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A World Record in the Improvement in Biological Standards of Living in Korea: Evidence from Age at Menarche

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Abstract

This paper uses age at menarche to understand the improvement in biological standards of living in South Korea. The main data set, the Korean National Health and Nutrition Examination Survey, provides a consistent source of nationally representative data with a large number of observations over a long period of time. We find that the mean age at menarche decreases from 16.64 years for the birth year 1941 to 12.68 years for the birth year 1992, decreasing 0.78 (or 0.81 in a regression) years per decade for the birth years 1941–1992. Comparisons with other populations demonstrate that this is the fastest ever known. Furthermore, the decreasing rate does not appear to slow. The results are consistent with the fact that Korea achieved rapid economic growth in the second half of the 20th century. In addition, we provide suggestive evidence for height and life expectancy at birth improving at the fastest rate in the world.

Keywords: menarche; anthropometrics; South Korea; 20th century; Korean National Health and Nutrition Examination Survey

JEL Classifications: I15; N35

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1. Introduction

The extraordinary speed of South Korean economic growth in the second half of the 20th century has been well recognized in the literature. Amsden (1989) wrote an authoritative book on the topic, and recently, Acemoglu and Robinson (2012: chs. 2, 3) contrasted South Korea and North Korea as a clear case for the importance of institutions for economic growth. The special case of the Korean growth experience can be understood by the fact that Korean real GDP per capita grew almost 11 times between 1961, when Chung Hee Park successfully led the May 16 coup, and 1997, when the Asian financial crisis took place (Bolt and van Zanden, 2013). An improvement in living standards at such a speed is rare in history. China shows promise candidate to match this record but has not yet done so. China's real GDP per capita grew slightly more than 8 times from 1978 to 2010, even when the starting point is 22% lower than that of Korea's (978 vs. 1247, 1990 international Geary-Khamis dollars: henceforth GK$).

Although real GDP per capita is a typical measure of living standard, economic historians have rightly argued that this measure was too narrowly focused. Hence, they distinguished between income-based and biological indicators of living standard (Steckel, 1998, 2009, for reviews). This distinction became more important, as Komlos (1987, 1996, 1998) and Komlos and Baten (2004) found that income and height did not move together in early industrialization in some countries, notably, the UK and the US. Komlos argued that the biological standards of living, measured by height, deteriorated in early industrialization despite the increase in income levels and dubbed this counter-intuitive phenomenon the Antebellum Puzzle. However, Bodenhorn et al. (2014) recently provided a challenge to this notion, arguing that the Puzzle could be an artifact of sample selection.

As shown by the discussion on the Puzzle, height is arguably the most used biological indicator of living standard. Height is an appealing indicator because it is sensitive to environmental circumstances, widely recorded, and comparable across time and space. However, height does not always reflect the biological standards of living more accurately than other biological indicators. Deaton (2007) compared population mean heights among developing countries and found no obvious pattern; Africa was the poorest of the regions and had the highest disease burden but was at the same time the tallest of the regions. Thus, it is of interest to find an alternative to height.

This paper employs age at menarche to measure the improvement in biological standards of living for Korean women born in 1941–1992. Their growth period covers mostly the period of fast economic growth, so the sample can substantially elucidate the improvement in living standards. Like height, age at menarche is known to be sensitive to environmental circumstances. In addition, it is comparable across time and space. However, unlike height, it has been used rarely in history. Studies regarding the trend in age at menarche are published mainly in medicine and human biology (see Subsection 4.2). Even when menarche was mentioned in relation to historical events, the focus generally lay on medicine and human biology rather than on history (e.g., Liestøl, 1982; van Noord and Kaaks, 1991; Tahirović, 1998).

Age at menarche is not always superior to height in measuring biological standards of living. For example, it has been found that some adverse circumstances, such as father absence, are related to early menarche (Kanazawa, 2001). Nevertheless, evidence in medicine and human biology affirms that better conditions are related to early menarche (Prentice et al., 2010, and references therein). In addition, different factors influence age at menarche and height. Thus, the relationship between age at menarche and height is negative in small-scale and agrarian societies, positive in developed countries (McIntyre and Kacerosky, 2011), and nil in a developing country, that is, Indonesia (Sohn, 2014). For these reasons, age at menarche can complement height and provide new insights into the issue. By employing nationally representative data, this paper shows that age at menarche decreased by 0.78 (or 0.81 in a regression) years per decade for Korean women born during 1941–1992. This is the fastest speed ever known, which is consistent with the astounding speed of Korean economic growth

2. Literature Review

Some historians have employed height to understand changes in the biological standards of living in Korea (e.g., Kim and Park, 2011), but no attempt has been made to use age at menarche for this purpose. As for other populations, the trend in age at menarche in Korea has been discussed conventionally in medicine, and only two studies are worth mentioning. Hwang et al. (2003) provided an early attempt for this. They examined a cross-sectional sample of women born in 1920–1986, residing in an industrial city (Ansan). They found that age at menarche decreased 0.64 years per decade, which is very fast compared to those for other populations. Although this study is of merit as an early attempt, the sample was restricted to one city; thus, it is difficult to generalize this finding to the entire population.

Cho et al. (2010) addressed this issue, employing nationally representative cross-sectional data from the Korean National Health and Nutrition Examination Survey (KNHANES) for the year 2005. This is the Korean version of the NHANES. Similar to Hwang et al. (2003), they considered women born in 1920–1985 and estimated that age at menarche decreased 0.68 years per decade. Thus, although the samples in the two studies differed, both presented almost the same decreasing rates of age at menarche.

However, both failed to consider survival bias, which may not be a small concern for estimating a decreasing rate of age at menarche. If healthy women in general experience menarche earlier and live longer than unhealthy women, the surviving women in the early birth years (i.e., old women) in the samples of Hwang et al. (2003) and Cho et al. (2010) would report earlier ages at menarche than the population in the same birth years. Then, the mean ages at menarche for the birth years were biased downward, and the decreasing rates of age at menarche were also biased downward. As a result, the estimated rates of the two studies can be regarded as lower bounds. If the length of birth years for which survival bias is suspected were small, the bias in the decreasing rate would be small. However, the length is not small. For example, in Cho et al.'s (2010) sample, the age range was 20–85 years. If survival bias starts to be serious at the age of 60 years, more than a third of the period would potentially be influenced by the bias.

In addition, Cho et al. (2010) did not include other series of the KNHANES. The KNHANES for the year 2001 was definitely available and possibly those for 2007 and 2008 as well. Because the KNHANES is a cross-sectional survey, one can increase estimation precision by pooling the available series. Cho et al. (2010) had only 31 observations for the birth years 1920–1924; only the birth years 1950–1954 and onward were there, on average, at least 50 observations per birth year, which we believe gives a sufficient degree of precision. From this perspective, Hwang et al.'s (2003) sample was worse; there were only 40 observations for the birth years 1920–1929, and no birth year contained, on average, at least 50 observations per birth year. In the following section, we address these concerns.

3. Data

We pool the KNHANES for the years 2001, 2005, and 2007–2013; that is, all survey years except for the earliest one in 1998, which does not have a variable of age at menarche. The Korean Ministry of Health and Welfare conducted the survey, using a stratified, multistage probability sampling design to select household units. The survey is nationally representative, covering non-institutionalized Korean civilians.

Age at menarche is recalled and self-reported. This feature may raise a concern of measurement error and bias, but a long list of studies stretching from Livson and McNeill (1962) to Dorn et al. (2013) has demonstrated that reported age at menarche is quite accurate. This high accuracy is probably due to the salience of menarche to a girl. For analysis, age at menarche is restricted to 8–19 years because values outside the range are probably due to a (random) recording error.

We consider two samples. One (potentially biased) sample considers the minimum age for sample inclusion (20 years), but not the maximum age. The minimum age takes into account the maximum age at menarche (i.e., 19 years). The other (unbiased) sample considers both minimum and maximum ages. By comparing the two samples, one can get a sense of the degree of bias.

We consider the number of survivors to set the maximum age. Figure 1 presents four curves of number of survivors at varying ages. The earliest year available is 1970, and three more curves are added at an interval of one decade. The upward shift of the curves demonstrates the rapid improvement of life expectancy (Yang et al., 2010). In addition, as Korean economic growth took off just before 1970, it is likely that the curve for earlier years would be similar to or slightly lower than that for 1970. In this case, a woman born in the year 1940 was expected to live up to 60 years with a probability of 72% (estimated for 1970) or slightly lower. However, as she aged, the probability increased, as shown by the upward shift of the curves. If she survived up to 60 years in 2000, the survival rate increased to 93%. Hence, we believe that 60 years is a reasonable age to alleviate survival bias. To be conservative, we could lower the maximum age below 60 year. We argue below that lowering the maximum age does not make much difference to the main results. Thus, an objection could be that the maximum age is too low. However, for each year, the curve turns sharply downward around the age of 60 years. Thus, as late as 2000, the survival rate up to 80 years was only 59%. This suggests that the studies of Hwang et al. (2003) and Cho et al. (2010) suffered from severe survival bias, as the maximum age was 82 years for the former and 85 years for the latter.

In addition, we consider only a birth year for which at least 50 observations are available to improve estimation precision. The birth year range is 1923–1992 for the biased sample and 1941–1992 for the unbiased sample. The sample size is 28,881 for the biased sample and 24,651 for the unbiased sample. When the minimum number of observations for each birth year is reduced from 50 to 30, the birth year range is 1921–1992 for the biased sample and 1941–1992 for the unbiased one. Because the decreasing rate of age at menarche is almost identical regardless of the minimum, only the results derived from the samples with the minimum of 50 observations are presented below.

Note that our interest lies in the long-run trend in age at menarche. Thus, we do not relate age at menarche to individual characteristics such as income and family size. Such an exercise has been widely employed in medicine and human biology, and Hwang et al. (2003) and Cho (2010) performed this particularly for Korea.

4. Results

4.1. Main Results

Figure 2 presents the trend in age at menarche. The shaded area refers to birth years to which the maximum age of 60 years is not applied. First, we focus on the trend outside of the shaded area. A downward trend in age at menarche is unambiguous. Age at menarche decreases from 16.64 years for the birth year 1941 to 12.68 years for the birth year 1992. It is worth pointing out that girls born in 1941 came of age mainly after the Korean War. Although the Korean War officially occurred in 1950–1953, serious conflicts in South Korea ended by late 1950. Thus, it is not anomalous to observe a downward trend line starting in 1941.

One may wonder whether the late age at menarche for 1941 is plausible. If this were biased upward for some reason, the decreasing rate of age at menarche would be biased upward. Because ethnicity influences age at menarche, even holding other things constant, we need to know the ages at menarche of Koreans neither born nor raised in South Korea. North Koreans meet these criteria. Ku et al. (2006) surveyed 411 North Korean women at a refugee camp located in South Korea. All of them had experienced menarche in North Korea and had immigrated less than three months prior to the survey. Their mean age was 31.3 years (standard deviation SD: 6.2) and the mean age at menarche was 16.0 years (SD: 2.1). Considering that they survived the North Korean regime and life-threatening emigration, this mean is likely to be biased downward. In addition, the biological standards of living (measured by height) did not improve at all for the birth years 1940–1989 (Pak et al., 2011).

Furthermore, there is a report that immediately after the colonization of Korea, a mean age at menarche of 16 years and 6 months was observed for women in North-western Korea (cited from Lee, 1930, 33); the area was in the middle income range in Korea at the time. This observation concerned women who went through adolescence long before women born in 1941. However, both groups experienced severe poverty (in the late Joseon dynasty for the former and during WWII, independence, and the Korea War for the latter), and so they may be comparable. Overall, it appears that the starting point in our trend (i.e., 16.64 years) is plausible.

More interestingly, the decreasing rate does not appear to slow. To detect a structural break in the trend formally, we perform a test proposed by Andrews and Zivot (1992). The lowest t-statistic (-3.52) was for the birth year 1971, but this figure did not reach even the critical value for 10% statistical significance (-4.11). This finding verifies that the downward trend does not bottom out, which is in contrast to the findings for several developed countries (Malina, 1990; Onland-Moret, 2005). In addition, this uninterrupted linear trend suggests that nationwide economic shocks, such as oil shocks in the 1970s and the Asian financial crisis in 1997–1998, did not adversely affect the biological standards of living measured by age at menarche. Korean individuals and the government somehow buffered the shocks to the biological standards of living, and in a sense, this is a success story not told by income-based indicators.

On the other hand, there is no clear trend with regard to the shaded area of Figure 2; instead, the trend is rather flat and consistent with Cho et al.'s (2010) finding. Because we do not know the degree of survival bias, it is unclear how much this flatness is attributed to survival bias. Flatness could genuinely reflect the adverse conditions that the population underwent. People suffered from the Japanese mobilization for imperial expansion and the Korean War in childhood, but recognizing such disastrous conditions, one may anticipate an upward, not flat, trend. Hoshi and Kouchi (1981) observed that mean ages at menarche in studies reported in Japan decreased from 15.0 to 14.2 in the publication years 1920–1940, and then returned to 15.0 in the publication years 1950–1952. They attributed this reversal to the destructive effects of World War II. Moreover, when this reversal happened to Japanese women, it is probable that the degree of reversal in the trend was greater for Korean women considering their status as a colonized population. Similarly, Wellens et al. (1990) observed that Flemish girls born in 1925–1929, who suffered from World War II in childhood, exhibited a higher mean age at menarche relative to the adjacent birth cohorts. Van Noord and Kaaks (1991) advanced consistent evidence based on Dutch women. It is revealing that in both studies, the trend in age at menarche reversed even for survivors; thus, the upward trends would be steeper without survival bias. Furthermore, the adversity of the conditions would reinforce survival bias—the survivors must have been considerably healthy.

The possibility of an upward trend is not idle speculation. The mean height increased for Korean men and women born in 1881–1920 (Kim and Park, 2011), so these birth cohorts might have exhibited a downward trend in age at menarche, followed by an upward trend for the birth cohorts in the shaded area. The fact that the trend in the shaded area is flat rather than increasing suggests that survival bias does exist.

We can formally estimate the decreasing rate of age at menarche, by regressing age at menarche on birth year. The rate is 0.81 years per decade (95% CI, 0.78–0.83) excluding the birth years in the shaded area. When the birth years in the shaded area are included, we can replicate Cho et al.'s (2010) rate of 0.68 (95% CI, 0.65–0.72). Because the degree of survival bias is unknown and birth cohorts differ in our and Cho et al.'s (2010) samples, it is difficult to assess the unbiased rate for birth years in Cho et al.'s (2010) sample. However, as far as birth years in our sample are concerned, the decreasing rate is the fastest ever recorded. Furthermore, this fast rate spans a period of 50 years, and as the test for a structural break indicates, this indicates a sustained rate for a long time. Thus, it is not an idiosyncratic fluctuation in a long trend. Similarly, this rate concerns an entire population, so it is not a special case of a group of women in a small area. It is also worth noting that the rate is derived from a single source of data. This guarantees consistency in samples for a long period of birth years.

One can appreciate the significance of the speed of the decline in age at menarche by comparing our findings with that of others. However, no study (except for Sohn, forthcoming) has employed a *single* source of *nationally representative* data with a *large* sample size to estimate a changing rate of age at menarche for a *long* period of time. Nevertheless, Table 1 lists decreasing rates of age at menarche provided by some representative studies. To save space, we explain how the rates were obtained in the appendix, alongside some cautions required in reading them.

4.2. Comparisons with Indonesia

Another way of appreciating the fast decrease in age at menarche among Korean women is to compare this trend with that of a country that had income levels similar to those of Korea at the beginning of the trend (i.e., the birth year 1941). In this regard, Indonesia provides a comparable case. According to Bolt and van Zanden (2013), Indonesian GDP per capita for 1940 is 1,127 GK$, which is 26% higher than that for Korea (893 GK$); the

Korean figures do not exist for 1941–1949. For 1950, when GDP per capita is again available for both countries, the figures are 817 GK$ for Indonesia vs. 854 GK$ for Korea. In 1951, Korea's lead is reversed to 864 GK$ vs. 787 GK$, respectively, followed by another reversal to 913 GK$ vs. 1072 GK$ in 1953, respectively. Since then, Korea's figure has been higher than Indonesia's. Thus, income levels in both countries were very similar at the beginning of the downward trend in age at menarche among Korean women.

We borrowed Sohn's (forthcoming) data, which considered the birth years 1944–1988.[1] We extended the birth years to 1997 using the Young Adult Productive Health Survey (YAPHS) for the years 2002, 2007, and 2012, which are special surveys of the Demographic and Health Survey for Indonesia. The IFLS and YAPHS differ in some aspects. For example, while the IFLS is longitudinal, the YAPHS is cross-sectional. However, Sohn (forthcoming) reconstructed the IFLS as cross-sectional data. A more concerning difference is that recalled age at menarche was obtained by ever-married women aged 15–49 years for the IFLS, but unmarried women aged 15–24 years for the YAPHS. Naturally, sample selection poses a concern for the latter. If married women tend to have menarche earlier than unmarried women of the same age, the mean age at menarche for the IFLS is biased downward and that for the YAPHS upward. That said, it is appealing that both surveys are nationally representative.

[1] Sohn (forthcoming) restricted age at menarche to 10–18 years, but we widen the interval to 8–19 years for consistency with the intervals of the KNHANES and YAPHS. This modification is inconsequential because it adds only a small number of respondents.

We depict the trends in age at menarche for Korea and Indonesia in Figure 3. Fortunately, the IFLS and YAPHS exhibit almost the same ages at menarche for the overlapping birth years. However, we focus on the IFLS trend for the overlapping period because it concerns a longer period of time. It is of interest that the mean age at menarche in Korea in the early period is very late, despite similar income levels between the two countries. For 1944, the mean is 16.6 years for Korea and 14.4 for Indonesia, a difference of 2.2 years.

However, because many factors determine age at menarche, it is possible for there to be such a large difference between two countries with similar income levels. Ethnicities are one possible reason for the large difference. Alternatively, it could be due to the perennial warm climate in Indonesia, which leaves energy for growth and promotes earlier onset of menarche. It would be possible to test this hypothesis if we had a long time series of age at menarche of Korean immigrants to warm countries. Unfortunately, such data do not exist, to the best of our knowledge. In addition, this hypothesis is not consistent with the fact that Indonesia belongs to a region whose people exhibited the shortest height in the world over the past 200 years (Baten and Blum, 2012). Indonesians were smaller than Koreans were, even in the early times. For example, the mean height of women born in 1941 is 147.4 cm for Indonesia (from the IFLS) and 153.3 cm for Korea (from the KNHANES). The difference between the means increases with birth year. Future research could address these contrasting findings on age at menarche and height between the two countries. In addition, the large difference in age at menarche with similar income levels implies that GDP per capita is a crude indicator of biological standard of living, which is exactly the argument that the economic historians of anthropometrics have advanced.

A more interesting finding is that despite the considerable late age at menarche at the beginning, Korea surpassed Indonesia in age at menarche very rapidly. For the birth year 1968, the age at menarche is the same for both countries, and from the birth year 1970 onward, the Korean age at menarche has been earlier than the Indonesian one. Thus, it took only about 25 years to close the gap of 2.2 years. This is an astounding speed. Note that Graham et al. (1999) reported the fastest speed in the literature, but even in their sample, it took about 40 years to witness a decrease of 2.8 years in age at menarche.

4.3. Comparisons with Height

The decreasing rate of our main variable of interest, age at menarche, is the fastest ever known. However, height has been investigated extensively in economic history, so it is tempting to compare the trend in age at menarche to that in height.

We augment our sample with the KNHANES for 1998 and chart the trend in height for each gender. The age range is the same as for age at menarche (i.e., 20–60 years), and at least 50 observations are guaranteed for each birth year. Because we incorporate the 1998 survey, the range of birth years for height is longer than that for age at menarche: 1938–1991 for men and 1938–1992 for women. Figure 4 presents the trends for both genders. It is of interest that in the early years, the trend is rather flat for men. Men of these birth years experienced the Korean War and its aftermath in childhood. However, the trend for women of the same birth years is not as flat. This continuous trend in height for women is consistent with the continuous trend in age at menarche. After the flat period, the trend for men is steeper than that for women up to the birth year 1989. One may notice that the mean male height rapidly decreases from the peak at 175.1 cm for the birth year 1989 to 173.0 cm for the birth year

1991. However, it is probably a small dip in an upward trend because the mean heights for the subsequent birth years rebound and surpass the previous peak: 174.7 cm for the birth year 1992 (N=27) and 176.5 cm for the birth year 1993 (N=23). We hastily require caution for our explanation because the number of observations for each birth year is small.

A precise rate of change in height for each gender can be estimated as follows. We calculate the mean height for each birth year and regress the former on the latter; each observation is weighted by its number of contributing observations. The rate is 2.08 cm per decade (95% CI: 1.98–2.18) for men and 1.88 cm per decade (95% CI: 1.80–1.96) for women; as the confidence intervals indicate, the results are statistically different.

How fast are the rates? Because this paper focuses on age at menarche, we do not provide as detailed a comparison for these rates as for those of age at menarche. Nevertheless, a secular increase in adult height was 1 cm per decade for Europe and North America during 1880–1950 (Malina, 1990: 211). The Korean rate is much faster than this. One could argue that the period is too long to be comparable to ours, particularly as height approached a plateau in the later years. Hauspie et al. (1997) provided a summary for shorter periods of time. The fastest rate in their summary was 3.0 cm per decade for Japanese men during 1950–1960 and for Czech women during 1973–1982. However, the periods are rather short and do not represent a rate of change in height over a long period of time. In fact, the rate drops to less than 1 cm per decade for Japanese men during 1980–1990. The second fast rate is 2.0 cm per decade for Polish men during 1965–1995. This period is relatively long, so it may be comparable to ours. As our rate is slightly higher than this, it appears that the increasing rate of height also appears to be the fastest in history, provided a period of several decades is considered.

5. Conclusions

We attempt to understand the improvement in biological standards of living in Korea, employing age at menarche as an indicator. This indicator has been widely used in medicine and human biology, but, unlike height, little used in history. However, unlike most studies in medicine and human biology, we use nationally representative data with a large number of observations for a long period of time. After purging the sample of potential survival bias, we estimate a decreasing rate of 0.78 (or 0.81 in a regression) years per decade for Korean women born during 1941–1992. This rate is the fastest ever known. In addition, we provide suggestive evidence that the increasing rate of height is also the fastest. What else can we find? Yang et al. (2010) argued that the increase in life expectancy at birth for Koreans was also the fastest, at least among OECD countries—it increased from 52.4 years in 1960 to 78.5 years in 2005, or 5.8 years per decade. If age at menarche, height, and life expectancy at birth are plausible indicators of biological standard of living, it appears that the biological standards of living in Korea have improved at an unprecedented rate.

However, past success does not easily convert to current success. There are several signs that the living standards of Koreans are not the best at present. One clear sign arises from the suicide rate. According to the OECD Health Data 2014, the Korean suicide rate was 29.1 people per 100,000 in 2012, which is considerably higher than the OECD average of 12.1 people. This is not a temporary situation; the Korean suicide rate has been the highest for the past 10 years consecutively. It is unclear whether past success is somehow related to these disappointing statistics. However, it is clear that much effort should be made to convert past success to current success.

Before concluding this paper, it would be of interest to speculate what drove the fast improvement in biological (as well as income-based) standards of living in Korea. An important immediate cause is probably the rapid increase of GDP per capita along with other correlates such as more nutrition, better public health, improved medical technology, smaller family size, and higher level of education. More interestingly, Baten and Sohn (2014) provided an ultimate cause. According to them, a small number of countries had low levels of income but high levels of human capital (measured by age heaping) circa 1820 but they exhibited fast economic growth thereafter; Korea is a conspicuous example of them. Thus, it appears that for some reason, the high level of human capital in Korea was not tapped into.

Baten and Sohn (2014) did not delve into this issue, but recent contributions on the economic history of Korea have provided some leads (Rhee, 2014). In contrast to historians inspired by Korean nationalism, econometricians in this field argued that government policies hindered market integration. The Chosun dynasty prohibited the trading of luxuries and strictly controlled the supply of money. Copper coins were available only in 1678 and media for trading high values, such as gold and silver coins, were not minted at all. Furthermore, the dynasty preferred in-kind taxes to monetary taxes, thereby slowing the development of markets. Another factor is civil servant examinations because passing them relied heavily on memorizing Chinese classic literature, thereby neglecting science-based knowledge. The implication is that institutions were not “right” during the dynasty but corrected during colonization and developed after independence. We acknowledge that this is speculation, albeit plausible. Future research could analyze this further.

Appendix

It took a long time (relative to Korea) for developed countries to achieve high income levels, and so their decreasing rate of age at menarche is expected to be lower than ours. Wyshak et al. (1982) nicely summarized this by collecting historical (but not quality) data on age at menarche. When they regressed age at menarche on calendar years (1790–1980), they found that the decreasing rate for Europe was 0.19 years per decade. The corresponding figure was 0.25 years for Europe excluding France, 0.27 years for Scandinavia, 0.17 years for Germany, 0.09 years for France, and 0.16 years for England. When attention is paid to 307,081 women born in 1915–1964, aged 35–70 years, and residing in nine European countries, the fastest rate was only 0.32 years per decade for Germany and for Spain (Onland-Moret et al., 2005).

In addition to Europe, the Japanese case is of great interest for several reasons. Japan and Korea share similar climatic conditions and ethnicities, and both countries have witnessed very rapid economic growth. In 1979–1980, Hoshi and Kouchi (1981) collected information on age at menarche from 284 schoolgirls born in 1961–1966 and residing in Tokyo and its outskirts; the girls were healthy and of middle socioeconomic class. From this sample, the authors calculated a mean age of 12.4 years. In addition, they collected 157 studies reported in Japan, covering the publication years circa 1880–1980. They found no clear trend before 1920, and then a downward trend from 15.0 to 14.2 years during the publication years 1920–1940 at a rate of 0.41 years per decade. Thereafter, the trend reversed to about 15.0 years of age at menarche during the publication years 1950–1952 and accelerated downward to the mean age in their sample (i.e., 12.4 years). From this information, we can roughly calculate the decreasing rate by (15.0 - 12.4) / (1980 - 1950) = 0.87 years per decade.

If this were true, this would be a world record in the decrease in age at menarche. However, it is doubtful that this rate is realistic. First, the quality of the 157 studies and data used for them are unknown. Hoshi and Kouchi mentioned only that they were reported in Japan. Because they collected a small number of observations for convenience as late as 1979–1980, it is unlikely that the data used for the 157 studies were any better than those of Hoshi and Kouchi (1981) were. In addition, the starting point of the downward trend is a point that deviates from the long trend, which makes the decreasing rate faster than otherwise. For example, if the mean age for 1920 is considered, then the decreasing rate of age at menarche during the publication years 1920–1980 drops to 0.43 years per decade. If the period considered is extended further to the early times when the trend was flat, the rate would be smaller. Furthermore, the end point of the trend is collected from schoolgirls from middle class families residing in Tokyo. This group probably exhibited the earliest age in Japan during the survey year, biasing the decreasing rate upward. Overall, it appears that the decreasing rate over a long period of time is not substantially faster than that of Europe.

On the other hand, considering that some populations outside of Europe experienced rapid economic growth, one may find faster decreasing rates. Next, we present decreasing rates of age at menarche in descending order for developing countries. Graham et al. (1999) considered the recalled age at menarche of 12,727 women aged 15+ years residing in two rural areas in Anhui, China in 1993. The maximum birth year was 1978, but the minimum birth year was not specified. Nevertheless, they stated that age at menarche decreased from 16.5 to 13.7 years over an approximate 40-year time interval. They did not regress age at menarche on birth year, so they did not provide a decreasing rate that is directly comparable to ours. However, using the information, we can roughly calculate a decreasing rate of 0.7 (=

(16.5 - 13.7) / 40) years per decade. Note that the time interval is greater than 40 years but not specified. Thus, the rate of 0.7 years is an upper bound.

Prentice et al. (2010) collected information on age at menarche from all female inhabitants aged 9–20 years in three neighboring villages in rural Gambia, West Africa in 1989 (N=239), 2000 (N=346), and 2008 (N=339). Using interval regression of the pooled data, they estimated a decreasing rate of 0.65 years per decade.

Loukid et al. (1996) surveyed 239 schoolgirls aged 11–17 years from Marrakesh, Morocco in 1991 and estimated a median age at menarche of 13.75 years by probit analysis. They compared this figure with that estimated by a previous study for girls in the city in 1982 (N=319). They concluded that age at menarche declined by about 0.55 years during 1982–1991. However, they selected an area in Morocco in which there was a rapid improvement in general living conditions and the time period covered was too short to say much about a long-term trend in age at menarche. The rate is likely to be an upper bound for Moroccan women in general.

Villamor et al. (2009) used information on recalled age at menarche from 3,206 students of the National University of Colombia, 948 students' mothers, and 1,423 students' sisters—their birth years in this sample ranged from 1941 to 1989. From the samples, they regressed age at menarche on birth year and estimated a decreasing rate of 0.55 years per decade. However, their sample size for the birth years 1941–1947 was only 128, which influenced the starting point of the decline of age at menarche. Thus, caution is required to accept this rate.

Jones et al. (2009) considered two races separately: 188 black girls and 99 white girls residing in Soweto-Johannesburg, South Africa in 2004. They used logistic curves and derived a median age at menarche of 12.4 years for black girls and 12.5 years for white girls.

Then, they compared these figures to previous studies and estimated a decreasing rate of 0.50 years per decade for black girls and 0.22 years per decade for white girls during 1956–2004. However, these rates are not definitive because they considered only mean ages at menarche at several points in time; furthermore, the study varied from previous studies in geographical location, socioeconomic status, methodologies, and sampling techniques.

Cameron et al. (1991) collected information on age at menarche from 230 rural South African girls aged 11–17 years and estimated a mean of 14.03 years using status quo techniques. Then, they combined the mean with those of previous studies (based on status quo techniques, except for one study) and regressed the mean age at menarche on the year in which the mean was determined. They reported a decreasing rate of 0.42 years per decade for rural and urban women combined over 40 years. Separately, the rate was 0.31 for rural girls and 0.64 for urban girls. However, the authors admitted that none of the samples of girls was drawn from the same geographical area, and therefore, the coefficient on the year might simply represent geographical variability rather than secular change.

In 1982–1983, Modebe (1987) gathered information on age at menarche from 2,207 schoolgirls in Enugu, the capital of Anambra State in south-eastern Nigeria. Then, he used probit analysis and estimated a mean age at menarche of 13.3 years. Finally, he combined this mean with those provided by four previous studies (published in 1950, 1962, 1976, and 1980) for girls from southern Nigeria since 1949. With these five mean ages at menarche, he regressed age at menarche on calendar year and estimated a decreasing rate of 4 months (0.34 years) per decade. However, as this rate was obtained from heterogeneous sources (not to mention the small number), the same caveats apply as to Jones et al. (2009).

Sohn's (forthcoming) study is of importance because the data characteristics are similar to ours. He exploited information on recalled age at menarche from 8,331 ever-married women born in 1944–1988 and aged 15–49 in the nationally representative Indonesian Family Life Survey (IFLS); the sample size is large, and the period considered is relatively long. He regressed age at menarche on birth year and estimated a decreasing rate of 0.24 years per decade.

Pasquet et al. (1999) collected information on age at menarche from 156 urban schoolgirls in Yaoundé (the capital of Cameroon), 466 suburban schoolgirls in the district of Mfou, and 195 rural schoolgirls raised in the Campo district; the girls were aged 9–19 years, and the survey year range was 1986–1995. Using the samples, they applied probit analysis to estimate the mean age at menarche for each geographical group. They combined this information with nationally representative samples of Cameroonian women aged 20–54 years and estimated a decreasing rate of 0.21 years per decade for women residing in Yaoundé and Douala and born in 1930–1984 (N=442). The corresponding figure, albeit with different birth years, was 0.09 years for other urban areas (N=821) and 0.020 years (statistically insignificant, N=2,166) for rural areas. However, they did not specify how they treated pre-menarcheal school girls in their sample. This issue is important because schoolgirls in their sample provided the end point of the trend. If pre-menarcheal schoolgirls were excluded from the estimation, the mean age at the end point would be biased downward, which would eventually bias the decreasing rate upward. In addition, they did not specify how they converted the menarcheal status of schoolgirls (yes or no) to age at menarche. In addition, the sample size for the highest rate (i.e., 0.21 years per decade) was very small—on average, 6.8 observations for each birth year. Thus, caution is required to accept this rate.

Adanu et al. (2006) collected recalled age at menarche from 2,644 women born in 1901–1985 and residing in Accra, Ghana. They regressed age at menarche on birth year and estimated a decreasing rate of 0.20 years per decade. Because the sample included women as old as 102 years, this rate is probably biased downward due to survival bias. That said, the rate is much smaller than ours is.

Padez (2003) considered 753 schoolgirls in Maputo, the capital of Mozambique, in 2000, but used only 407 schoolgirls who had started menstruation and recalled their ages at menarche. Then, they calculated the mean age at menarche, which clearly biased their estimate downward. Despite this, they proceeded to compare their mean with that estimated from isolated samples collected from 1963–1964. They concluded that there was no evidence for a decrease in age at menarche. Because this rate was calculated by comparing two means estimated from two varying sources, it suffered from the same concerns as those of Jones et al. (2009).

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Table 1 Decreasing Rate of Age at Menarche around the World

Study	Country (or Area)	Rate (years per decade)
This Study	South Korea	0.81
Wyshak (1982)	Scandinavia	0.27
Onland-Moret et al. (2005)	Germany and Spain	0.32
Hoshi and Kouchi (1981)	Japan	0.43
Graham et al. (1999)	China	0.70
Prentice et al. (2010)	Gambia	0.65
Loukid et al. (1996)	Morocco	0.55
Villamor et al. (2009)	Colombia	0.55
Jones et al. (2009)	South Africa	0.50
Cameron et al. (1991)	South Africa	0.42
Modebe (1987)	Nigeria	0.34
Sohn's (forthcoming)	Indonesia	0.24
Pasquet et al. (1999)	Cameroon	0.21
Adanu et al. (2006)	Ghana	0.20
Padez (2003)	Mozambique	No trend

Notes: If a study presents more than one rate, the highest rate is listed.

Figure 1 Number of Survivors at Varying Ages

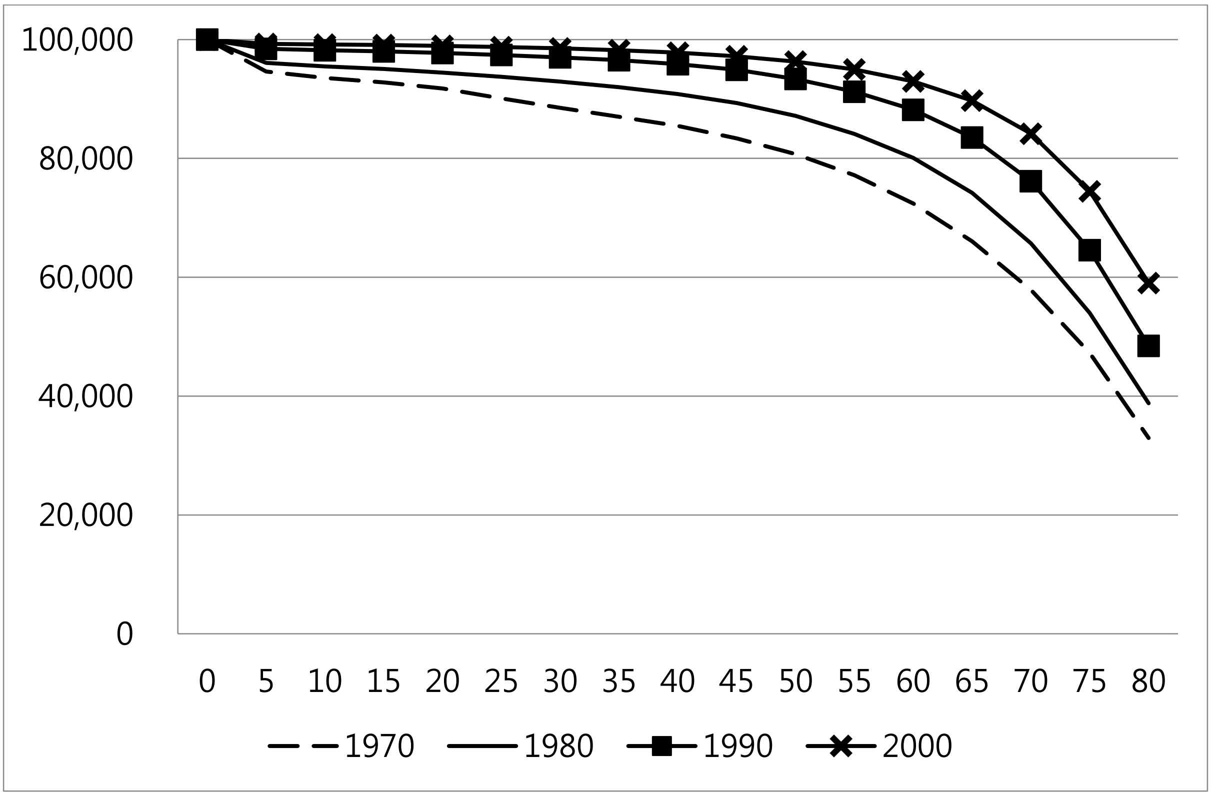

Figure 2 Trend in Age at Menarche for Koreans

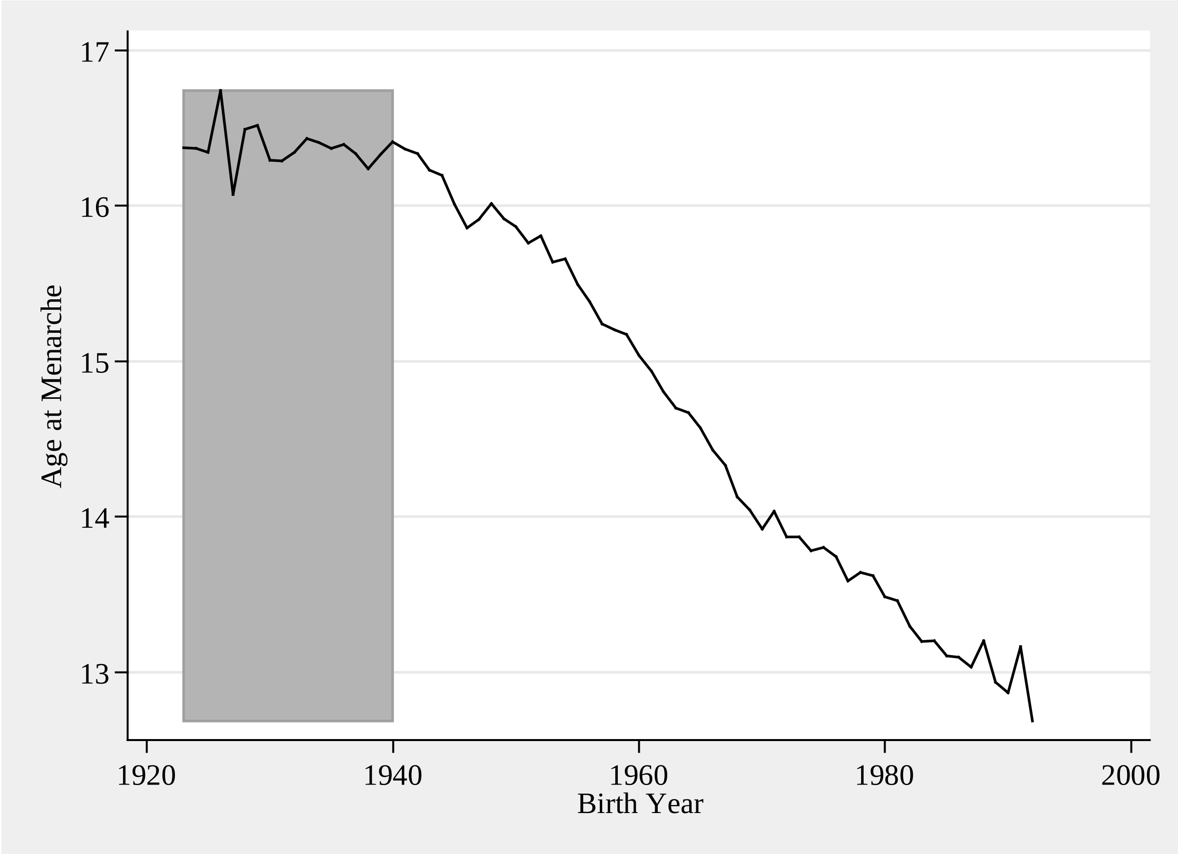

Figure 3 Trend in Age at Menarche by Country

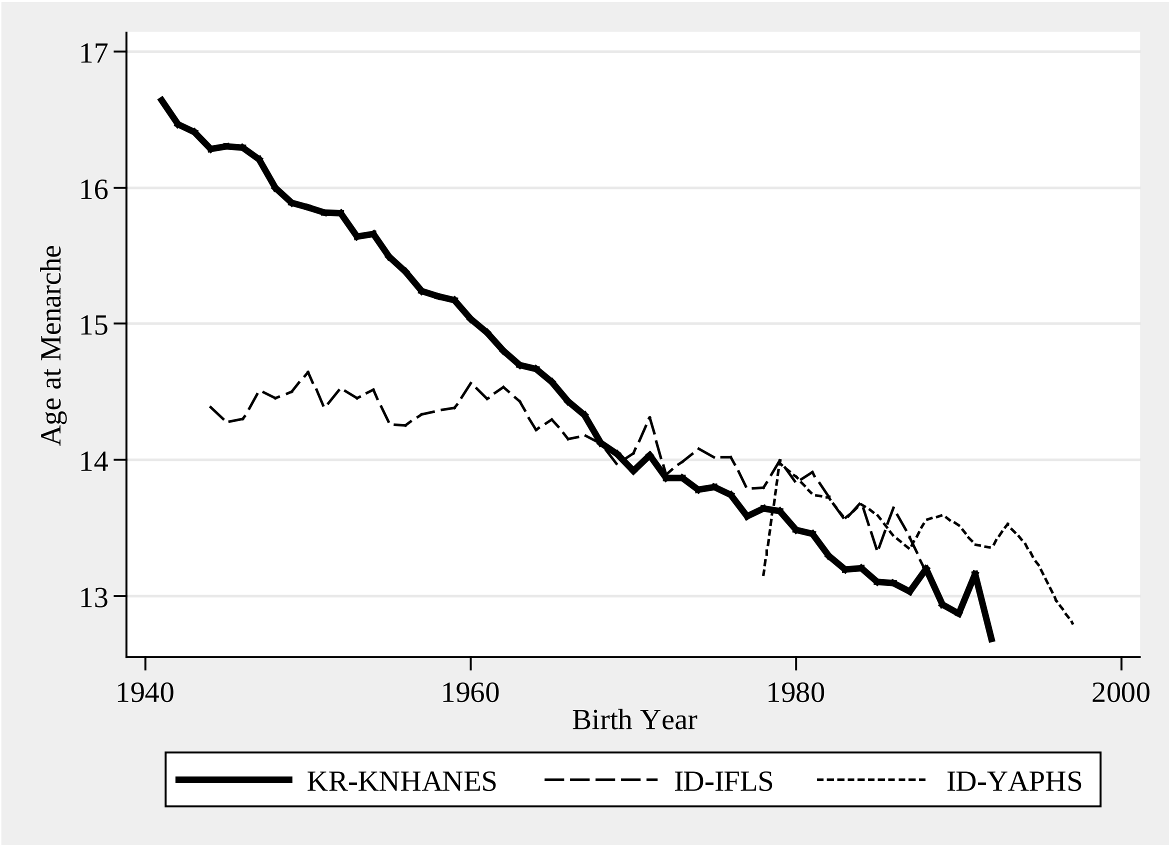

Figure 4 Trend in Height for Koreans by Gender