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An Attempt to Comprehend Children's Height, by Means of A/P/C Model: Han Chinese Over the Periods 1985 to 2019

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1. Abstract

Human height is determined by genetics and "supply of inputs to health" (Steckel, 1995) [1]. In most econometric investigations, mean height of young adults is regressed against average supply(-consumption) of essential nutrients, such as animal protein, in the final stage of human growth, say the late-adolescents (Baten, 2009; Beer, 2012; Grasgruber et al.,2016; etc.) [2-4]. A number of human biologists refer to the importance of "the first years of life", including the gestation period (Cole, 2003; Deaton, 2007; also many pediatricians)[5, 6]. A recent human biology study concludes, "most of the height increment seen in adults had already accrued to the age 1.5 years" (Cole and Mori, 2017) [7]. The A/P/C approach contains cohort elements which cover the supply of inputs to health from birth to the current years of investigation on top of elements of age and period. This study analyzes a series of mean height surveys by age, male and female, provided by CNSSCH [8], Chinese government, 1985 through 2019, by five-year intervals. There are two models at hand, Bayesian(Nakamura, 1986) [9] and IT(Yang Y. et al., 2008) [10][1].

[1]For the past decades, the author has employed these two models in running cohort analyses of consumption of various food products with technical advice from mathematical statisticians (Clason; Saegusa). He is in no position to assert which model is superior. Whenever he had problems in running the programs, Clason and Saegusa have assisted him, in upgrading or refining the Bayesian programs [11, 12].

2. Decomposing the Data by Bayesian Cohort Model

When we have per capita consumption, classified by age groups, *i* years old: 5~9, 10~14, 15~19, ---, at time, *j*: 1990, 1995, 2000,--,for example, we format the equation as below:

$$Y_i = B + A_i + P_j + C_k + E_{ij} \qquad (1)$$

Where:

B=the grand mean effect

A_i = the effect to be attributed to age, *i*

P_j = the effect to be attributed to period, *j*

C_k = the effect to be attributed to (birth) cohort, *k*

E_{ij} = random errors

Equation (1) may look simple or easy to determine econometrically. We, however, encounter multicollinearity problem: $i + k = j$ which is called "identification problem" (Mason and Fienberg,eds.,1985) [13] in cohort analyses. An easy way to overcome the problem could be an equality constraint in adjacent parameters, such as $C_k = C_{k+1}$; $A_i = A_{i+1}$, which is very easy to impose but is not free from subjective arbitrariness in selection. Nakamura, T. mathematician, introduced intuitively natural assumption of zenshinteki hennka (adjacent parameter estimates in the age, period and cohort series to be small) imposed under variable wights to minimize *ABIC* (*Akaike's Bayesian Information Criteria*) [14].

Table 1A: Mean Height of Han Male Students by Age, 1985 to 2019.

age	1985	1990	1995	2000	2005	2010	2014	2019
7	119.51	120.87	122.23	122.58	124.15	125.52	126.62	126.9
8	123.96	125.35	126.74	128.12	129.52	130.74	131.97	132.4
9	128.86	130.35	131.84	132.93	134.44	135.81	137.18	137.8
10	133.51	135.18	136.85	137.98	139.33	140.88	142.09	143.1
11	138.27	140.29	142.31	143.05	144.74	146.25	148.08	149.7
12	142.92	145.58	148.23	149.13	150.56	152.39	154.54	156.3
13	151.02	153.64	156.26	157.05	157.92	159.88	161.40	163.48
14	157.25	159.60	161.94	162.69	163.74	165.27	166.48	168.6
15	162.29	163.98	165.66	166.82	167.73	168.75	169.79	171.3
16	165.76	166.86	167.95	169.23	169.75	170.53	171.35	172.6
17	167.54	168.24	168.94	170.20	170.78	171.39	172.05	173.0
18	168.21	168.76	169.31	170.25	171.00	171.42	172.00	172.75

Table 1B: Mean Height of Han Female Students by Age, 1985 to 2019.

age	1985	1990	1995	2000	2005	2010	2014	2019
7	118.47	119.80	121.13	121.60	122.65	124.13	125.13	125.5
8	123.12	124.61	126.10	126.91	128.28	129.40	130.48	131.3
9	128.31	129.88	131.45	132.54	133.80	135.02	136.30	137.34
10	133.79	135.66	137.53	138.62	139.81	141.25	142.64	143.9
11	139.74	141.84	143.94	144.85	146.08	147.24	149.34	150.8
12	145.08	147.39	149.69	150.22	150.83	152.16	153.74	154.9
13	151.47	152.81	154.14	154.32	154.91	155.99	157.04	158.2
14	153.99	154.96	155.93	156.59	156.97	157.79	158.65	159.6
15	155.43	156.21	156.98	157.63	157.95	157.79	159.38	160.2
16	156.44	157.03	157.62	158.34	158.57	157.79	159.76	160.7
17	156.97	157.43	157.88	158.54	158.96	157.79	159.83	160.8

Sources; CNSSCH, various issues.

Table 2: Cohort Parameters of Mean Height of Han School Boys by Age, 7 to 17 years old, 1985 to 2019, by means of Bayesian Estimator Grand Mean= 149.75(.08).

Age Effects			Period Effects			Cohort Effects		
Age	Effects	(SE)	Year	Effects	(SE)	Cohrt #	Effects	(SE)
7	-27.13	0.56	1985	-4.44	0.40	C1	0.16	0.90
8	-21.97	0.47	1990	-2.81	0.31	C2	-0.22	0.81
9	-16.73	0.38	1995	-1.21	0.23	C3	-0.79	0.72
10	-11.5	0.29	2000	-0.38	0.17	C4	-1.16	0.62
11	-5.74	0.23	2005	0.58	0.17	C5	-1.32	0.52
12	0.45	0.20	2010	1.70	0.23	C6	-1.36	0.42
13	8.36	0.23	2014	2.77	0.31	C7	-1.21	0.33
14	14.22	0.29	2019	3.79	0.40	C8	-0.95	0.24
15	18.22	0.38				C9	-0.56	0.19
16	20.45	0.47				C10	-0.09	0.19
17	21.38	1.54				C11	0.44	0.24
						C12	0.80	0.33
						C13	1.09	0.42
						C14	1.11	0.52
						C15	1.15	0.62
						C16	1.13	0.72
						C17	0.99	0.81
						C18	0.81	0.90

Sources: Derived by the author by means of Bayesin Estimator.

Table 3: Cohort Parameters of Mean Height of Han School Girls by Age, 7 to 17 years old, 1985 to 2019, by means of Bayesian Estimator Grand Mean= 146.24(.07).

Age Effects			Period Effects			Cohort Effects		
Age	Effects	(SE)	Year	Effects	(SE)	Cohrt #	Effects	(SE)
7	-25.03	0.60	1985	-3.30	0.40	C1	0.55	0.99
8	-19.48	0.50	1990	-1.95	0.31	C2	0.15	0.89
9	-13.54	0.39	1995	-0.68	0.22	C3	-0.38	0.79
10	-7.04	0.29	2000	-0.11	0.15	C4	-0.77	0.67
11	-0.30	0.21	2005	0.46	0.15	C5	-1.09	0.56
12	5.10	0.17	2010	0.90	0.22	C6	-1.65	0.45
13	5.10	0.21	2014	2.01	0.32	C7	-1.77	0.34
14	9.68	0.29	2019	2.67	0.42	C8	-1.61	0.24
15	11.76	0.39				C9	-1.29	0.18
16	13.10	0.50				C10	-0.93	0.18
17	13.10	1.69				C11	-0.38	0.24
						C12	0.16	0.34
						C13	0.80	0.45
						C14	1.28	0.56
						C15	1.58	0.67
						C16	1.82	0.79
						C17	1.83	0.89
						C18	1.70	0.99

Sources: Derived by the author by means of Bayesin Estimator.

Table 4: Predicted Mean Height of School Boys and Girls by Age, 2024, Based on Esimated A/P/C Parameters.

Age	Male Students		Female Students	
7	NA	NA	NA	NA
8	132.89	132.59	131.66	131.46
9	138.31	138.01	137.73	137.53
10	143.68	143.38	144.22	144.02
11	149.46	149.16	150.72	150.52
12	155.61	155.31	155.82	155.62
13	163.5	163.2	155.34	155.14
14	169.07	168.77	159.28	159.08
15	172.71	172.41	160.82	160.62
16	174.41	174.11	161.61	161.41
17	174.88	174.58	161.25	161.05

P_{2024}=4.30, P_{2024}=4.00, P_{2024}=3.2, P_{2024}=3.0

Sources: Based on Cohort parameters, Bayesian A/P/C model.

3. Parameter estimates of male and female Han students' height by age, 1985 to 2019

Mean height estimates of school boys and girls from 7 to 17 in age over the period, 1985 to 2019, as reported in CNSSCH, 1985, 1995, 2000, 2005, 2010, 2014, and 2019 were decomposed into age, period (year) and cohort effects, by means on Nakamura's Bayesian model, as programmed by Clason and Saegusa. The author came across two data problems: the one is the absence of the survey year of 1990; the second is the fact that the survey was conducted in the year of 2014, one year earlier than normal. The author created the mean height data for 1990 by simply averaging those in 1985 and 1995. With the second problem, the survey data for 2014 were used, without any modifications.

Parameters[*2], age, period, and (birth) cohort, were estimated individually by male and female students, as shown in Tables 2 and 3. Nakamura's Bayesian model reaches the solutions by minimizing ABIC (*Akaike's Bayesian Information Criteria*), unlike the ordinary least square, R^2. In view of the standard errors provided, for three parameters, age, period, and cohort, the model employed looks good in performance.

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

Where:

B=the grand mean effect

A_i = the effect to be attributed age, i

P_j = the effect to be attributed to period, j

C_k = the effect to be attributed to (birth) cohort, k

E_{ij} = random errors

*2 With the additional common constraints: $\Sigma A_i=0$, $\Sigma P_j=0$, $\Sigma C_k=0$

4. Conclusions

In order to predict mean height of school boys and girls, by age, respectively in 2024, we follow the equation (2) below:

$H_{i,j} = B + A_i + P_j + C_k$ (2)

In the case of boys:

B =149.75

A_7=-27.13, A_8=-21.97, A_9=-16.73, ------, A_{16}=20.45, and A_{17}=21.38

P_{2024} =unknown, but should be close to P_{2019} in value, probably 0 cm, or a little less or greater than P_{2019}.

Minimize:

$$\sum[X_{it} - (B + A_i + PE_t + C_k)]^2$$

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

17year-olds in 2024 belong to C_9, 16 year olds C_{10}, ---, 12 year olds C_{14}, ---, with the 7 year olds undetermined in the model.

Table 4 displays predicted mean height of school boys and girls by age in the year of 2024, with the only arbitrary assumption that the period effects for the year, 2024: around 4.3 or boys and around 3.2 for girls, based on the calculated differences between P_{2019} and P_{2014}, for boys and girls, respectively.

The approach is straightforward but hasn't been undertaken widely in human biology.

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