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Jean-Pascal Bassino
and Noriko Kato

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Institute of Economic Research
Hitotsubashi University
2-1 Naka, Kunitachi, Tokyo, 186-8603 JAPAN
http://cei.ier.hit-u.ac.jp/English/index.html
Tel:+81-42-580-8405/Fax:+81-42-580-8333

Rich and slim, but relatively short
Explaining the halt in the secular trend in Japan

Jean-Pascal Bassino [a] and Noriko Kato [b]

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Abstract

An almost complete halt in the secular trend in stature at a relatively low level is observed in Japan since the late 1980s with average height of around 171 cm for males and 158 cm for females at age 18. Unidentified characteristics in the Japanese genetic pool or in the nutritional intake do not provide a convincing explanation. Japan is unique among OECD countries in combining contrasted health outcomes: a stagnation of height suggests a decline in biological well-being, but this picture is not consistent with high life expectancy and extremely low prevalence of infant mortality, overweight/obesity, and other pathologies. Individual data that could allow investigating the influence of socio-economic and other environmental conditions are unavailable. As a second best, we take advantage of the regional variance in average height and other indicators across the 47 Japanese prefectures and use data covering the period 1950-2005. A positive and significant influence of income and housing conditions on height is identified but the effect is fading. Caloric restraint of pregnant women, and the decrease in sleeping time observed since the 1980s appear as possible explanatory variables of the halt in the secular trend and a symptom of a decline in well-being. Public health policy implications are considered.

Keywords: height, income, housing, sleep, sexual dimorphism, Japan
JEL classification: I10, R0, Z13

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[a] University of Montpellier III and Economic Development and International Finance research unit (DEFI), University of Aix-Marseille II, Château La Farge, Route des Milles, 13290 Aix-en-Provence, France (Corresponding author). E-mail: jpbassino@gmail.com; Phone +33 442935993; Fax: +33 442939585. I worked on this research project during successive stays at the Institute of Economic Research, Hitotsubashi University (Tokyo, Japan) and wishes to express my sincere gratitude to this institution for its hospitality.
[b] National Institute of Public Health, Director of the Department of Health Promotion, 2-3-6 Minami, Wako, Saitama, 251-0197 Japan; E-mail: kato@niph.go.jp

Rich and slim, but relatively short
Explaining the puzzling halt in the secular trend in Japan

1. Introduction

Although the role of socioeconomic factors as determinants of improvements in biological wellbeing has been extensively studied, a number of phenomena are still unexplained. One of the most puzzling is the stagnation since the mid-1980s of the height of Japanese children and adolescents at a relatively low level by Asian and international standards. An almost complete halt in the secular trend in stature is observed with national level average height at around 171 and 158 cm at age 18 for male and female cohorts born since the late 1980s (around 172 and 159 respectively for those aged 20 to 24).[1] This recent development could be due to changes occurring during gestation, infancy, and/or adolescence, in various aspects of living conditions such as in income level and/or distribution, nutritional status, health conditions, exposure to transmissible diseases, stress, physical activity, and other environmental factors, or to unidentified characteristics in the genetic pool of the Japanese population.

As access to high quality nutriments and health services is largely determined by per capita income, income level and distribution are generally identified as major explanatory variables.[2] A positive and significant relationship is generally observed using micro data at a country level with causality from household income to individual height of children; this relation is particularly strong in lower-income countries, for instance India (Deaton 2008). In the meantime, height is also a significant predictor of self-esteem and academic performances of teenagers (Rees, Sabia, Argys 2009) and individual income (Schultz 2002), and is also identified as playing an important role in the labor and marriage markets.[3] This is relevant in the sense that parents have good reasons to be concerned with the height of their children but the causality running from income to height has limited importance in this study. Due to data constraint, we only use means recorded for regional sub-samples of Japanese cohorts. In population with a relatively homogenous lifestyle, the distribution of individual among intervals of heights follows a normal distribution. It is therefore acceptable to compare regional level or country level means (or medians, in principle identical, and in fact similar since the distribution is close to normal) and their evolution over time.

A positive and significant relation is also found between stature and lagged value of income, using pooled cross section data of country-level averages of PPP adjusted per capita GDP and height. The predicted values obtained by Steckel (1995) using average height data recorded in the period 1950-1990 for populations of European ancestry and Maddison's GDP per capita estimates are 163 cm for men and 152 cm for women at 1000 constant US dollars of 1985 (USD) adjusted for differences in purchasing power, 170 and 158 at 5000 USD, 173

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[1] Height data are collected in yearly Survey undertaken by the Japanese Ministry of Education using randomized sample at the prefecture-level; the return are published in Annual Reports of School Health Statistics (*Gakko hoken tokei chosa hokokusho*).

[2] Nutritional status and health conditions are inputs that explain the rise of average height, but also, as such, indicators of wellbeing. Since the main purpose of this paper is to explain height stagnation, no attempt is made to consider multidimensional aspects of wellbeing, e.g. relatively short but healthy populations versus tall and unhealthy.

[3] And therefore height influences reproductive success, although only for males (Pawlowski *et al*. 2000; Mueller and Mazur 2001; Nettle 2002*a*); a U curve is observed for females (Nettle 2002b). Anecdotal evidence suggests that the influence of height various socio-economic and biological attributes and performances could be observed in Japan as well but the lack of micro-data reduces the feasibility of such studies.

and 162 at 12000 USD.[4] Personal income distribution also matters and a similar relation is found using micro-data (Deaton 2003, 2008). Country-level results are robust to the inclusion of indicators of personal income inequality such as national level Gini, which as a positive and significant coefficient, as expected.

Due to the initial low level of stature in the late 19th century (Bassino 2006), Japan has been and remains an almost extreme outlier in terms of relation between income and stature at the country-level. Static analysis leads to overlook the long lasting effect of socio-economic hardship experienced by relatively distant biological ancestors, particularly in the maternal lineage. Even when environmental conditions are optimal, the rate of growth from one generation to the next that occurs mainly in the first 2 years of life, due to increases in leg length[5], is constrained to avoid the cost of too rapid catch-up (Cole 2003). This cost is essentially related to the higher risk of complication during gestation and delivery for short women having tall babies, resulting in biological mechanism reducing height at birth even if nutritional status and health conditions are excellent. In Northern Europe, the upward trend in height has lasted for 150 years or more, i.e. for six generations.[6] Epigenetic influences originating in earlier generations explains why average stature is comparatively low in Japan, but also in countries such as South Korea, Hong Kong, and Singapore that have currently high per capita income.[7]

Considering that socio-economic conditions have been far from optimal in Japan for the generations born before the 1950s, average height should be still rising fast, as it is actually the case in southwestern Europe. This implies that the rise in stature over several generations is hindered by powerful unidentified variables. The alternative interpretation would be that Japanese teenagers already reached their biological optimum due to some unobserved characteristics in the genetic pool of the population.

In this paper, we argue that a genetic interpretation is implausible and therefore that the halt of the secular trend could be as a symptom of a decline in welfare. If such is the case, it should be regarded with serious concern and thoroughly analyzed. Individual longitudinal data that could allow investigating the influence of socio-economic conditions and changes in lifestyle are unavailable. As a second best, we take advantage of the regional variance in average height and other indicators across the 47 Japanese prefectures and use data covering the period 1950-2005. We identify the dramatic contraction in sleeping time that occurred in Japan during the last three decades as a strong suspect, and discuss possible public health policy implications.

2. The puzzling halt in the secular trend in Japan: genetic factors or change in welfare?

The halt in the secular trend in Japan has been identified with some concern by pediatricians analyzing yearly height data collected by the Ministry of Education. These

[4] This relation is not necessarily observed with a sample of lower income countries because differences in disease environment play an important role. It should be noted that, since sizable grains in height have been observed in Europe and other regions during the last two decades, although per capita income did not increase much, the implied height at top income level would be higher.

[5] Most of the gain in human stature is related to legs' length, while sting height remains stable. This phenomenon is also observed on Japanese prefecture-level data.

[6] Average height of young male adults was 165 cm in Denmark around 1850, and 167 cm in the Netherlands in 1830 (Komlos and Baur 2004). The recent figures are 180 and 184 cm respectively.

[7] Tanner et al. (1992) document the Japanese case using longitudinal data for 1957-1977. Schooling et al. (2008) also highlight these influences in a study using individual longitudinal data for southern Chinese children from Guangzhou province. The biological mechanism could also explain why certain populations in present-day poor countries have relatively high stature, in particular some areas of sub-Saharan Africa.

surveys have been carried out in a consistent pattern since the 1950s on the basis of a large sample of male and female student of the different cohorts aged 7 and 18. Using these data Ayub, Uetake and Ohtsui (2000) identify a trend towards greater relative leg length among Japanese children that has been sharply slowing down or has stopped for both male and female cohorts born after the mid-1960s. Surprisingly, few attempt have been made to analyze the cause of halt in this trend.

Such a stagnation of height was unexpected because Japan has been one of most impressive human development success stories of the 20th century. Economic growth has been associated with a rapid upward trend in human stature during the 20th century from very low initial levels. Average height of male Japanese aged 20 rose from about 156 cm for the cohorts born around 1870, at that time, one of the lowest levels in the world, to above 170 cm for those born in the 1980s.

The recent halt in the secular trend is also puzzling because Japan is unique among OECD countries in combining apparently contradictory health outcomes. The performances remain impressive when indicators of biological wellbeing other than height are used. The Japanese population has currently the highest life expectancy in the world, and also the lowest infant mortality rates, on a par with Sweden and Finland. The prevalence of obesity and overweight is the lowest among OECD countries, both for males and females, barely increasing during the last decades, and the rates are also comparatively low for most chronic pathologies.

Figures 1 and 2 show the evolution of national level average heights of male and female cohorts aged 6, 8, 10, 12, 14, 15, 16, and 18 between 1950 and 2005.[8] For both boys and girls aged 6, the present height is almost identical to the one reached in 1988 (116.7 and 115.9 cm). An upward trend, albeit extremely weak, is still observed at age 8, 10, 12, and 14 for both boys and girls until the early 2000s, but not at age 15, 16 and 18. This finding suggests that some change in environmental conditions that occurred in the late 1980s and early 1990s affected simultaneously the gain in height during infancy and early childhood, and the growth spurt of adolescence. The stagnation of female height could be due to some extent to the decline of age at menarche, but a similar trend in other OECD countries did not prevent the growth of average female height (161 cm in South Korea, 166 in Finland, 167 in Germany and Sweden).

Figures 1 and 2 around here

A particular attention should be given to the relatively high sexual dimorphism (ratio of male to female mean height) in Japan, 1.085 at age 18 and similar at age 20-24, in comparison with other OECD and other Asian non-OECD countries. The magnitude indicates that the low average height is more marked for female than for male cohorts Sexual dimorphism is generally related to both income level and gender gap. A wide range of dispersion is for instance observed across regions of India (Guntupalli and Baten 2006; Deaton 2009). But it is also influenced by biological mechanisms. A high level of diamorphism does not necessarily imply a low social status and disproportionate heavy burden for women in countries where living standards and average height are high as indicate the figures for the Netherlands (1.083), Finland, Germany, and the UK (1.084), or Sweden

[8] Data for the cohorts aged 20 at the time of measurement are also available (until 1997) but since the information was collected using a sample of students in higher education, a concern of selection bias exists, particularly for the earlier period. The curves at age 18 and 20 are parallel from the late 1950s, with a stable gap relative to the height of the same cohort at age 18 of around half a cm for males and almost identical for females. Data are also available for the cohorts aged 20 to 24 since 1998 but their erratic variation relative to data for age 18 suggests sampling problems.

and the USA (1.088); age at menarche plays an important role in determining final height of women.

But the medical literature offers no explanation of the high Japanese level of sexual diamorphism in comparison with other Asian countries where average height of males is in the same range (urban China 1.073; South Korea 1.080); among countries for which data are available and in which average height of male is broadly comparable, only Iran is at the same level as Japan (1.085).[9] The social status of women is comparatively high in Japan. One of the best evidences is the low gender gap in education observed since the early 20th century that even reversed since the 1970s (information on enrolment rates is discussed in the next section). It is equally unlikely that sexual diamorphism results from discrimination in access to health or nutrition. This reinforces the impression that the stagnation in stature is due to environmental factors that resulted in a delinking of income and height, or offset the positive income effect.

Other countries have experienced a recent halt in the secular upward trend in human stature. In Northern Europe, average adult height tends to stabilized above 180 and 167 cm for young male and female cohorts, respectively. The most accepted interpretation is that the population reached its biological optimum in terms of stature. In the Japanese case, the genetic explanation is popular but it is essentially a conjecture. Eveleth and Tanner (1990: 180-181) compare height means of male and female children of European (Denmark) and Asiatic (Japan) populations and interpret the divergence of the curves around age 15 for boys and 13 for girls as evidence of differences in the genetic pools. They acknowledge that "ideally [we] should compare representative groups… growing up, so far as possible, under similar, and preferably optimal, environmental conditions" but they rely on studies that did not control for differences in nutritional status and other determinants. Recent medical studies have identified genes associated with comparatively short stature. But, for time being, these findings could only allow identifying some underlying factors in the normal distribution of individual across height intervals observed in all populations with a relatively homogenous lifestyle.

Studies in physical anthropology and in social sciences indicate that differences in the genetic pool of a population do not account for much in terms of average adult height.[10] A biological optimum 10 cm lower than the northern European level seems therefore implausible[11]. Asian populations such as South Korean and northern Chinese that are close to the Japanese in genetic terms (Cavalli-Szorza, Menozzi, Piazza 1993; Nei 1995) did not experience the same low-level stagnation in the recent years. With an average height of male and female students born in the late 1980s of around 171 and 157 cm respectively (and around 172 and 158 respectively for those aged 20 to 24), Japanese youth are already 2 cm shorter than their South Korean counterparts. Average height of South Korean male and female students aged 17 was 173.1 and 160.2, respectively, and 174.2 and 161.3 at age 20 (Kim et al. 2008). The situation is comparable in urban areas of China where average height is similar to the Japanese level in spite of differences in living standards and standard health indicators, not to mention harsh socioeconomic conditions experienced until the 1980s. In addition, a high

[9] Sexual diamorphism calculated using data for urban China, Iran, South Korea, and Iran reported in Yang, Li et al. (2005), Haghdoost et al. (2008), and Kim et al. (2008), respectively.

[10] International comparison of average height points to the role of nutrition and health conditions as powerful explanatory variables Moradi and Baten (2005) show for instance that protein consumption is a key explanatory variable for differences in average height among ethnic groups across Sub-Saharan African countries. The large variance in height does not seem related to genetic distance among African ethnic groups.

[11] 10 cm is equivalent to the gain in average male height that occurred in Japan between 1892 and 1960 (156 to 166 cm) or between 1930 and 1980 (160 to 170 cm).

degree in regional variance is observed across Japanese regions.[12] These findings tend to rule out a purely or mostly genetic explanation. It is therefore unlikely that the Japanese teenagers reached their biological optimum in terms of height.

A delinking of per capita income and average height due to adverse changes in lifestyle and in social conditions is conceivable since it has been already observed in the past. In the early and mid-19th century, the United Kingdom and the USA experienced an absolute decline in average height and a rise in infant mortality in a context of rising per capita income. This delinking, labeled for the US as the antebellum puzzle (Haines, Craig, Weiss 2003), has been identified as a consequence of urban penalty. Urbanization resulted in an increased exposure to transmissible diseases and was associated with a decline in nutrition quality due to availability of addictive goods, in particular more sugar, coffee, and tea, and a lower animal protein intake.[13] Industrializing nations of late 19th and early 20th century, continental European countries and Japan, did not experience a similar phenomenon. Improvements in public health in the second half of the 19th century offset the nutritional component of urban penalty and the same pattern is also observed after 1945 in developing countries.

A recent delinking of income and height is also observed in the USA. On average, young US born adults who are using English at home are currently shorter than their northern Europeans counterparts of the same age and gender; what is more, southern Europeans are catching up at a rapid pace. The average height of lower-income US born Americans stagnated since the 1980s[14], an outcome interpreted as the consequence of rising income inequality and reduced access to health services (Komlos and Baur 2004). Canada, a country with a lower income and wealth inequality than the US, and a welfare state closer to the European type, did not experience the same pattern. Interestingly, the index of economic well-being calculated by Osberg and Sharpe (2002) points toward a stagnation of income in the US since the 1980s; the rise in income inequality implies a decline in economic well-being for lower and middle-income households.

In light of the strong influence of the level and distribution of income on height, it is tempting to consider the economic slowdown that occurred in Japan after the bursting of the real estate and stock markets bubbles in the late 1980s as explaining height stagnation. But the slowdown in the upward secular trend in stature actually started earlier than the bursting of the bubble and apparently did not result in a significant decline in living standard among household with children or adolescents. In addition, the rise of average height in Western Europe has not been affected by poor economic performances, in most cases much worse than the comparatively mild Japanese economic stagnation. Income and wealth distribution and welfare policies are unlikely to play an important role in Japan. Available measures indicate that inequality is on the rise, but from a low level; the Gini coefficient fluctuated during the last decades in the same range as in Nordic countries. Health indicators such as infant mortality and life expectancy suggest that the relatively low level of public social expenditures in Japan could not have a strong adverse effect on biological well-being.

Because average height at a given age reflects a large array of cumulated past environmental influences, it is sensitive to changes affecting the youngest cohorts that may be still imperceptible in the rest of the population. The recent height stagnation could either

[12] It should be acknowledged genetic distances relative to Korean and northern Chinese are not identical across Japanese regions; but the distance within Japan is smaller (Cavalli-Szorza, Menozzi, Piazza 1993; Hammer and Horai 1995; Nei 1995). Okinawa populations are outliers, probably due to inflows from southern China (Hatta et al. 1999), but only in relative terms among Japanese (Hammer and Horai 1995; Nei 1995).

[13] A comparable effect on infant mortality is observed in Nazi Germany 1933-1937, as a consequence of rise, in urban areas, of the price of animal proteins induced by the autarchy policy (Baten and Wagner 2002).

[14] And even declined for white females and a number of sub-groups defined by income or education level.

indicates that a delinking of the causal effect of income on biological wellbeing is taking place in Japan, or that other factors are offsetting the weak income and health effects.

3. Growth of income, improvements in housing conditions, and secular trend in height

This section proposes an assessment of the evolution in the relationship between income and height since the middle of the 20th century. In order to investigate the Japanese puzzle, we should ideally use a large sample of longitudinal individual data including a number of control variables. As a second best, we take advantage of the regional variance in height. Sizable regional differences are observed when relying on Japanese prefecture-level data recorded by the Ministry of Education: for the male cohort born in 1987, average height measured at age 17 was 171.7 cm in Shiga (a prefecture close to Kyoto), and 171.5 in Tokyo, but only 169.7 in Nagasaki, and 168.9 in Okinawa (see map for the localization of Japanese prefectures). Figures 3 and 4 show the extent of regional variance for selected years.

As a first step, two major potential explanatory variables are taken into account: per capita income (in constant terms) and housing conditions. The importance of income as indicator of socioeconomic conditions, in particular nutrition and health, has been already discussed, in the previous sections; an additional consideration is that, although the overall improvement in nutrition status, in particular the increase in animal protein intake and in the diversity of foodstuffs consumed, is well documented at the national level, indicators of regional patterns are not readily available for the first decades. Figure 5 indicates the extent of regional inequality but also illustrates the process of convergence that occurred during the second half of the second century.

Regarding health conditions, recurrent exposure to pathologies due to contact could have a negative impact on height, particularly important in the case of infants and young children not attending school, which explains that in-house crowding has been identified as important determinants of height in studies using micro data (Mascie-Taylor 1991; Terrell et al 1991; Bonnefoy et al. 2003). Among the different indicators of housing available, the most relevant is the average surface per resident. A positive influence of average surface on height is expected, akin to the effect identified as Farr's law, a correlation initially observed in 19th century European big cities between urban population density and death rate at the district level (Brownlee 1920). Farr's law reflects in particular infant mortality, a strong correlate of infant and child morbidity. Crowding at the household level results in the presence of carriers of communicable disease at close proximity of children, and therefore a higher exposure. Interestingly, prefecture-level data of per capita income and surface of housing per capita are almost orthogonal in Japan. Figure 6 shows the regional variance in housing conditions and the extent of the improvement experienced since the 1960s.

Figure 3, 4, 5, and 6 around here

Although height and other data are available for the entire period starting in 1947, it is advisable to exclude the earlier period in order to avoid spurious results. It appears that a catch-up from an anomalously low level occurred in the 1950s, in comparison with the pre-1940 period Figure 7 compares average height of students measured at age 16, 18, and 20, and of conscripts measured at age 20 (years of birth). A difficulty in the interpretation of these data is that prewar and postwar students do not represent the same population; most of the prewar students originated from higher income households, as evidenced by the gap of more that 2 cm at age 20 between the height of students and that of conscripts who accounted for almost 100% of the cohort. A counterfactual scenario without any impact of WWII would imply an upward trend of the height of conscripts with an average stature that would have been barely the same as students aged 18 in the immediate postwar. A larger proportion of the cohorts accessed to education up to age 18 than in the prewar but they still represented a population enjoying a relatively high standard of living.

The sharp height increase observed for postwar students aged 16 indicates a catch-up but could also reflect a concentration of the growth spurt of adolescence at an earlier age, a common feature in populations experiencing a rapid improvement in nutritional status and health conditions. This interpretation is consistent with a contemporaneous acceleration of the decline on the curve of infant mortality is observed during the same period. Because neither nutritional intake nor infant mortality rates are readily available for the postwar at the prefecture level, no attempt was made to disentangle the influence of the different underlying factors.

Figure 7 around here

Information on enrolment rates suggests that the rise in stature at age 16 would be even stronger if adjusted for changes in sample composition. Since school attendance became mandatory only until age 15 after the postwar reforms of education (with actual enrolment rates already above 99% from 1948 onward), a selection bias could exist when using height data for the cohorts aged 16, 17, or 18 for the earlier postwar period. Enrolment rates in upper secondary schools (from age 15 to 18) increased rapidly thereafter: 60 and 56% in 1960 for males and females, respectively, 82 and 83% in 1970, and 93 and 95% in 1980.[15] This rise corresponds to children from lower-income households accessing upper secondary school. Hence, the rise in enrolment can only lead to understate the rapid rise in stature observed for students aged 16 in the 1950s and 1960s. This is consistent with information on intra-prefecture height inequality available from 1960 onward. The low prefecture-level coefficients of variation (CV) of height reported in the surveys of the Ministry of Education indicates that most of the dispersion was mostly related to genetic differences among individuals. The CV is in a range between 0.031 and 0.036 at age 17, depending on prefectures, and almost constant over time. It appears therefore that there is no need to include personal distribution of height in the list of variables taken into account when investigating the determinants of the secular trend in stature.

In order to capture possible regional difference in unobserved variables such as protein intake and access to health services, the determinants of height are investigated using semi-log OLS estimation with prefecture fixed effect. Prefecture-level independent variables investigated are per capita income (y) and surface of housing measured in tatami per capita. A time trend is also introduced in order to capture possible positive effects related to improvements in public health services and nutrition (the results are robust to the exclusion of the time trend and fixed effect). Table 1 presents the results for average height at age 17 with a 4-year lag for per capita income and a 9-year lag for housing. The choice of age 17 is motivated by a focus on height close to final stature and the fact that this is the last year for which prefecture-level data are available. A 4-year lag for income is intended at assessing the influence of socio-economic conditions during the growth spurt of adolescence. A 4-year lag is used for housing in order to take into account crowding during adolescence. Similar results are obtained with slightly different lags. Estimations were also performed for height at age 5 in order to capture effects during the earlier period and give comparable results.

[15] Enrolment rates are from: Historical Statistics of Japan (Statistics Bureau, Ministry of Internal Affairs and Communication, http://www.stat.go.jp/english/data/chouki/index.htm).

The coefficient for income is positive and significant for both male and female height equations and the results are not sensitive to the inclusion of prefecture fixed effects. However, the R^2 and the coefficients for income and housing conditions are lower during the second half of the period, from around 1980. This suggests that the income and housing effects, that were extremely powerful in the first period, in a context of high-speed economic growth, are gradually fading afterward. The stagnation of height observed from the mid-1980s could be due to some extent to the modest improvements in per capita income during the last decades. But, amid economic stagnation, improvements in housing size per head that occurred during the same period had also little impact on measured height of children and adolescents. These results suggest the presence of negative forces offsetting the positive influence of housing measured in tatami per person. The next section attempts to identify possible explanatory variables related to these negative effects and to assess their impact.

Table 1 around here

4. Explaining the recent height stagnation

Information on average height of different cohorts presented in section 2 provides evidence of a halt in the secular trend since the late 1980, a development entirely overlooked in recent public health policy. The seriousness of the situation can be assessed using measures of physical fitness that show either stagnation or decline for performances such as endurance run at age 13, 16, and 19 recorded in the same surveys of the Ministry of Education since the 1950. The different indicators point consistently towards a decline in welfare since the 1980s.

This section investigates the possible role of food deficiency, caloric restraint, and chronic sleep deprivation on height. Indicators of nutritional status are commonly used by economists as yardsticks of welfare as well as dependant or explanatory variables, but sleep is more rarely taken into account In a seminal paper, Biddle and Hamermesh (1999) investigate the determinant in sleep allocation. They find that higher wage rates reduce sleep time among men but increase the waking nonmarket time by an equal amount (among women the wage effect on sleep is negative but very small). They also find that, in their US data, each additional hour of work reduces time spent sleeping by about 7 minutes. In the Japanese context of the last three decades, sleeping time declined sharply (by one hour on average between 1980 and 2000) while working hours went down; in the meantime, Yamada, Yamada and Kang (1999) find a positive relationship between sleeping time and household income (for males; no relation for females), suggesting that the decrease in sleeping time corresponds indeed to a decline in welfare. Using cross-section prefecture level average levels, a negative correlation is also observed between sleeping time and income (slightly lower than 0.5 in 1970 and 1980, around -0.55 in 1990 and 2000).

Considering the likeliness of an impact of stress, affection deprivation syndrome, and other psycho-social conditions in childhood on the growth of height of children and adolescents (Gulliford et al. 1990; Nyström Peck and Lundberg 1995), it is also important to envisage possible indirect effect of economic stagnation on nutritional disorder and sleep disturbance. One hypothesis that would be worth considering is that the economic stagnation enhanced depressive symptoms among adolescents, and as result their health related quality of life, in particular sleep disturbance (Palermo and Kiska 2005).

The Japanese economic slowdown of the “lost decades”, i.e. after 1990 resulted in stagnation in economic well-being but at a high level. A decline per capita caloric intake is observed since the 1970s in national-level series unadjusted for changes in age-composition, from slightly less than 2300 to around 1950 kcal per day in recent years (about the same as in

1946). This trend is not surprising considering the drastic improvements in the heating and cooling of buildings, and the transformation of industrial production processes towards less human energy demanding activities for blue-collar workers. Therefore, the net availability of calories that can be used for metabolic functions was less affected. Protein intake, which increased from around 60 g to 80 g per day in national average between 1946 and 1970, remained mostly stable thereafter.[16] Albeit still relatively low in comparison with other OECD country, animal protein intake increased steadily since the mid 20th century and, almost equally important from a nutritional viewpoint, became more diversified. Furthermore, eating habits are reasonably balanced; a study on Japanese female university students based on individual data shows that a large majority (80%) take breakfast and three meals daily compared to 36% having breakfast and only 30% having three meals daily in a similar sample of South Korean university student (Sakamaki et al. (2005).

A much more serious issue, and a plausible explanatory variable, is related to the tendency toward caloric restraint among pregnant women that developed since the 1980s. A decline in average birth weight is indeed recorded in all prefectures, albeit with some clear regional patterns (Figure 8). Since birth weight is a close correlate of birth length, it could be indeed an explanatory factor of the halt in secular trend, although not the sole one since the decline in birth weight occurred in only from the 1980s, when the cohorts born in the 1970s were already experiencing stagnation in stature at age 17. Itoh and Kanayama (2009) discuss the possibility of an association of low birth weight with a risk of obesity in a study based on Japanese longitudinal micro data, but they do not take into account the impact on height, which is disputable since they use the Body Mass Index (BMI) as indicator of overweight and obesity. In particular, they do not consider the possibility that nutrition deficiency during the last month of pregnancy could influence BMI through a reduction of height at birth.

A similar remark applies to many of the numerous other studies investigating the determinants of overweight and obesity. A large body of literature points toward a negative effect of chronic sleep deprivation in childhood and adolescence using longitudinal micro data.[17] These studies use BMI as indicator of overweight/obesity without taking into account a possible direct effect on height.[18] Chronic sleep deprivation, i.e. below certain thresholds that could varies among individuals, is identified more generally as an important factor of risk for various pathologies (Fallone, Owens and Deane 2002; Tazawa and Okada 2002; Hale 2005; Knutson et al. 2007; Grandner et al. 2009) and also poor academic performances, in the US (Perez-Chada et al. 2007), and in Hong Kong (Chung and Cheung 2008).[19]

Although the relationship between sleeping time and height is often mentioned in the medical literature analyzing variation among individuals in growth hormone secretion levels during sleep and wake hours (e.g. Costin et al. 1989), relatively few studies measured the impact of sleep on final adult height. Gulliford et al. (1990) identify a weak negative association, after adjusting for the effect of other variables in a study based on British micro data. Strong evidences are found in recent studies, e.g. Tikotzky et al. (2010) on infants in Israel, and Bénéfice, Garnier and Ndiaye (2004) on adolescent girls in Senegal (in these two

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[16] Nutrition data are available from Historical Statistics of Japan, Statistics Bureau, Ministry of Internal Affairs and Communication (http://www.stat.go.jp/english/data/chouki/index.htm).

[17] Cappuccio et al. (2008) provide a meta-analysis.

[18] Burkhauser and Cawley (2008) highlight that BMI is flawed, in particular because it does not distinguish fat from fat-free mass. Individuals with the same sitting height, trunk size, and percent body fat, but significantly different standing heights (i.e. different leg lengths), are likely to have different BMI measures.

[19] The severity of the implication of chronic sleep deprivation should not be understated; Van Dongen et al. (2003) estimate that chronic restriction of sleep to 6 h or less per night produced cognitive performance deficits equivalent to up to 2 nights of total sleep deprivation.

cases, both height and obesity are investigated).[20] The small number of studies is explainable: in most OECD countries the medical community has good reason to be more preoccupied by obesity, that either reached high level or tends to be on the rise, than height, that is generally following an upward trend (except in Japan and in the USA). In the meantime, there seems to be little interest for analyzing the causes of the height stagnation in Japan, probably because the validity of the genetic hypothesis is taken for granted. An additional explanation is that the rapid rise in the prevalence of excessive slenderness among female adolescents of young adults is understandably a much more serious concern in this country; since the mid-1990s, 20 to 25% of females aged 20 to 29 have a BMI below 18.5, according the returns of the National Nutritional Survey (*Kokumin eiyo chosa*); in the same age range, only 7 to 8% have a BMI above 25 according to the same source.

Figure 8 around here

The extent and severity of chronic sleep deprivation among Japanese adolescents can be assessed from a study on 3478 Japanese high-school students (Tagaya et al. 2004). Mean values for bed and rise times were found to be 00:03 and 06:33 am, respectively, resulting in a mean sleep duration of 380 minutes. The prevalence of short sleep duration (defined as less than 6 hours) was 25.6%. Spain provides a convenient yardstick for an international comparison: in this country, one-fifth of the adolescents (out of samples of 1,040 males and 1,139 females) reports insufficient night sleep in a study by Ortega et al. (2007), but they define short sleep as less than 8 hours.[21] Interestingly, Tagaya et al. also find that short sleep duration is associated with earlier rise time, longer study duration outside school hours, longer commuting duration, and being female.[22] The first three correlates were expected; the last one, being female, could provide a clue for understanding the high degree of sexual diamorphism in height if the growth of Japanese adolescents is indeed influenced by sleeping time.

In an attempt to test this hypothesis, we use available prefecture-level data for mean duration of sleeping time between age 10 and 60 collected in the National Lifestyle Time Survey (*Kokumin seikatsu jikan chosa*) carried out by the Japanese national broadcasting company NHK. Prefecture-level data are available only for 1970, 1980, 1990, and 2000. Figure 9 shows the extent of the regional variance and of the decline in mean sleeping time that occurred since the 1980. Unfortunately, there is no breakdown at the prefecture-level by age-group, and therefore no information on sleeping time of teenagers. The overall mean for Japan in NHK data is broadly consistent with the average figures found by Tamakoshi and Ohno (2004), sleeping hours of 7.5 and 7.1 hours per day in weekdays for men and women aged 40 to 79, in a 10-year longitudinal study (43,852 men and 60,158 women). This suggests

[20] However, Jenni et al. (2007) find a large variability of individual sleeping time with no association with height, but their study is on children aged 1 to 10, that is before the adolescence growth spurt.

[21] For cultural reasons, in particular late family dinner, Spain is one of the European countries with the shorter sleeping time of adolescents. No mean sleeping time data based on individual surveys were found for Japanese primary school children. For the USA, Spilsbury et al. (2004) find mean sleep duration for all children aged 8 to 11 was 9.63. Recommended sleeping time in the US is 9 hours at these ages. 53% of 10- to 11-year-old minority boys reported less than 9 hours nightly sleep, and 5% to 26% of the other age, sex, and ethnicity subgroups. Among Japanese children of the same age is unlikely that even the mean is close to 9 hours.

[22] Surprisingly they conclude that short sleep duration of Japanese high-school students is associated with their lifestyle as well as sleep problems, but not with psychosomatic problems; a major shortcoming of this study is related to the measure of health based exclusively on scores in a composite index (Japanese version of the 12-item General Health Questionnaire).

that adolescents are also in the same range and that NHK figures can be used as proxy for assessing regional variance and changes in sleeping time of adolescents.[23]

Figure 9 around here

Regression analysis is performed in log-log form with height at age 17 as dependant variable, a 4-year lagged value of sleeping time, along with per capita income, and housing conditions, without and with prefecture fixed effects. Average height in t-10 (at age 7) in the same prefecture is also included in an attempt to capture an influence akin to a cohort effect. The final results are presented in table 2 (similar results were obtained with other lags for income and housing surface). The coefficients are significant and of the expect sign for all variables, except tatami per head that is either weakly or non significant without prefecture fixed effects. The positive coefficient for sleeping time indicates that the decline offsets the positive effects on height related to the moderate rise in per capita income and the sizable improvements in housing conditions. Sleeping time is identified as a positive and strongly significant determinant of height, a 10% decline in sleeping time, roughly the extent of the change observed between 1980 and 2000, being associated with a decrease in stature close to 0.6% (slightly less than one cm).

A similar exercise is performed with height at age 5 as dependent variable; the results are presented in table 3. Average birth weight of the same cohort, i.e. measured at the prefecture level in t-5, is also introduced in order to identify a possible effect on height of children related to caloric restraint by pregnant women during gestation. Positive and significant coefficients are observed for income and tatami, as in the previous cases, but also for sleeping time and birth weight. These results indicate that both sleep disturbance during infancy, related to short sleeping time of parents, and caloric restraint during gestation can be suspected to contribute to the stagnation of stature.

Tables 2 and 3 around here

If the causal link between sleep and height of adolescents at age 17 (that is almost close to final adult height), and the influence of caloric restraint we tentatively uncovered are confirmed by further studies, policy implications should be considered. Since BMI calculation includes height in a quadratic form in the denominator, it is critical to take height stagnation into account when analyzing the prevalence of underweight among young women. In addition, caloric restraint during gestation has been identified in Japan as a public health issue that is related to a desire for excessive slenderness among young women that can be related to hight. It is well established that a large proportion of Japanese female adolescents and young adults have a BMI target in mind (e.g. Sakamaki et al. 2005). They also express individual preferences in terms of ideal body shape characterized by high degree of slenderness, in particular long legs, a feature largely due to mass media exposure and female peer-pressure (their male peers usually express different preferences associated with much higher BMI).

[23] Other information on time usages, commuting and sport, are not taken into account because these figures are means calculated using a population sample aged 10 to 60 and may therefore differs from means for adolescents. Additional justifications are that commuting has been identified as a strong correlate of sleeping time (Tagaya et al. 2004). The lack of physical exercise does not appear as a plausible suspect although a link with short sleeping is identified (e.g. Padez et al. 2009). Lack of physical exercise is a strong correlate of obesity, whose prevalence is extremely low in Japan. For most children and adolescents, particularly in big cities, most of the commuting implies walking or cycling from home to the train or bus station and from there to the point of destination. On shorter distances from house, walking or cycling are almost as common as in the Denmark and Netherlands.

Pathological underweight affects not only individual health but also reproductive capacity, and eventually the health of offsprings. It is therefore a public health issue.

Public health policy could aim at increasing height by promoting awareness of the importance of sleeping time, which could in turn reduce the risk of pathological forms of underweight. Since this type of recommendation is unlikely to generate any adverse effect, early warning could be considered without waiting the results of studies based on individual longitudinal data. The recommendation to the parents, and adolescents could be: sleep more to increase the likeliness of having long legs. Due to the constraints on wake up time, the message to the target population could be in fact very short and simple: sleep earlier if you want to have long legs.

In order to achieve this objective, an identification of underlying factors of sleep deprivation is necessary. This requires in turn extensive studies based on micro-data. In the case of Japanese children aged 6 to 11, Tazawa and Okada (2002) identify television-game (TVG) playing as a major explanatory variable. They acknowledge that other factors may cause sleep deprivation. Tazawa and Okada also find a strong gender gap: boys spent more time on TVG playing than girls (means 1.1±0.7 hour/day *vs* 0.4±0.6 hour/day), respectively. Considering the high level of sexual dimorphism in Japan, It is particularly important to understand the underlying factors for women. Since sleep deprivation is observed for males and females, gender gaps must exist in opposite direction, probably early wake up for body care (e.g. daily morning shampoo and air care) due to mass media exposure and peer-pressure.

5. Conclusion

Our findings suggest that chronic sleep deprivation during childhood and adolescence is a significant explanatory variable of the halt in the secular trend observed in Japan since the late 1980s; another explanatory variable identified using prefecture-level data is caloric restraint. Further studies, ideally using longitudinal micro data, would be necessary to confirm this result. In spite of these limitations, the possible implications of the stagnation in height at a relatively low level should taken into consideration, particularly because an indirect link is suspected with the prevalence of underweight among young females, which is one of the most serious public health problems in the Japanese society.

If Japan is, so far, the only country in which height stagnation is manifest, other Asian countries could be on a similar track. Yang, Kim et al. (2005) find sleep deprivation even more acute than in Japan among adolescents living in the city of Pusan (Korea) with average sleeping time of 6.0, 5.6, and 4.9 hours at age 14, 15, and 16, respectively. They highlight that “these findings stress the need to promote awareness of the magnitude of adolescent sleep deprivation and its detrimental effects in Korean society.” A similar tendency, albeit less severe, is also observed in Hong Kong with a mean sleeping time of 7.3 hours in weekdays measured for a sample 1629 adolescents aged 12 to 19 (Chung and Cheung 2008).

Sleep deprivation is associated with an alteration of biological functions during adolescence that may have irreversible consequences other than adult final stature, particularly the prevalence of overweight that seems on the rise among the first cohorts of males affected by height stagnation. Insufficient sleep duration is also important because it increase the risk of pathologies and psychosocial stress, and affect academic performances. The halt of the secular trend observed in Japan should be regarded as a symptom of a decline in welfare and a cause of concern.

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TABLES

Table 1. Estimation results for average height at age 17 (years of measurements: 1964, 1969, 1974, 1979, 1984, 1989, 1994, 1999, and 2004)

	(1)		(2)	
	Male	Female	Male	Female
Income (t-4)	.0114***	.0092***	.0135***	.0096***
Tatami ((t-4)	.0103***	.0092***	.0068***	.0083***
Intercept	2.1839***	2.1583**	2.1803***	2.1574***
Region FE	NO	NO	YES	YES
Adjusted R^2	.90	.86	.95	.93

Notes: Region FE: prefecture fixed effect; ***, **, and *: significant at the 1%, 5% and 10% level, respectively; all variables in log; sample size 420.

Table 2. Estimation results for height at age 17 (in 1974, 1984, 1994, and 2004)

	(1)		(2)	
	Male	Female	Male	Female
Income (t-4)	.0070***	.0064***	.0132***	.0102***
Tatami (t-4)	.0040*	.0027	.0132***	.0090***
Sleep (t-4)	.0588***	.0524***	.0522***	.0551***
Height (t-7)	.2857***	.2600***	-.0182	.0704
Intercept	1.453***	1.494***	2.073***	1.8613***
Region FE	NO	NO	YES	YES
Adjusted R^2	.83	.76	.90	.88

Notes: Region FE: prefecture fixed effect; ***, **, and *: significant at the 1%, 5% and 10% level, respectively; all variables in log; sample size 187.

Table 3. Estimation results for height at age 5 (in 1974, 1984, 1994, and 2004)

	(1)		(2)	
	Male	Female	Male	Female
Income (t-4)	.0091***	.0121***	.0096***	.0110***
Tatami (t-4)	.0088***	.0100***	.0117***	.0126***
Sleep (t-4)	.0703***	.0905***	.0706***	.0926***
Birthweight	.2360***	.2532***	.1070*	.2168**
Intercept	1.700***	1.624***	1.760***	1.649***
Region FE	NO	NO	YES	YES
Adjusted R^2	.64	.64	.83	.82

Notes: Region FE: prefecture fixed effect; ***, **, and *: significant at the 1%, 5% and 10% level, respectively; all variables in log; sample size 187.

FIGURES

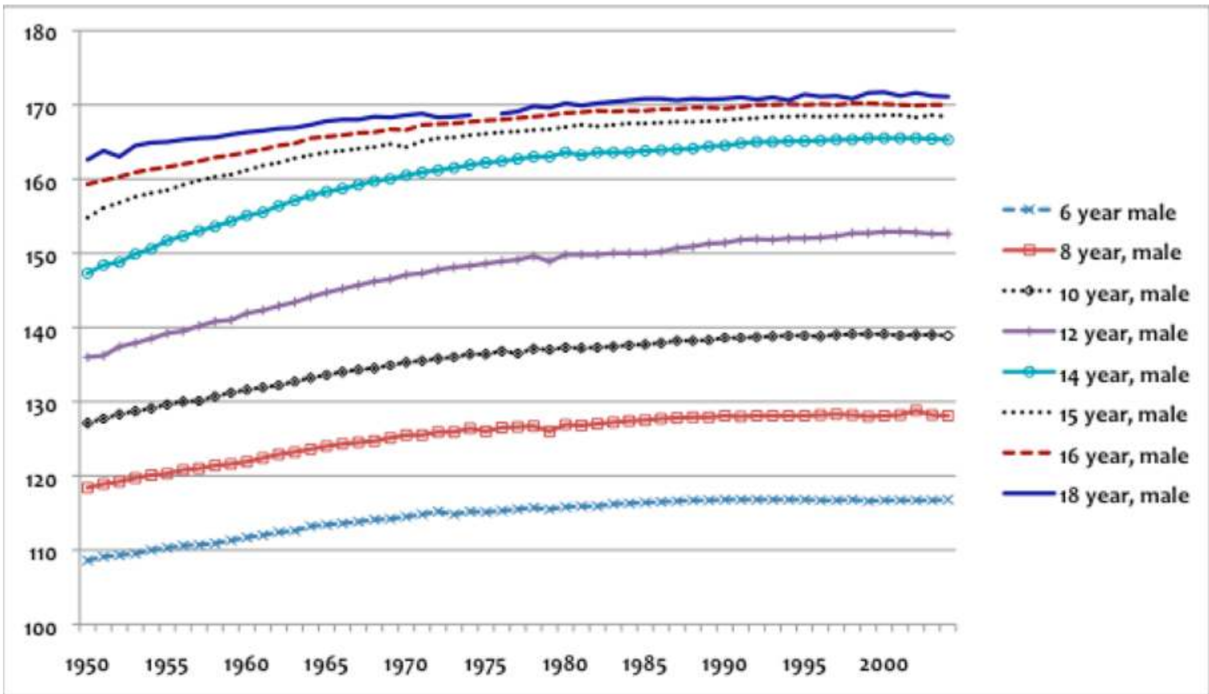

Figure 1. National average height of male students at different ages (year of measurement)
Source: Ministry of Education, Annual Report of School Health Survey, various years.

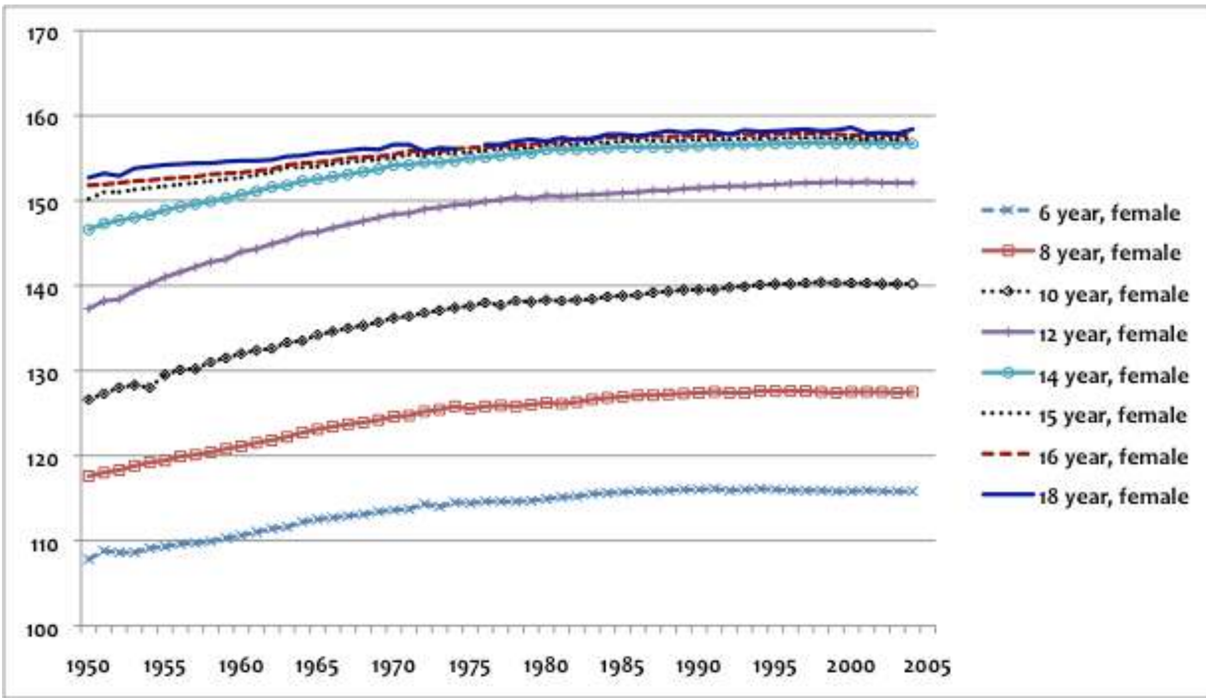

Figure 2. National average height of female students at different ages (year of measurement)
Source: Same as Figure 1.

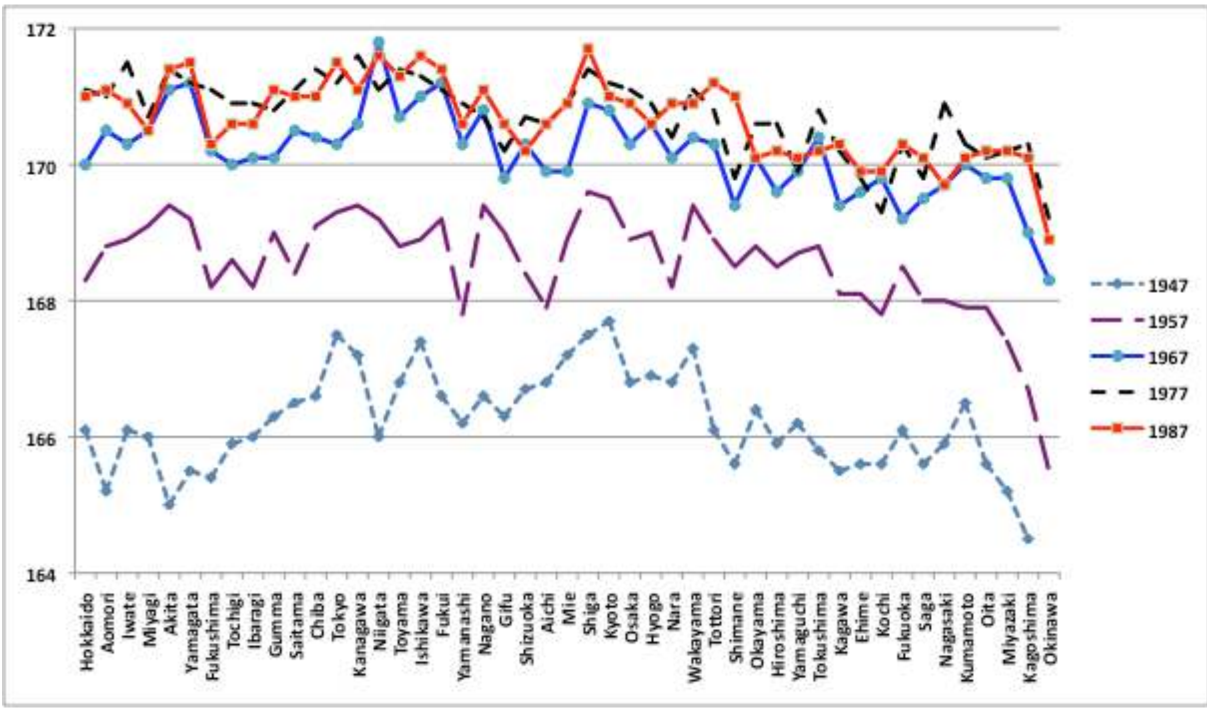

Figure 3. Prefecture-level average height at age 17 of male students (year of birth).
Source: same as figure 1.

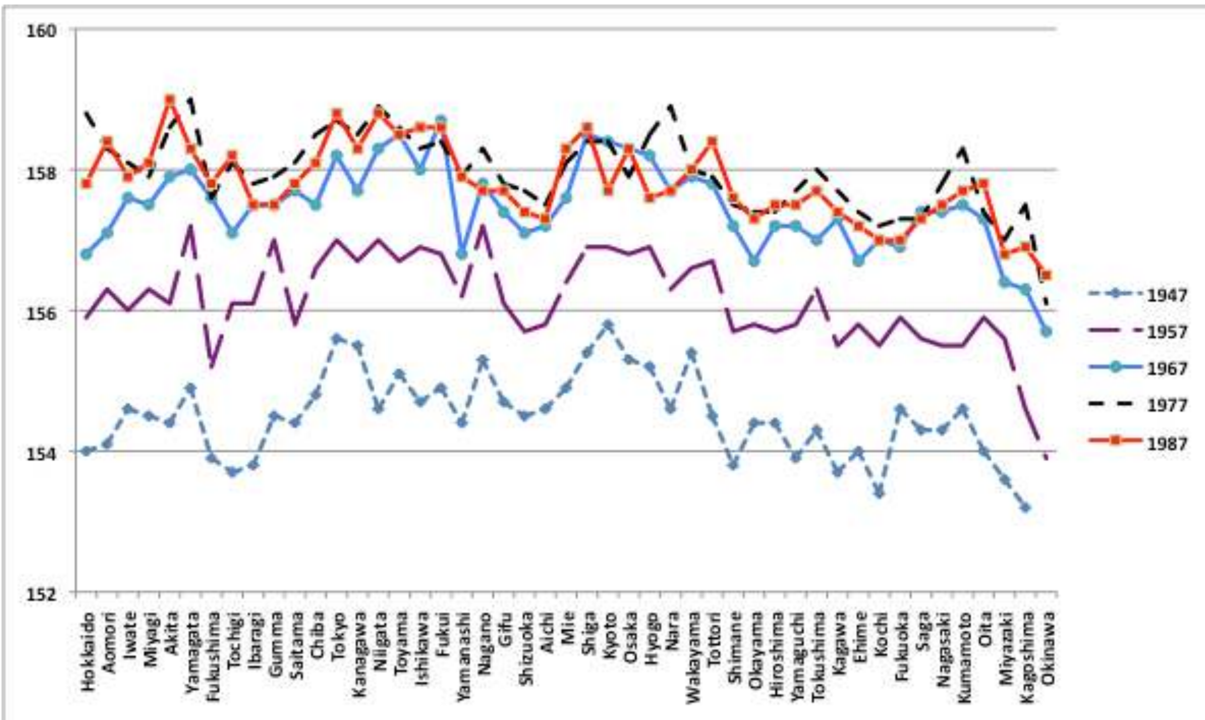

Figure 4. Prefecture-level average height at age 17 of female students (years of birth).
Source: same as figure 1.

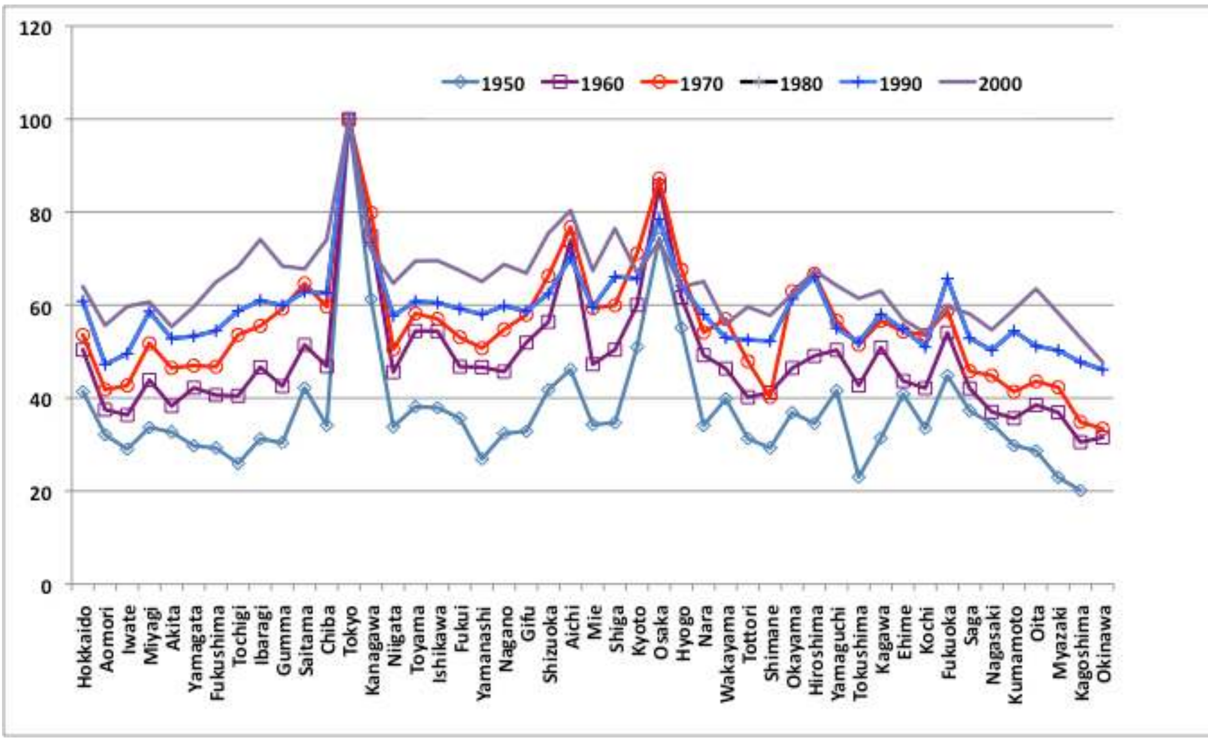

Figure 5. Prefecture-level per capita income relative to average per capita in Tokyo
Source: Statistical Yearbook of Japan, various years.

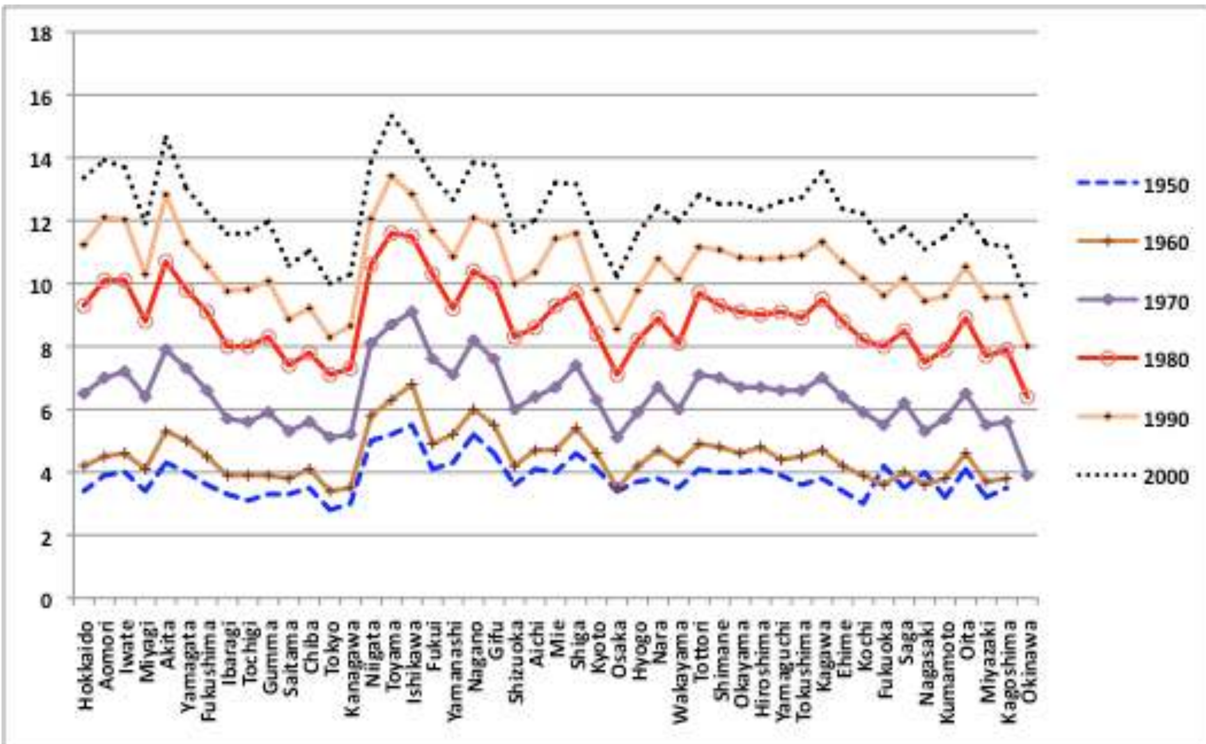

Figure 6. Prefecture-level housing surface per capita (in tatami)
Source: same as figure 5. Note: tatami size adjusted (1 tatami is around 1.55 square meter in the Tokyo area, 1.66 in Nagoya area, 1.82 in Kyoto area).

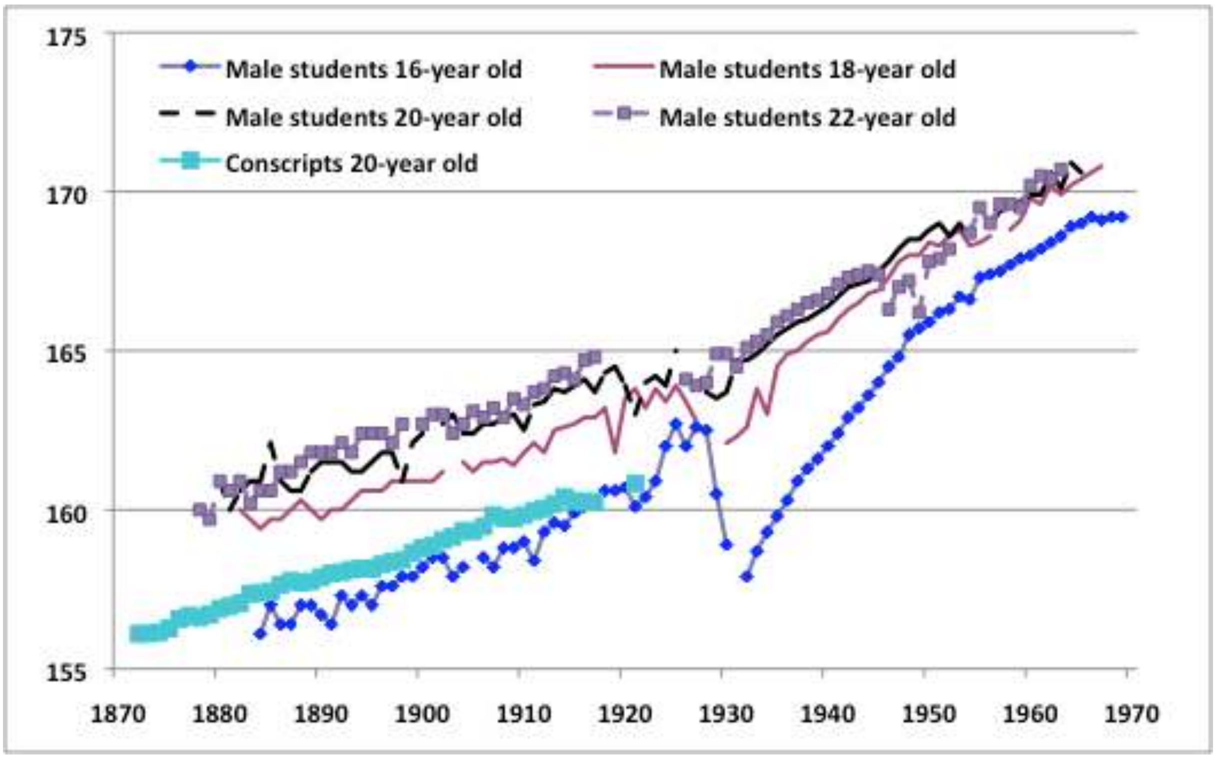

Figure 7. Average height of male students and conscripts (years of birth)

Sources: for students, Historical Statistics of Japan (Statistics Bureau, Ministry of Internal Affairs and Communication, http://www.stat.go.jp/english/data/chouki/index.htm); data sources for conscripts are described in Bassino (2006).

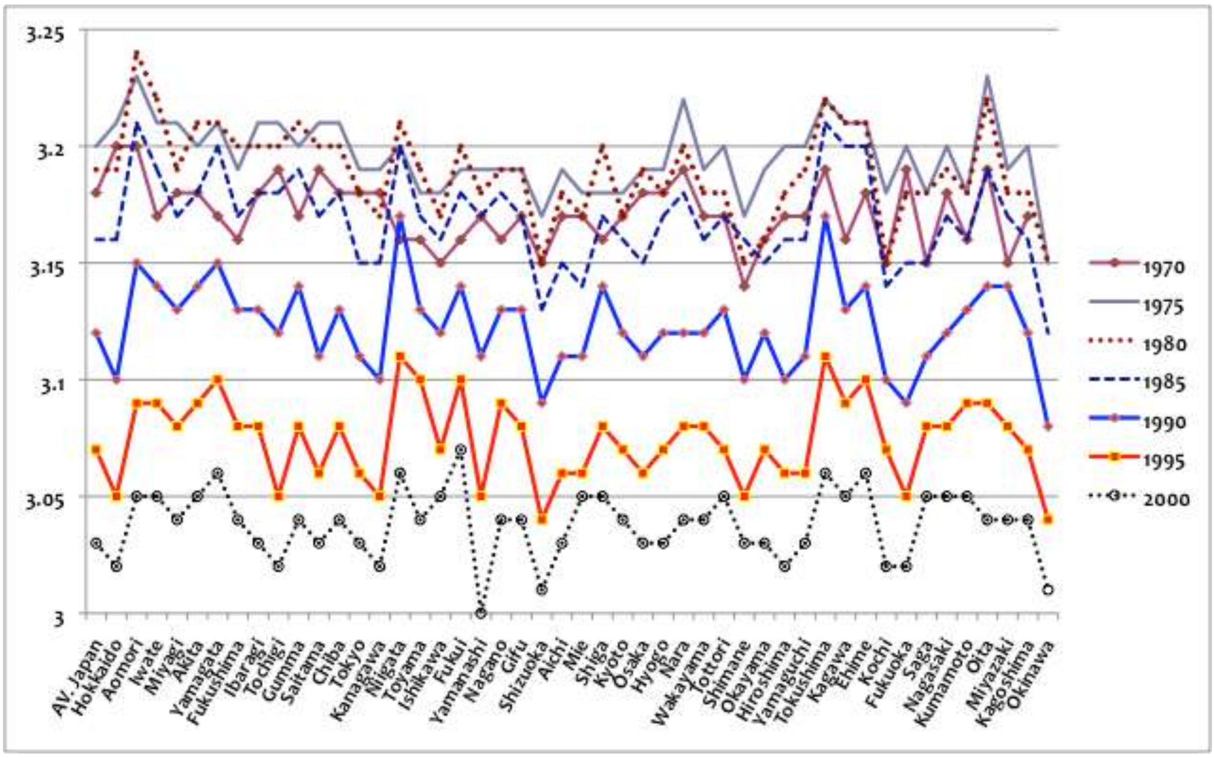

Figure 8. Average birth weight for selected years
Source: Ministry of Heath and Welfare.

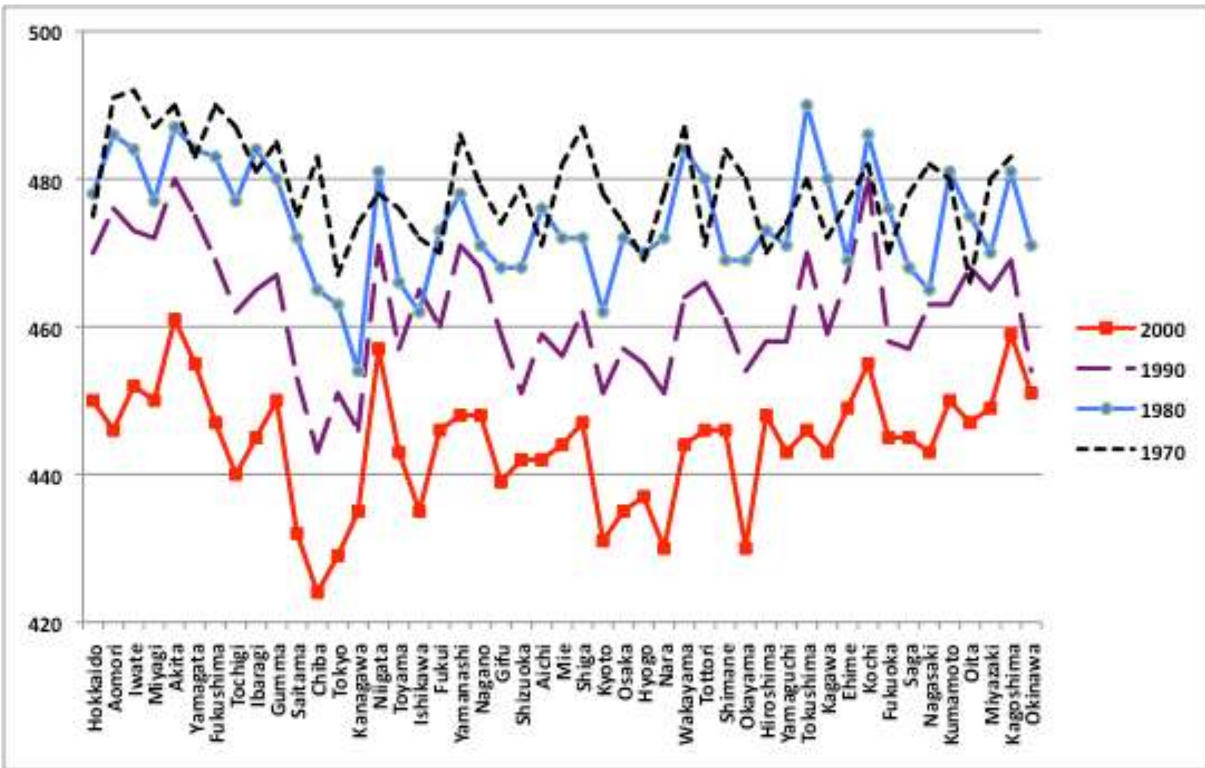

Figure 9. Prefecture-level weekday average daily sleeping time in minutes.
Source: NHK, National Lifestyle Time Survey.

MAP

Source: http://www.world-geographics.com/maps/asia/map-of-japan-regions-and-prefectures/