Economic Bulletin of Senshu University
Vol. 56, No. 1, 31-40, 2021

Animal sourced food products and human height —The cases of Japan and South Korea : simple regressions

Hiroshi Mori*

Abstract

By either cross-sectional or time-series analyses, greater consumption of animal protein proves effective in increasing body height. In the past half century, Japan and South Korea have achieved rapid and steady economic progress to improve food consumption to a great extent, i.e., per capita consumption of animal-sourced products increased conspicuously. In both countries, children increased in height unprecedentedly for half a century but ceased to grow any taller lately whereas consumption of animal protein still kept increasing.

Have they depleted in reserves of the gene potential for height? Quite likely so. One thing common in the two countries, however, is that children in both countries steered away from fruit and vegetables, while increasing consumption of animal-sourced foods.

JEL classification : B41, C22, I115, P46

Key words : animal protein, body height, regression, fruit/vegetables, Japan, South Korea

Introduction

Based on either internationally cross-sectional surveys or time-series analyses in selected countries, it is well accepted in the realm of human biology that consumption of high-quality protein in animal sourced foods results in increasing human height [1][2][3][4] (Baten and Blum, 2010 ; Grasgruber et al., 2014, 2020 ; Heady, Hirvonen, and Hoddinott, 2018). Japan and South Korea (the latter with a two-decade lag due to Korean War, 1950-53) in North-East Asia achieved marvelous economic progress in the past half century. People's living standards improved immensely and food consumption amplified both in quantity and quality, with animal products augmented in per capita caloric supply (Table 1). Children in the two countries increased conspicuously in height at all ages accordingly (Table 2) [5] (Steckel, 1995).

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* Professor Emeritus, Senshu University <the0033@isc.senshu-u.ac.jp>

Table 1 Changes in per capita caloric intakes : all foods and animal products, Japan and S. Korea, 1970 to 2015

(kcal/capita/day)

	Grand Total		Animal Products	
Year*1	Jp	Kr	Jp	Kr
1970	2721	2812	425.7	108.3
1975	2736	3097	474.3	169.7
1980	2785	3046	539.0	229.7
1985	2854	2982	577.3	275.3
1990	2950	2990	618.3	317.3
1995	2938	3021	624.0	411.3
2000	2895	3090	600.3	449.0
2005	2816	3104	577.7	475.0
2010	2691	3279	549.0	544.7
2015	2705	3341	548.3	603.3

Notes : *1 3-year moving average.
Sources : FAOSTAT, *Food Balance Sheets*, Old and new.

Table 2 Changes in mean height of school boys by age, South Korea and Japan, 1950 to 2017

(cm)

Japan	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2017
6yrs	108.8	110.3	111.7	113.4	114.5	115.2	115.7	116.4	116.8	116.8	116.7	116.7	116.7	116.5	116.5
12yrs	135.9	139.1	141.7	144.7	147.0	148.6	149.5	150.1	151.5	152.0	152.8	152.6	152.4	152.6	152.7
17yrs	161.7	163.4	164.9	166.7	167.9	168.8	169.6	170.2	170.5	170.9	170.9	170.8	170.7	170.7	170.6
S.Korea			(1962)	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2017
6yrs	NA	NA	111.4	111.9	112.9	112.9	115.4	116.2	117.7	119.0	120.2	121.0	121.8	120.5	120.6
12yrs	NA	NA	140.2	141.8	143.7	143.2	145.2	147.6	149.7	152.0	154.8	156.9	158.0	156.7	157.2
17yrs	NA	NA	163.3	163.8	166.1	166.0	167.3	168.9	169.7	171.0	172.9	173.7	173.7	173.4	173.5

Sources : *School Health Surveys*, Dept. Education, respective country.
Note : 3 year moving average, as 2000 = average (1999 : 2001)

data in regard to food supply and child height, based on food balance sheets and nationwide school health survey statistics, respectively for the past half century, this technical note examines quantitative correlations between per capita supply of animal sourced foods and child height over the past half century in the two countries. The author had already realized that a high consumption of animal protein alone does not result in increasing body height, if the consumption of other essential nutrients is insufficient [6][7][8][9] (Blum, 2013 ; Mori, 2018 ; Mori, 2019 ; Mori, Cole and S. Kim, 2021). This note is expected to provide quantitative evidence on the degree to which consumption of animal products contributes to increasing human height, if other nutritional conditions prevail, in North East Asia.

Data

Nutritional surveys provide per capita intakes of major food items, along with nutritional components, such as protein, fats, minerals, vitamins, etc., across residential areas (big cities, rural areas, etc.), and across age groups, after 1996 in Japan [10]. South Korea initiated a very intensive health and nutritional survey in 1998, followed by second and third rounds in 2001 and 2005 [11] (KNHNES). These national surveys also provide physical characteristics, such as stature, blood pressure, etc. and are valuable for identifying physical conditions from nutritional perspectives but while useful to our analyses, lack a long enough time series.

For food consumption, we rely on food balance sheets, prepared by a national agency every year on consistent and uniform formulae determined by the international agency, FAO, United Nations. FAOSTAT, *Food Balance Sheets* started in 1961 and are available until the year 2018 [12]. As the Japanese government, Ministry of Agriculture, publishes, food balance sheets, from the fiscal year of 1946, we use *Food Balance Sheets*, published by Ministry of Agriculture [13], for Japan, for the period of 1946 to 2018, whereas FAOSTAT data are used for South Korea, for the period of 1961 to 2018. *Food Balance Sheets*, prepared by KREI [14], are available to the author for the period from 1980 to 2018 to verify the data from FAOSTAT in this project.

School health surveys have been conducted every year on a national scale both in Japan and South Korea for a long time (Japanese government, Ministry of Education, *School Health Examination Survey* ; Republic of Korea, Department of Education, *School Health Examination Survey*) [15][16]. The surveys, however, cover 12 school grades, from 1st grade in primary school to senior grade in high school : age 6 to age 17. Pre-school years from 0 to 5 are not available. We often come across the contention that the first 1,000 days should be critical for adults' height in the future years [17][18][19][20] (Cole, 2003 ; Cole and Mori, 2017 ; Deaton, 2007 ; Prentice et al., 2013 ;). School health surveys provide reliable and continuous data on school children, from 6 years on. No one can command the perfect data-sets, as required.

Regression Analyses

We have the data on food supply by commodity, from 1946 to 2018 for Japan, based on food balance sheets, Ministry of Agriculture. For South Korea, we rely on FAOSTAT, which started to publish food balance sheets in 1961. As regards boys' height, *School Health Surveys* provide mean height of 1st graders in primary school to 3rd graders in high school, conducted every year in the first month of the school year. With the help of Ms. A. Kubota, Senshu University, Ikuta [21], the author obtained the stature data, from 1960 to 2018 for South Korea, which was not an easy job to compile. In order to mitigate annual fluctuations in mean height by age, particularly in the earlier years of the survey, we employ the 3 year moving averages for all grades in such a way as : $H_{it} = (H_{it-1} + H_{it} + H_{it+1})/3$, where i denotes age, and t year of survey, for the entire period either for S. Korea or Japan.

We first run simple regressions, with mean height of high school 3rd graders in the selected survey year, as Y_{17t} and per capita caloric supply from animal products in the preceding years as explanatory variate. Mean height of 17 years old in the survey year, t should have been determined by the accumulated environmental effects from the year of birth, *t-18* to *t-1*, the previous fiscal year of the survey. As a simplified approach, mean height at year *t* is regressed against average per capita caloric supply from animal products in per capita kcal/day in the preceding 5 years*1.

Japan

$$H_{J17\,t} = 162.55 + 0.0163\, AP_t$$
$$(997.8) \quad (40.74)$$
$$\text{Adj } R^2 = 0.9629 \qquad (1)$$

S. Korea

$$H_{K17\,t} = 163.59 + 0.0192\, AP_t$$
$$(697.1) \quad (29.87)$$
$$\text{Adj } R^2 = 0.9459 \qquad (2)$$

Where AP_t represents daily caloric supply from animal-sourced foods in the preceding 5 years, *t-5* to *t-1*.
Figures in parentheses denote t-values.

The author is not well experienced in regression analyses of either economic or biological events but can assert that equations (1) and (2) demonstrate that caloric supply from animal products do statistically explain actual changes in mean height of school boys, 3rd graders of high school, 17 years of age in the post-war half century, to a high degree of accountability, both for Japan and South Korea. One may be allowed to predict that boys in high school senior grade, either in Japan or South Korea, will be taller in mean height, if they increase intakes/consumption of animal products in the future years, after the mid-2010s. More concretely, if school children increase animal-sourced foods by 100 kcal/day on average in 5year time, they are predicted to grow in height by 1.63 cm in Japan and 1.92 cm in South Korea, respectively.

Fig. A traces actual changes in mean height of school boys at age 17 and average daily per capita caloric supply from animal products in the past half century in Japan and South Korea, respectively*2. Per capita consumption of animal products was increasing steadily toward the end of the 1990s and kept this high consumption afterwards in Japan but Japanese boys did not increase in mean height any longer after the early-1990s. With a two decade-lag, South Korea followed the similar pattern as Japan, i.e., per capita consumption of animal products was increasing vigorously toward the end of the 2010s but Korean boys ceased to grow any taller in the mid-2000s. Per capita caloric supply from animal products increased by 142.2 kcal from 2005 to 2017 in South Korea but high school seniors declined in mean height by 0.3 cm, in place of increasing by $0.0192 \times 142.2 = 2.73$ cm, over the same period.

A glass of milk (180 cc) furnishes 124 kcal and a piece of fat-trimmed pork, 50 gr, furnishes 130 kcal of energy, respectively. Under the current food condition, prices and supply situations either in the Japanese or S. Korean economy, it may not be unreasonable to pose a question, if children increase their animal-sourced foods by 100 kcal/day*3 in a five year-time, what will be the changes in average stature be?

As a matter of fact, per capita caloric supply from animal products in Japan increased from 450 kcal in the end of the 1980s to 540 kcal in the early-2000s but children did not grow any taller in mean height after the early-1990s. Per capita caloric supply from animal products in South Korea kept increasing from 430 kcal in the mid-2000s to 600 kcal in the end of 2010s but children did not grow any taller after the mid-2000s. One could easily conclude that these stagnations in body height resulted from

Fig. A Changes in mean height of school boys in high school senior grade, and per capita-per day caloric supply from animal products, Japan and South Korea, 1951 to 2015

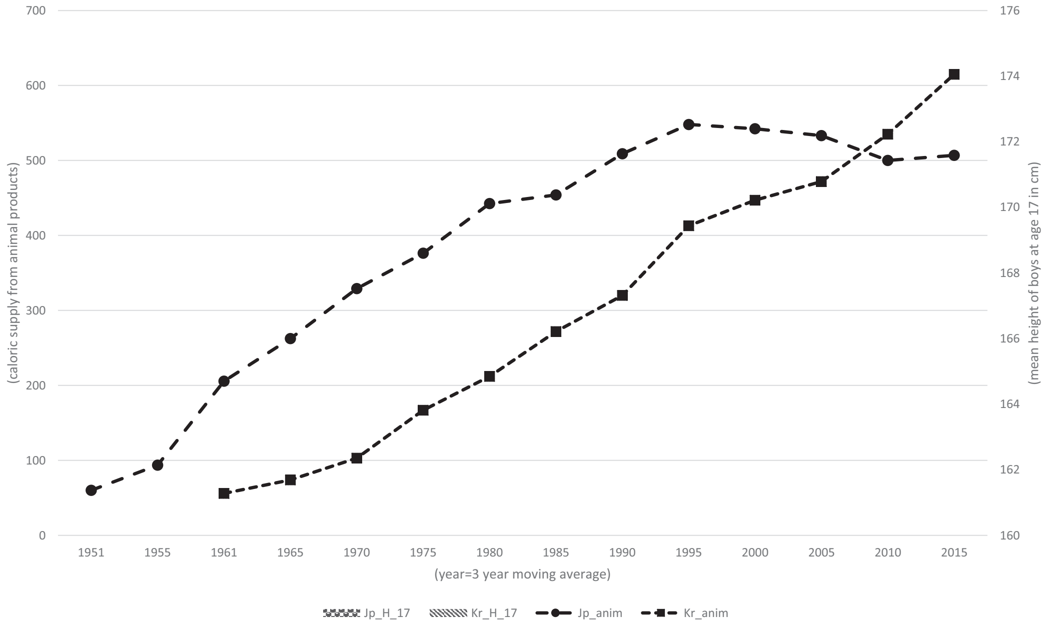
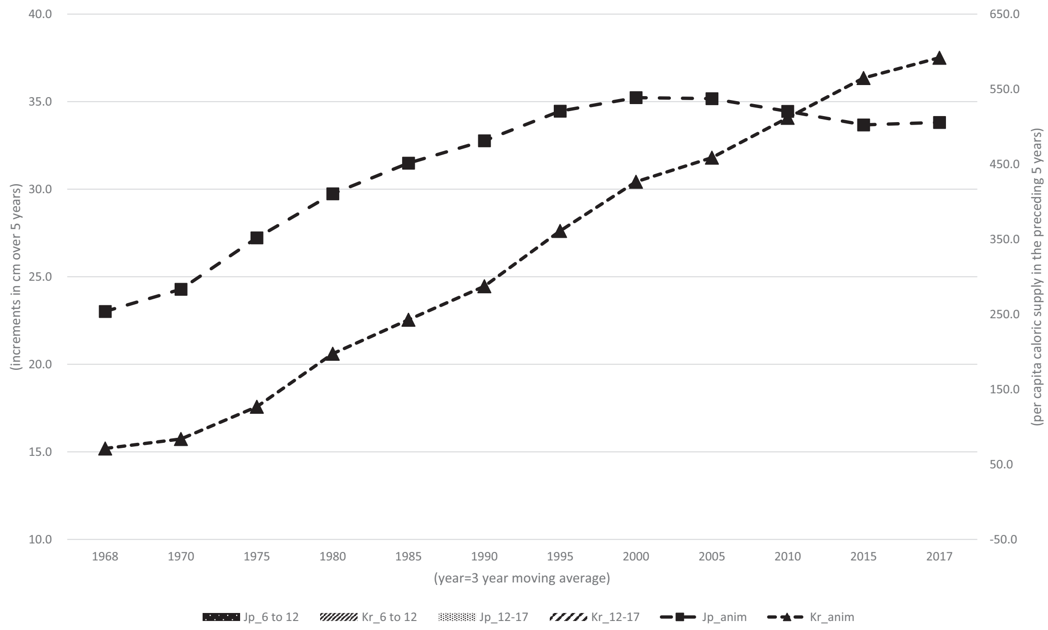


Fig. B Changes in increments from 6 to 12 and 12 to 17 years of age, school boys, and per capita-per day caloric supply from animal products, Japan and S. Korea, 1968 to 2017



"the depletion in reserves of the gene potentials" endowed to the two different ethnics, Japanese and Koreans, respectively [22] (Kopczynski, 2016, p. 52, p. 57). Anthropologists, if not all, may take this view. Observing ordinary young men in Japan, including the author's sons and grandson, who is 181 cm tall, he simply cannot admit that either Japanese or Koreans have depleted their "reserves of the gene potentials" in body height. The author has long been concerned that the young in Japan have quit eating properly for some decades, i.e., very little fruit and/or very little vegetables, as will be discussed in the next section.

Mean height of boys at age 17 in a given year, say in 1980, consists of mean height of boys at age 12 in 1975, plus increments in height between 12 and 17 and, likewise, mean height of boys at age 12 in 1975, consists of increments in height from 6 in 1969 to 12 in 1975. Fig. B displays increments in mean height of boys age 6 to 12 and age 12 to 17, respectively from year 1968 to 2017, with 5 year-interval.

＊1 Mean height of high school seniors in the first month of school year has been influenced by the food intakes in the preceding 17 years, from age 0 to age 16, in a complex manner. A "distributed-lag model" [23][24] (Nerlove, 1956; Anderson, 1974) could be designed, but is far beyond our analytical ability.

＊2 In order to avoid congestions, years are shown every 5 years, i.e., 1970, 1975, and 1980.

＊3 80 kcal, 90 kcal, 100 kcal, 110 kcal, and 120 kcal will average to 100 kcal/day.

Why did children cease to grow taller while animal products kept increasing?

White Paper on Agriculture, 1994, Ministry of Agriculture, Japan issued a remark on the tendency of *wakamono no kudamaono-babare* ("steering away from fruit by the young"), with no explicit implications for the outcome [25]. Children in Japan started to turn away from, i.e., reduce eating fruit at home in the end of the 1970s. They ate only 10 % of the fruit that was consumed some 20 years ago in the end of the 1990s and they further reduced fruit consumption afterwards (Table 3) [26] (Mori and Stewart, 2011). The author was aware that an increase in animal proteins alone does not result in increasing adult height, if the consumption of other essential nutrients is insufficient [6] (Blum, 2013), i.e., fruit may include 'essential nutrients' [27] (Mori, 2018). Only a year or

Table3 Changes in per capta at-home consumption of fresf fruit by age groups, 1971 to 2010, Japan

(kg/year)

	1971	1980	1985–86	1990	1995–96	2000	2008–10
0〜9	36.3	26.5	15.2	8.9	4.7	2.3	3.0
10〜19	45.6	30.5	20.1	14.9	9.4	5.7	4.7
20〜29	48.3	31.5	23.4	16.8	15.1	11.8	10.5
30〜39	46.1	43.8	36.6	30.4	23.6	21.8	16.4
40〜49	51.0	52.6	48.5	44.9	37.2	33.4	22.6
50〜59	54.4	59.9	56.6	54.0	50.5	48.5	36.4
60〜	42.9	56.4	60.4	61.2	60.4	63.3	57.1
Grnd-ave	45.6	41.6	36.4	33.8	31.5	31.1	28.9

Sources: derived by the author from *FIES* [32], various issues, the TMI model.

Table 4 Changes in per capita household expenditures on vegetables by age groups, 1990 to 2019, S. Korea

(% of the 50's)

age group	1990–91	1995–96	2000–01	2005–06	2010–11	2014–15	2017–19
0～9	49.8	31.4	30.5	19.4	12.6	13.6	8.5
10～14	51.8	34.5	34.1	22.5	15.3	15.1	10.1
15～19	51.6	35.1	36.5	25.9	18.9	16.8	12.9
20～29	55.2	42.1	43.8	34.5	27.7	25.5	22.4
30～39	73.3	64.7	62.3	54.0	48.2	50.2	45.6
40～49	96.0	87.8	85.5	78.0	72.6	73.3	68.1
50～59	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60～	95.1	98.3	104.0	107.0	116.2	121.1	130.5
percapita							(kg/year)
supply	131.7	156.4	154.5	149.7	143.4	145.6	142.5

Table 5 Changes in per capita household expenditures on meats by age groups, 1990 to 2019, S. Korea

(% of the 50's)

age group	1990–91	1995–96	2000–01	2005–06	2010–11	2014–15	2017–19
0～9	41.4	39.6	49.5	41.4	45.2	49.8	48.0
10～14	42.6	41.7	52.0	46.2	49.6	52.9	48.4
15～19	38.5	37.0	50.7	47.1	49.2	53.0	46.0
20～29	45.1	43.2	54.8	50.0	50.1	52.6	44.3
30～39	72.3	72.9	73.8	66.6	69.9	70.4	67.8
40～49	95.6	95.6	93.7	91.8	98.2	93.3	91.9
50～59	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60～	92.5	98.1	96.1	98.7	88.1	87.4	92.8
percapita							(kg/year)
supply	24.2	33.4	37.9	37.5	44.0	52.2	56.4

Sources : Derived in current won from *Kr Household Expenditure Surveys*, by the author by means of the TMI model.
KREI, *Food Balance Sheet*, various issues, for per capita supply.

so ago, the author obtained *Household Income and Expenditure Surveys*, classified by the age groups of household head, 1990 to 2019, Statistics Korea [28]. Table 4 provides changes in at-home vegetable consumption by age groups of individual household members, not household consumption by age of household head simply divided by the number of household members, from the early-1990s to the end of the 2010s. Children in Korea started to turn away from vegetables in the early-1990s and they are estimated to eat only 10 % of vegetables consumed by adults in their 50s in the end of 2010s.

Tables 5-6 provide per capita at-home consumption of meats and dairy products, in terms of expenditures, by age groups of household members, 0～9, 10～14, 15～19, 20～29, --, 60～, from the early-1990s to the end of the 2010s in South Korea. The author derived the expenditures by age groups of household mem-

Table 6　Per capita expenditures on dairies by age groups of household members by age groups, 1990 to 2015, S. Korea,

(in 2015 Won)

age/year	1990–91	1995–96	2000–01	2005–06	2010–11	2015–16
0～9	13798	17126	15798	14858	14935	12464
10～14	11290	13342	12077	12033	12554	10809
15～19	9386	10326	9807	10714	11247	9376
20～29	10386	12494	12701	12955	12569	9785
30～39	10616	13412	13727	13397	13694	12369
40～49	8519	8474	8606	8170	8355	10048
50－59	6831	6943	6968	7031	6751	8993
60～69	6948	6102	7203	7197	6800	9155
Av.supply						(kg/cap)
of milk	31.8	38.5	49.3	54.0	57.0	63.6

Sources: Derived in current won from *Kr Household Expenditure Surveys*, by the author, by means of the TMI model.
KREI, *Food Balance Sheet*, various issues, for per capita supply.

bers from *Household Income and Expenditure Surveys*, using the Tanaka, Mori, and Inaba–model [29].

The author has no background in nutritional biology. He wishes to invite the audience to the similar statistical phenomena, in which child height growth has been hindered not by insufficient consumption of animal products but by vegetables/fruit or other food products. Teens in Japan ceased to grow any taller in the 1990s, while consumption of animal products was increasing steadily. Their Korean peers also ceased to grow taller in the mid–2000s*4, while consumption of animal products was increasing vigorously until the end of the 2010s. Children in Japan started to turn away from fruit in the end of the 1970s and their Korean peers started to turn away from vegetables in the early 1990s and they ate substantially less vegetables than before. These changes in food eating patterns in the two countries seem to be “structural” [30][31] (Mori, Inaba and Dyck, 2016; Mori, 2020).

*4 As mentioned earlier, these trends in mean height may have resulted from “the depletion on reserve of the gene potential” assigned to the two ethnicities, respectively [22] (M. Kopczynski, 52; 56–57). Nutritionists, either in Japan or South Korea, may need to learn what have been taking place in food consumption by cohorts from old to new.

Brief Conclusions

After the end of WW II, Japan’s economy recovered to the pre–war level in 10 years and made remarkable progress steadily to the end of the century. South Korea, with a two–decade lag, due to Korean War (1950–53), made rapid and steady progress in the past half century. Food consumption improved in quantity and quality, as well, i.e., consumption of animal products increased to a great extent in both countries. Accordingly, children’s height increased unprecedentedly in the two countries.

Japanese children ceased to grow any taller in the early–1990s, however, when consumption of animal products was still increasing. Korean children also ceased to grow in height in the mid–2000s, while consumption of animal sourced food was increasing vigorously.

Children in Japan started to turn away from fruit in the end of the 1970s and consumed extremely less fruit in the 1990s–2000s than some 20 years ago, whereas their Korean peers also started to turn away from vegetables in the early 1990s and ate only 10% of vegetables as compared with the older generations in the late –2010s. Fruit and vegetables could be 'essential nutrients' for animal protein to be effective for children's normal growth in height.

References

［1］ Baten, J. and M. Blum（2014）Why are you tall while others are short? Agricultural production and proximate determinants of global heights. *European Review of Economic History*, 18, 144–65.

［2］ Grasgruber, P., J. Crack, T. Kalina, and M. Sebera（2014）The role of nutrition and genetics as key determinants of the positive height trend. *Economics and Human Biology*, 15, 81–100.

［3］ Grasgruber, P. and E. Hrazdira（2020）Nutritional and socio–economic predictors of adult height in 152 world populations, *Economics and Human Biology*, 20, 1–24（before authors' proof）.

［4］ Heady, D., K. Hirvonen, and J. Hiddnott（2018）Animal sourced foods and child stunting, *Am J Ag Economics*, aay053, 31, July.

［5］ Steckel. Richard（1995）Stature and the standard of living, *J of Economic Literatures*, XXXIIL, 1903–1940.

［6］ Blum, Mathias（2013）Cultural and genetic influences on the 'biological standard of living', *Historical Methods*, Jan–Mar, 46（1）, 19–30.

［7］ Mori, Hiroshi（2018）Secular changes in child height in Japan and South Korea : Consumption of animal proteins and 'essential nutrients', *Food and Nutrition Sciences*, 9, 1458–1471.

［8］ Mori, Hiroshi（2019）Why did Japanese children cease to grow taller in height in the midst of a booming economy in contrast with South Korean youth? *Annual Bulletin of Social Science*, No. 53, Senshu University, 223–240.

［9］ Mori, H., T. Cole and S. Kim（2021）Boys' height in South Korea in the past three decades : Why they ceased to grow taller?—Steering away from Kimchi, *Economic B Senshu U*, 55（3）29–39.

［10］ Japanese Government, Ministry of Health and Welfare, *National Nutrition Surveys*, various issues.

［11］ Republic of Korea, Korea Centers for Disease Control and Prevention, *Korea National Health and Nutritional Examination Survey*, various issues.

［12］ FAO, United Nations, FAOSTAT, *Food Balance Sheets*, 1961–2018.

［13］ Japanese Government, Ministry of Agriculture, *Food Balance Sheets*, 1946 to 2018.

［14］ Republic of Korea, KREI, *Food Balance Sheets*, 2002–2018.

［15］ Japanese government, Ministry of Education, *School Health Examination Survey*, various issues.

［16］ Republic of Korea, Department of Education, Center for Educational Statistics, *Statistical Yearbook of Education*, various issues.

［17］ Cole, T.J.（2003）. The secular trend in human physical growth : a biological view. *Economics and Human Biology*, 1, 161–168.

［18］ Cole, T.J. and H. Mori（2017）. Fifty years of child height and weight in Japan and South Korea : Contrasting secular trend patterns analyzed by SITAR. *Am J Hum Biol*, https : //doi.org/10.1002/ajhb.23054.

［19］ Deaton, Angus（2007）. Height, Health, and Development. PNAS, vol. 104, no. 33, 13232–13237.

［20］ Prentice, A., K. Ward, C. Goldberg, L. Jarjou, S. Moor et al.（2013）. Critical windows for nutritional interventions against stunting," *Am J Clin Nutr*, 97, 911–8.

［21］ Kubota, Ai（2019）Senshu University, Ikuta Library（Courtesy）.

［22］ Kopczynski, Michal（2016）Body height as a measure of the standard of living : Europe, America and Asia, BOCZNIKI DZIEJOW SPOLECZNYCH I GOSPODARCZYCH Tom LXXVI, 39–60.

［23］ Nerlove, M.（1956）Estimates of supply of selected agricultural commodities, *Journal of Farm Economics*, 38（2）, 496–509.

［24］ Anderson, Kym（1974）Distributed lags and barley acreage response analysis, *Australian J Agri-*

cultural and Resource Economics, 18 (2), 119–132.

[25] Japanese government, Ministry of Agriculture, Forestry and Fisheries (1995) *White Paper on Agriculture 1994*, Tokyo.

[26] Mori, H. and H. Stewart (2011) Cohort analysis: ability to predict future consumption—The case of fresh fruit in Japan and rice in Korea, *Annual Bulletin of Social Sciences*, Senshu University, 45, 153–173.

[27] Mori, Hiroshi (2018) Secular changes in child height in Japan and South Korea: consumption of animal protein and 'essential nutrients', *Food and Nutrition Sciences*, 9, 1458–1471.

[28] Republic of Korea, Statistics Korea, *Household Income and Expenditure Survey*, 1990 to 2019.

[29] Tanaka, M., H. Mori and T. Inaba (2004) Re-estimating per capita individual consumption by age from household data, *Japanese J Rural Economics*, Vol. 6, 20–30.

[30] Mori, H., T. Inaba, and J. Dyck (2016). Accounting for structural changes in demand for foods in the presence of age and cohort effects: the case of fresh fish in Japan, *Evolut Inst Econ Rev*, published on line: 19 September 2016.

[31] Mori, Hiroshi (2020) *Structural changes in food consumption and human height in East Asia*, LAMBERT Academic Publishing, Berlin, 1–156.

[32] Japanese government, Bureau of Statistics, *Family Income and Expenditure Survey*, various issues.

Acknowledgements: The author is dearly appreciative to Mr. Kyungrok Lee, formally in Graduate School, Korea University for his time consuming cooperation on data preparations. Sincere thanks go to Mr. John Dyck, formerly at ERS/USDA, for his thorough editing of the original draft.