Decomposing Individual Consumption by Age From 1987 to 2006 Into Age, Cohort, and Period Effects

Applying the A/P/C analysis to the estimates of individual consumption by age group in table 4 allows for quantifying age effects for different age groups as such, cohort effects for different birth cohorts as such, and (pure) period effects for different years as such. This analysis uses the Bayesian cohort model first developed by Nakamura (1986) and modified by Clason (Mori, 2001). To overcome the "identification problem" inherent in the linear additive A/P/C model (Mason and Fienberg, 1985), Nakamura introduced *zenshintekihenka* (gradual changes) between successive parameters for the entire range of each of three effects, instead of equality of a few chosen parameters of either age, cohort, or period effects (Rodgers, 1982; Smith, 2004). These identifying constraints of zenshintekihenka are calibrated by hyperparameters ranging from 2^8 to 2^{-8} subject to ABIC (Akaike's Bayesian Information Criteria). Mathematically, the Nakamura model can be expressed as follows:

$$X_{it} = B + A_i + PE_t + C_k + E_{it} \qquad (6)$$

X_{it} : average consumption by person of i years of age at period t

B: grand mean effect

A_i : age effect to be attributed to age i years old

PE_t : period effect to be attributed to period t

C_k : cohort effect to be attributed to cohort k [12]

E_{it} : random error

Minimize:

$$\Sigma\left[X_{it} - (B + A_i + PE_t + C_k)\right]^2 \qquad (7)$$

Minimize:

$$\frac{1}{\sigma_A^2}\Sigma(A_i - A_{i+1})^2 + \frac{1}{\sigma_P^2}\Sigma(PE_t - PE_{t+1})^2 + \frac{1}{\sigma_C^2}\Sigma(C_k - C_{k+1})^2 \qquad (8)$$

$$\Sigma_i A_i = \Sigma_t PE_t = \Sigma_k C_k = 0 \qquad (9)$$

In the particular case of oranges, where the differences in consumption per person between the younger and older age groups have widened in recent years (to the order of 1 to 10), the logarithms of X_{it} perform significantly better than the untransformed variables. Table 5 provides estimates of age, period (annual year), and (birth) cohort effects on top of the grand mean effect, all in logs, which explain the changes in individual consumption of oranges by age from 1987 to 2006. For easier visual assessment, estimated cohort parameters in actual numbers are presented in table 6, although the statistical fits are substantially inferior.

---

[12] In the case of a standard cohort table, in which the survey period matches the age classification, a cohort in a particular age cell moves down to the next age cell at the subsequent survey period—that is, every cohort follows a diagonal line in the table. In the data used by this study, age is classified by 5-year intervals, and data are available for each year (period) from 1987 to 2006. A moving average operator in the design matrix apportions the cohorts into annual age cells. Consider cohort k in the ith age cell in 1987, for example. It is assumed that 20 percent of cohort k has moved to the next age cell (i + 1) in 1988 and that the ith age cell in 1988 comprises 20 percent of the next younger cohort (k + 1) and 80 percent of the remaining cohort k. Nakamura (1986) pioneered this general cohort analysis, and further details on the methods used in the current study are given in chapter 10, "Age in Food Demand Analysis" (pp. 323-34 in particular) in Mori (ed.), *Cohort Analysis of Japanese Food Consumption* (2001).

The data in table 4 cover all age groups from age 0 to 4 to age 75 and older. Using all the age cells from the youngest to the oldest provides more degrees of freedom in running the least square estimation of equation (7), subject to the identifying constraints of equation (8). However, previous research has shown that estimates of individual consumption by age are less stable for the younger age groups, particularly children under age 15.[13] Including these young age groups could change the size of the period effects and, consequently, other effects in the row. Therefore, the three youngest age groups, 0-4, 5-9, and 10-14, were excluded from this cohort analysis of orange consumption.

Table 5

Changes in individual consumption of fresh oranges, decomposed into age, period, and cohort effects

Age effects: A_i		Period effects: P_t		Cohort effects: C_k	
Age groups (years)	*Logarithm*	Calendar year	*Logarithm*	Years born	*Logarithm*
15-19	-0.1725	1987	0.1123	~ 1912	-0.1453
20-24	-0.2076	1988	0.0378	1913-17	-0.0783
25-29	-0.2221	1989	0.0693	1918-22	0.0206
30-34	-0.1494	1990	0.0933	1923-27	0.0949
35-39	-0.0534	1991	-0.1232	1928-32	0.1349
40-44	-0.0088	1992	0.1127	1933-37	0.1689
45-49	0.0050	1993	0.1167	1938-42	0.1781
50-54	0.0170	1994	0.1543	1943-47	0.1699
55-59	0.0415	1995	0.1347	1948-52	0.1695
60-64	0.0853	1996	0.0573	1953-57	0.1050
65-69	0.1518	1997	0.0860	1958-62	0.0450
70-74	0.2276	1998	0.0210	1963-67	-0.0065
75 ~	0.2855	1999	-0.2561	1968-72	-0.0289
		2000	-0.0249	1973-77	-0.0614
		2001	-0.0830	1978-82	-0.1606
		2002	-0.1168	1983-87	-0.2599
		2003	-0.0895	1988 ~	-0.3459
		2004	-0.1229		
		2005	-0.0930		
		2006	-0.0862		

Note: Grand mean effects = 0.7912 (original unit: 100 grams).
~ means lower than or equal to, before a number, and older than or equal to, after a number.
Source: Estimates from minimization exercise with original quantity data transformed into logarithms.

---

[13] For example, Ishibashi, in two publications from 2007, found several cases of negative consumption estimates for the younger age groups, using methods and data similar to those used in this study. Also, for the case of ages 0-9, in particular, see Mori, Hiroshi, and William D. Gorman, "A Cohort Analysis of Japanese Food Consumption—Old and New Generations," chapter 8 in Mori (ed.), 2001, pp. 265-6.