few years of 2010 to 2012, have been mitigated on the surface.

*6 When the trend extrapolated from 1992 to 2002 applied, no significant differences occurred in the results.

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