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ABSTRACT

Japanese prefecture level panel data for the period 1986–2003, was used to analyze and compare the determinants of teenage body mass index (BMI) by sex and geographical area. Major findings through random effects estimation were as follows: (1) BMI consistently increased during the period in males aged 10–16 and in females aged 10–13 years, but not in 16-year-old females; (2) there was no difference in this trend between urban and other areas in most cases. However, the BMI of 16-year-old females was markedly lower in urban areas than in other areas. These findings suggest that girls who reach adolescence have a greater incentive to go on a diet and this tendency is more distinct in urban areas than in other areas.

JEL classification: I10; I30; R11

Keywords: BMI; Diet.

1. Introduction

It has recently been widely acknowledged that obesity is one of the major issues in the field of economics (e.g., Costa-Font and Gil, 2004; Cutler et al., 2003; Knai et al., 2007; Loureiro and Nayga, 2005). According to the Organisation for Economic Co-operation and Development (OECD, 2009), the rates of obesity in 2006 for Western developed countries such as the United States, United Kingdom, Australia and New Zealand were higher than 10%, whereas that of Japan was only 3.9%.[1] This suggests that, in comparison with Western countries, the problem of obesity is not as serious in Japan. However, rates of obesity in Japan were 2% in 1980 and 2.3% in 1990, approximately half of that in 2006. The proportion of the population that was obese was stable between 1980 and 1990, and it then increased between 1990 and 2006. A change in the lifestyle of Japan as a consequence of economic growth might partly explain the increasing rate of obesity.

A major change in the socioeconomic situation occurred in Eastern European countries, with transition to a free market economy, and this particularly influenced adolescent perceptions and lifestyles through the mass media (Vigenerova, 2007). The information inflow from Western developed countries had a major effect on adolescent behavior. Consequently, body weight and body mass index (BMI) were affected (Chrzanowska et al., 2007). The economic situation changed similarly in Japan, leading the lifestyle to be deeply influenced by that of Western developed countries. Hence, this study of adolescent BMI change in Japan may allow examination of the extent to which the findings in Eastern European countries can be generalized to other countries.

It has been reported that the lifestyle change in Japanese society influenced the degree of obesity of elementary school students in Japan (Kobayashi and Kobayashi, 2006). Socioeconomic factors may have a different effect on BMI in teenagers, according to age, sex and geographical area. Using Japanese prefecture panel data covering the period of the increase in BMI (1986–2003), this study examined adolescent BMI across age groups and sexes and also compared the changes in BMI between urban and other areas.

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[1] Rate of obesity is defined in this paper as percentage of the total population with body mass index over 30 kg/m^2.

2. Data and methods

3.1. Data

The data were aggregated at the prefecture level, comprising 47 prefectures, for the years 1986–2003 in Japan. The structure of the data set used in this study was panel. The source of the data (real *per capita* income, height and weight, calorie intake and animal fat intake) was the Index Corporation (2006). BMI was calculated by height and weight and then used in the analysis.

3.2. Econometric Framework

Following the description above, the estimated function takes the following form:

$$Ln(BMI)_{ait} = \alpha_0 + \alpha_1 Ln(Per\ capita\ income)_{it} + \alpha_2\ URBAN_i + \alpha_3\ Ln(CALO)_{it} + \alpha_4\ Ln(AFAT)_{it} + e_t + v_i + u_{it},$$

where $Ln(BMI)_{ait}$ represents the dependent variable in age group *a*, prefecture *i* and year *t*. α represents the regression parameters. e_t captures the change in BMI during the period 1986–2003. v_i represents the unobservable individual effects of *i*'s prefecture (a fixed effects prefecture vector). v_i encompasses the time invariant feature, while *u* is an error term.

Special attention must be paid to the omitted variable bias stemming from the unobservable time-invariant prefecture's effects. With the aim of controlling for this bias, the random effects model was employed to capture v_i. It is known that the fixed effects model provides the unbiased estimates (Baltagi, 2005). Besides dummy variables, dependent and independent variables take the log form and so coefficients of dependent variables can be interpreted as the elasticity. Urban dummy is the key variable in this model and its result is required to examine whether the urban area teenager has a different BMI from the other area teenager. The urban dummy is, however, one of the time-invariant prefecture's effects. Hence, results of *URBAN* are not shown because they are completely controlled for when the fixed effects model is employed. On the other hand, the results of *URBAN* can be available under the random effects model. The Hausman test asks if the fixed effects and the random effects estimates are significantly different. The random effects estimate is considered as valid when there is no difference. Accordingly, in the following section, the results of the Hausman test should be checked to validate the random effects model.

The definition and basic statistics of the independent variables are exhibited in Table 1. I used *Ln(per capita income)* as an independent variable to control for the level of income. *URBAN* takes 1 if it is the top 4 most densely populated prefectures in 1988 (Tokyo, Kanagawa, Aichi, and Osaka), otherwise it is 0. *URBAN* captures the difference between urban and other areas. To capture eating habits, *CALO* and *AFAT* are incorporated as independent variables. These variables were, however, at the average level of the prefecture by using observations composed of various age groups. Although *CALO* and *AFAT* cannot directly reflect the lifestyle of teenagers, these values are thought to mirror it to some extent.

3. Overview of the change in teenage BMI.

Fig. 1 compares *per capita* income between urban and other areas.[2] It can be seen that the *per capita* income increased from 1985 to 1991 and did not markedly change after 1992. In addition, the level of *per capita* income in the urban areas was consistently markedly higher than the other areas.

Figs. 2 and 3 demonstrate the changes in BMI by age group in males and females, respectively. In these Figures, panel (1), (2) and (3) represent 10-year-old, 13-year-old and 16-year-old groups, respectively. An increase in male BMI over the period was generally observed, with the exception of 16-year-olds in the urban areas. There was no marked difference in male BMI between urban and other areas in any age group. In general, an increase in female BMI was observed in most age groups, apart from 16-year-old females in urban areas. In addition, there was a marked difference in the BMI of 16-year-old females between urban and other areas, which

[2] In this paper, the top 4 most densely populated prefectures in 1988 (Tokyo, Kanagawa, Aichi, and Osaka) are defined as the urban areas. The rest of the prefectures are defined as the other areas.

was not observed in the other age groups. Joint consideration of Figures 1, 2, and 3 suggests that the increase in teenage BMI could be partly explained by the increase in *per capita* income before 1991, leading to changes in other factors which are thought to influence BMI e.g., lifestyle changes such as the use of air conditioning during the summer holidays encouraging children to stay indoors (Kobayashi and Kobayashi, 2006) and excessive calorie intake encouraged by the increased use of fast food in daily life. Nevertheless, the BMI of 16-year-old females did not increase, even under the socioeconomic changes.

4. Estimation results and their interpretation

Tables 2 and 3 show the results of the random effects estimations. *CALO* and *AFAT* were not available for 122 observations and so sample size used for estimation became smaller when these variables were incorporated. In all estimations, the random effects model is valid because there is no systematic difference between the results of the fixed effects estimation and the random effects model according to the Hausman test.

I will begin by discussing the results of Table 2. Concerning year dummies, in columns (1)–(5), most of the coefficients' signs are positive and statistically significant. In addition, the value of the coefficients and z-statistics increased monotonically as the years passed. On the other hand, in column (6), the signs of the coefficients are not stable and coefficients are not statistically significant. These results imply that BMI has increased over time in most age groups in males as well as in females, with the exception of the 16-year-old females. Similar results were obtained in the results incorporating *CALO* and *AFAT*, although they are not reported in Table 3. This indicates that girls entering adolescence maintain the same level of BMI during the studied period although other teenage groups increased BMI, which is consistent with the finding in Germany (Zellner et al., 2004).

INCOM shows positive signs in all estimations and is statistically significant for 13-year-old boy males and 10-year-old females. On the other hand, *URBAN* shows negative signs in all estimations and is statistically significant at the 1% level only for 16-year-old females.

With respect to Table 3, it can be seen that *INCOM* has significant positive signs in columns (2), (3) and (4). Furthermore, the value of the coefficient in column (3) is larger than that in column (2). These indicate that the positive effects of income level on BMI increased as male teenagers became older, whereas the positive effect disappeared when females became older. This result was obtained after controlling for calorie and animal fat intake, and so the effect of *INCOM* did not reflect the eating habits. The BMI reflects not only the magnitude of obesity, but also the degree of muscularity. I interpret this result as suggesting that the higher the income level and the older the teenage boy, investment in physical exercise increased leading to an increase in BMI. On the other hand, teenage girls are more likely to reduce their BMI as they become older, leading to the positive effect of income disappearing. *URBAN* continued to have a negative sign and be statistically significant at the 1% level for 16-year-old females while it was not statistically significant in other estimations.[3] *CALO* and *AFAT* both had positive and negative signs and were statistically insignificant in all estimations, indicating that lifestyle has a greater influence on BMI[4] than calorie intake.

Self image plays an important role in determining body weight and BMI (Costa-Font and Gil, 2004). Western standards of beauty, strongly emphasizing thinness, have spread across transitional Eastern European countries via the mass media, influencing the teenage lifestyle (Vignerova et al., 2007). As argued by Chrzanowska et al. (2007), the inflow of American culture caused girls to desire to be thin and the boys to be muscular. The tendency for girls to be more sensitive to BMI change in urban than other areas implies that body self-image is promoted through abundant information concerning fashion and social interaction in urbanized, more densely populated areas. Japanese society became strongly influenced by American culture in the postwar period. The evidence provided in this study suggests that Japan experienced the same lifestyle changes as Eastern Europe.

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[3] The fact that BMI of adolescents in urban areas is more likely to be lower than in rural area is observed in the United States (Auld and Powell, 2009).

[4] Zellner et al. (2007) found recently in Poland that the relationship between calorie intake and BMI weakened after 1985, and asserted that the increase in the prevalence of overweight and obesity not only arises from an increased energy intake, but also reflects a more inactive lifestyle of children and adolescents.

5. Conclusion

Average BMI is relatively low in Japan, but has increased since the 1990s. Using Japanese prefecture-level panel data, this paper aimed to ascertain the determinants of teenage BMI by age and sex. Major findings from the random effects estimation were as follows: (1) BMI has increased consistently during the period in 10–16-year-old males and 10–13-year-old females. This tendency, however, is not observed in 16-year-old females; (2) there is no difference in BMI between urban and other areas in for most cases. However, the BMI of 16-year-old females in the urban areas is markedly lower than in other areas; (3) the level of income has a positive effect on male BMI and its effect increased with age, whereas the positive income effect on female BMI disappeared with age.

These findings suggest that girls who reach adolescence have a greater incentive to diet, and this tendency is more distinct in urban areas than in other areas. The self-image influenced by the inflow of American culture in the postwar era appears to play a critical role in determining teenage BMI, which is consistent with the evidence provided by previous studies in Eastern European countries.

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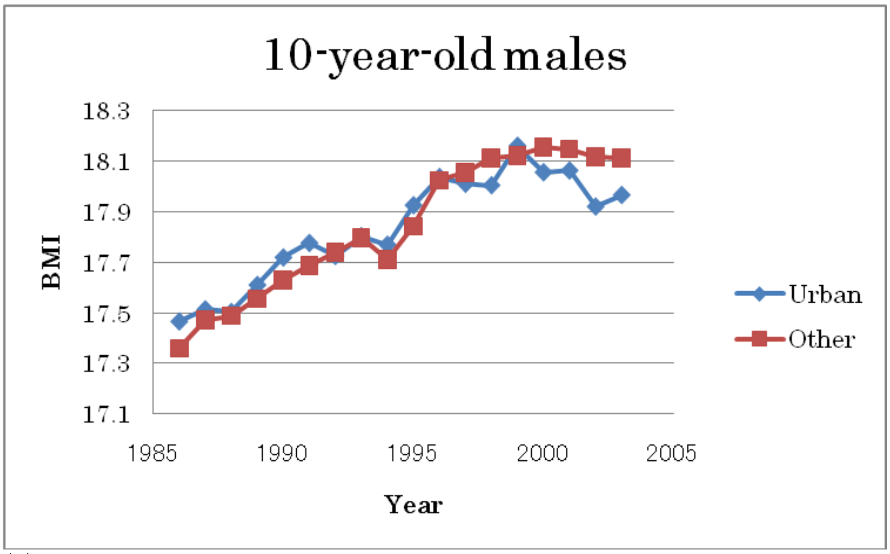
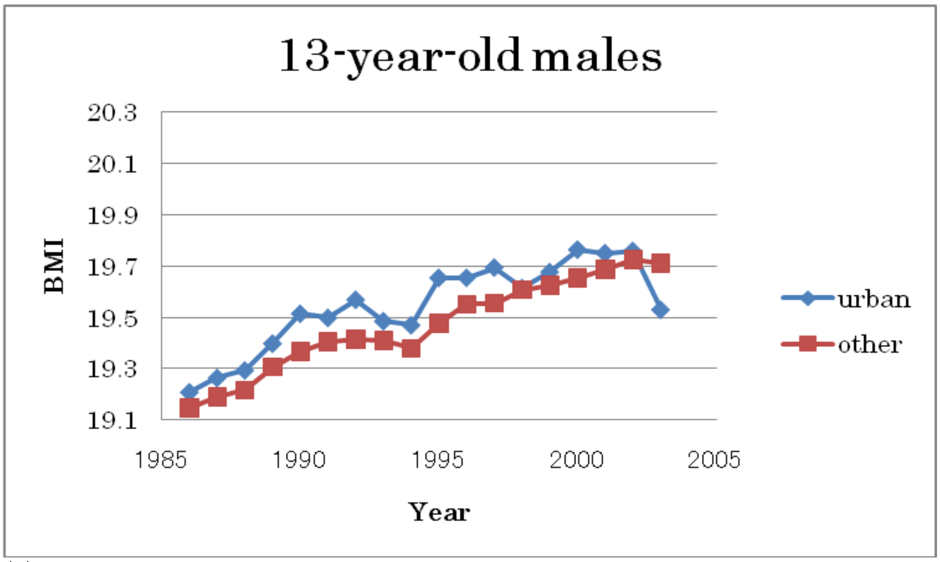
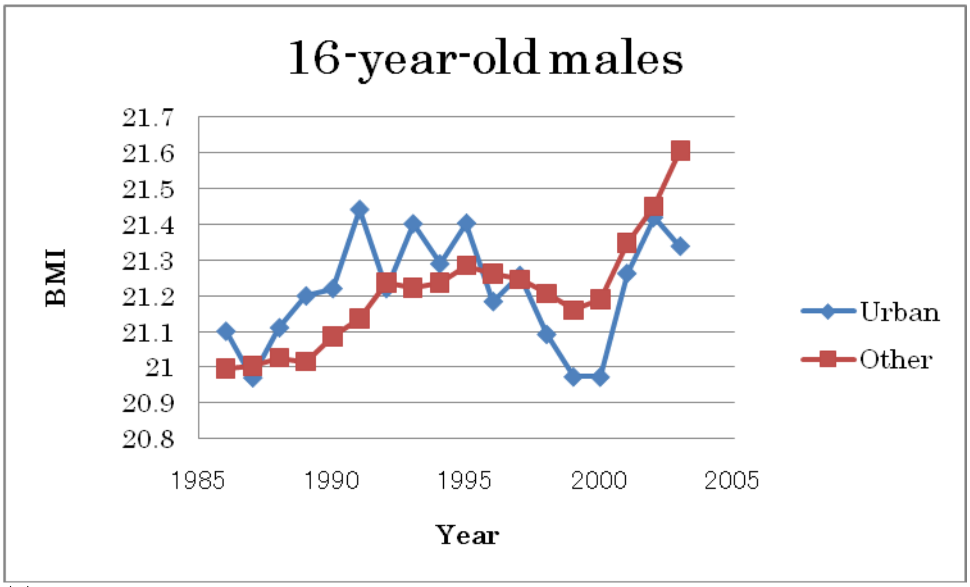


(1) 10-year-old males



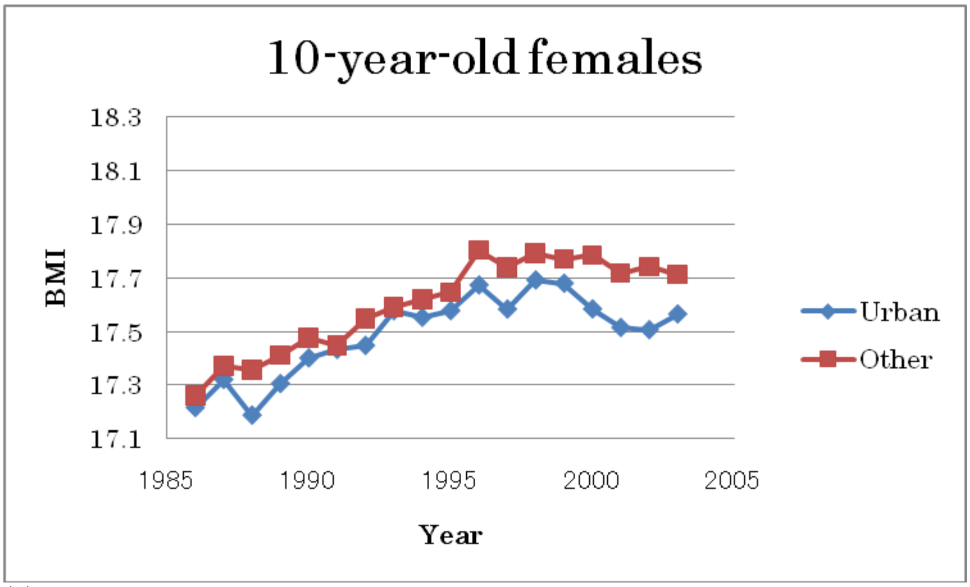
(2) 13-year-old males



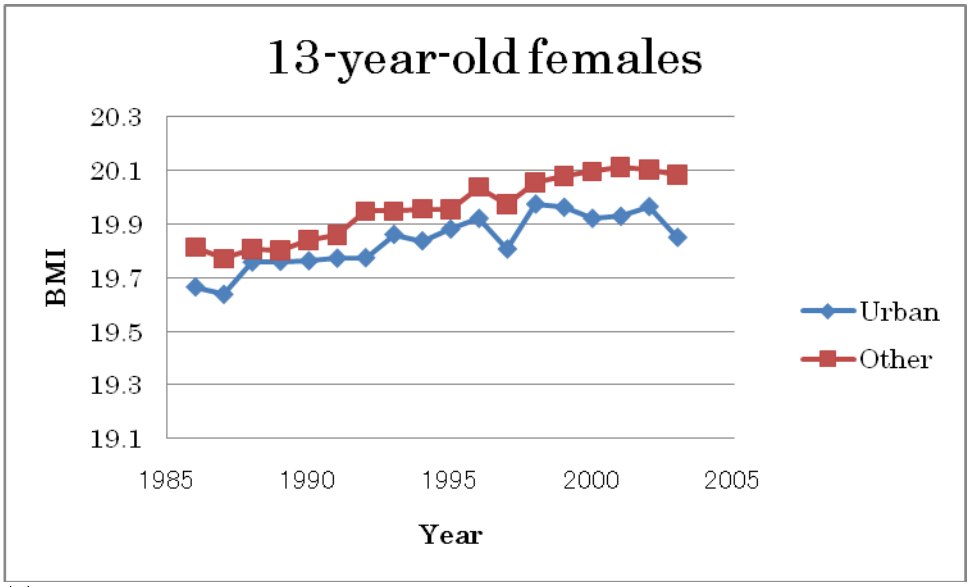
(3) 16-year-old males

BMI: body mass index.

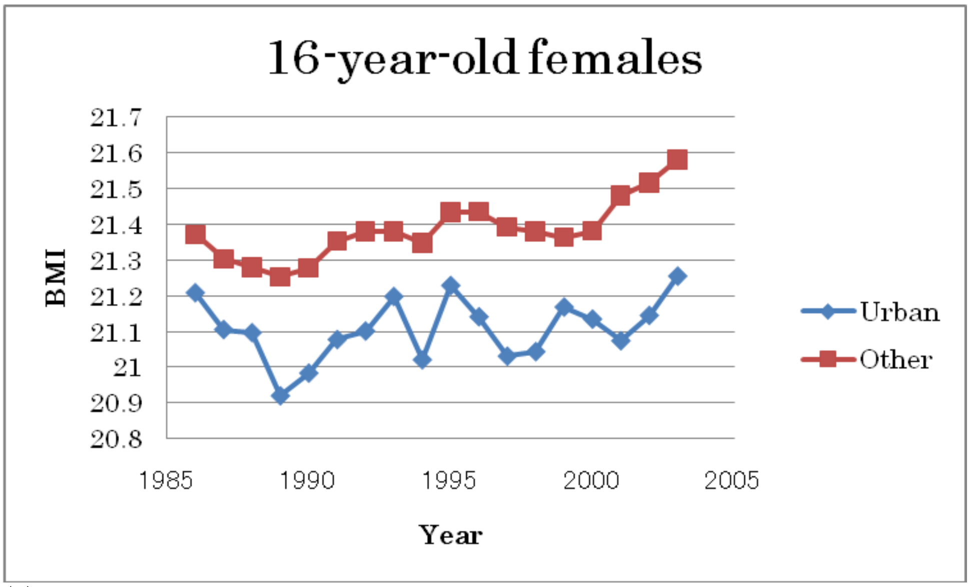
Fig. 2. Comparison of male adolescent BMI between urban and other areas by age.



(1) 10-year-old females



(2) 13-year-old females



(3) 16-year-old females

BMI: body mass index.

Fig. 3. Comparison of female adolescent BMI between urban and other areas by age

Table 1

Definition and basic statistics of independent variables used for the estimation

Variables	Definition	Mean	Standard deviation
INCOM	Annual *per capita* income (in thousands of yen)	2774	431
URBAN	Urban area dummies. In the case of the top 4 most densely populated prefectures in 1988 (Tokyo, Kanagawa, Aichi, and Osaka), it takes a value of 1, otherwise 0	____	____
CALO	Calorie intake per day (kcal)	2015	99
AFAT	Animal fat intake per day (g)	27	2
Y1988 –*Y2003*	Year dummies	____	____

Source: Index Corporation (2006)

Table 2
Determinants of BMI by age group and sex (Random Effects Model)

	Males			Females		
	(1)	(2)	(3)	(4)	(5)	(6)
	10 years	13 years	16 years	10 years	13 years	16 years
Ln(INCOM)	0.007	0.016*	0.012	0.013*	0.002	0.0004
	(0.83)	(2.30)	(1.48)	(1.87)	(0.50)	(0.06)
URBAN	-0.002	-0.0006	-0.003	-0.10	-0.006	-0.01**
	(-0.28)	(-0.09)	(-0.46)	(-1.51)	(-1.28)	(-2.32)
Y1986	Reference group			Reference group		
Y1987	0.005**	0.0009	-0.001	0.005**	-0.002*	-0.003*
	(3.14)	(0.74)	(-0.70)	(3.43)	(-2.08)	(-2.07)
Y1988	0.005**	0.001	-0.0004	0.003	-0.0003	-0.004*
	(2.82)	(0.93)	(-0.21)	(1.63)	(-0.23)	(-2.18)
Y1989	0.009**	0.005**	-0.001	0.005**	-0.0007	-0.006**
	(3.71)	(2.67)	(-0.60)	(2.72)	(-0.43)	(-2.98)
Y1990	0.013**	0.007**	0.001	0.008**	0.0009	-0.005*
	(4.92)	(3.90)	(0.52)	(4.19)	(0.54)	(-2.21)
Y1991	0.016**	0.009**	0.004	0.007**	0.001	-0.001
	(5.87)	(4.50)	(1.58)	(3.48)	(1.01)	(-0.64)
Y1992	0.019**	0.01**	0.008**	0.013**	0.005**	-0.0001
	(7.64)	(5.23)	(2.93)	(6.30)	(3.46)	(-0.06)
Y1993	0.022**	0.009**	0.008**	0.016**	0.006**	0.0002
	(8.80)	(4.94)	(3.13)	(7.85)	(3.66)	(0.12)
Y1994	0.017**	0.008**	0.007**	0.017**	0.006**	-0.001
	(6.70)	(3.87)	(3.01)	(8.25)	(3.67)	(-0.78)
Y1995	0.025**	0.013**	0.01**	0.018**	0.006**	0.002
	(9.15)	(5.95)	(3.55)	(8.21)	(3.54)	(1.04)
Y1996	0.034**	0.016**	0.008**	0.026**	0.010**	0.002
	(11.3)	(6.73)	(2.62)	(10.6)	(5.17)	(0.87)
Y1997	0.036**	0.017**	0.008**	0.023**	0.007**	0.00006
	(12.2)	(7.71)	(2.83)	(9.94)	(3.78)	(0.03)
Y1998	0.039**	0.019**	0.006*	0.026**	0.011**	-0.0003
	(14.4)	(9.43)	(2.32)	(12.5)	(6.48)	(-0.15)
Y1999	0.040**	0.020	0.003	0.025**	0.012**	-0.0006
	(15.8)	(10.5)	(1.34)	(12.0)	(7.51)	(-0.27)
Y2000	0.041**	0.022*	0.004*	0.025**	0.013**	0.00001
	(14.7)	(10.8)	(1.70)	(11.5)	(7.37)	(0.01)
Y2001	0.041**	0.024**	0.01**	0.022**	0.014**	0.004*
	(16.2)	(11.8)	(5.24)	(10.1)	(8.60)	(1.88)
Y2002	0.039**	0.026**	0.01**	0.023**	0.013**	0.005**
	(15.1)	(13.6)	(6.92)	(11.5)	(7.73)	(2.75)
Y2003	0.039**	0.024**	0.02**	0.022**	0.012**	0.008**
	(14.7)	(12.2)	(9.14)	(10.4)	(7.85)	(3.70)
Observations	846	846	846	846	846	846
Groups	47	47	47	47	47	47
Hausman test	Yes	Yes	Yes	Yes	Yes	Yes

Note: Numbers in parentheses are z-statistics. * and ** indicate significance at 5 and 1 percent levels respectively (one-sided tests). "YES" means that there is no systematic difference between the result of the fixed effects estimation and that of the random effects estimation. Constant is included but not reported because of limited space.

Table 3

Determinants of BMI by age group and sex. (Random Effects Model)

	Boys			Girls		
	(1)	(2)	(3)	(4)	(5)	(6)
	10 years	13 years	16 years	10 years	13 years	16 years
Ln(INCOM)	0.014	0.014*	0.018*	0.016*	-0.0004	-0.003
	(1.51)	(2.13)	(2.01)	(1.97)	(-0.06)	(-0.54)
URBAN	-0.003	0.0001	-0.004	-0.010	-0.005	-0.011**
	(-0.45)	(0.02)	(-0.06)	(-1.38)	(-0.97)	(-2.44)
Ln(CALO)	-0.008	-0.003	-0.006	0.005	0.003	0.006
	(-0.81)	(-0.51)	(-0.71)	(0.72)	(0.50)	(0.62)
Ln(AFAT)	0.004	0.002	0.006	0.002	-0.0004	-0.001
	(1.03)	(0.82)	(1.54)	(0.77)	(-0.14)	(-0.54)
Observations	724	724	724	724	724	724
Groups	47	47	47	47	47	47
Year dummies	Included	Included	Included	Included	Included	Included
Hausman test	Yes	Yes	Yes	Yes	Yes	Yes

Note: Numbers in parentheses are z-statistics. * and ** indicate significance at 5 and 1 percent levels respectively (one-sided tests). "YES" means that there is no systematic difference between the result of fixed effects estimation and that of random effects estimation. Constant and year dummies are included but not reported because of limited space.