Adjustment of age-related height decline for Chinese – a ‘natural experiment' longitudinal survey using archival data*

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Paper presented at the Economic History Society Annual Conference,
University of Durham, 26-28 March 2010

Abstract: Height data are a useful and concise summary measure of human welfare for historical populations in absence of conventional economical data. Most historical studies use the final attained height of adults aged between about 20-23 and 49 years on the premise that younger subjects were still growing and older subjects had begun to shrink. Data outside this range are discarded. For many studies the data lost is small and of little consequence for the study. However, where the sample includes many people older than 50 years the exclusion of these may make analysis impractical because of the resulting small sample size. Several studies have used a variety of approaches adjust height-for-age of older subjects to estimate the original attained height before next estimating the secular trend in heights. These adjustments are based on studies of the aging of European-origin populations, which may not fit the pattern observed in other human populations, such as the Chinese. In this paper I use data for nineteenth-century born Chinese immigrants to Australia whose heights were recorded repeatedly to simulate a longitudinal age-related height shrinkage study. The estimates of shrinkage are compared with estimates from other studies and applied to other archive-derived height data for Chinese to examine the reliability of adjusted height estimates in calculating secular trends in height, and in turn making inferences about their welfare.

Keywords: China, human welfare, height, age-related shrinkage, measurement

JEL codes: C23, C89, I31, N30, N35

* Acknowledgement: Data collection was supported by a Faculty of Economics and Commerce Research Grant, University of Melbourne. Thanks for research assistance by Dan Luo and Fiona Herron, and comments from participants at the Economic History Association Annual Meeting, 11-13 September 2009, and the Asia Pacific Economic and Business History Conference, Wellington, 17-19 February 2010.
Introduction

Height data have proved useful in exploring human welfare in past populations for which we have few conventional economic data such as income and wages (Steckel, 1995, 2009). The sources of these data have been diverse, including military rolls, slave musters, prison registers, and passport and driving license registrations. In focusing on the final attained adult height, scholars have excluded the young, who have not reached maturity, along with the older subjects, whose height has begun to diminish. The sample age range has typically been restricted to those aged between their early 20s and 49 to avoid these age-related height biases. For military data, the exclusion of subjects older than 50 years is rarely a problem compared with biases arising from the immaturity of younger soldiers and the truncation of the sample population distribution due to height minima regulations. For other data sources such as prison and immigration registers, we find many aged in their 40s, 50s or older. The exclusion of these subjects is an expensive waste of data.

To avoid wasting the height of those older than 49 years, we need to adjust for the effect of age on height, which results in the measured height of an elderly subject being less than their final attained height. Age-related decline in stature will therefore bias downward the estimates of height in any sample where we have large numbers of elderly subjects. In other words, we need to discover an algorithm to estimate the original attained or maximal height knowing the age and height of a person at the time of measurement. Several studies of populations of European origin have estimated the rate of stature shrinkage (Chandler and Bock, 1991; Cline et al., 1989; Galloway, 1988). These studies provide coefficients to estimate the maximal height of a subject for when they were aged 40 years. Economic historians have used these estimates to adjust historical height data for populations other than Europeans, such as the North American Plains Indians (Prince and Steckel, 2003) and nineteenth century-born Chinese imprisoned in colonial Australia (Morgan, 2009).

However, are these coefficients appropriate to use with non-European populations such as the Chinese? Several factors might suggest otherwise. Potential genetic differences may change the age of the onset and the rate of height decline. In addition, past populations were engaged in more physically strenuous occupations than many of those measured in mid-late twentieth century longitudinal studies. Manual labor accelerates the physiology of aging, such as vertebrae disc compression, osteoporosis.
and spinal deformity. This paper attempts to answer the question using a sample of Chinese who migrated to Australia in the nineteenth century. In this paper we draw on nearly 19,000 records related to Chinese who were resident in Australia after 1901 and select a subsample of those related to Chinese who made two or more recorded departures. At the time of each exit from Australia, the Chinese had to obtain a certificate that established their prior residence in Australia and eligibility to return. Each certificate included their height. Some Chinese made more than a dozen trips over 40 or more years, during which they aged from 20-something to 70 years or older. Each time a certificate was issued a height was recorded, which creates the data to simulate a longitudinal age-shrinkage experiment. Estimates of shrinkage rates will be used to estimate original adult height in previously collected data for Chinese and compare these newly derived estimates of height trends with those using coefficients from longitudinal studies of European populations that were used previously to adjust Chinese stature (Morgan, 2006a, 2009).

The paper is organized in the following way. Section 2 will discuss briefly the problem of aging for anthropometric studies. The next section will describe the data and methods used to derive new age-related shrinkage coefficients for the Chinese. Section 4 will present the results and Section 5 will apply the derived coefficients to an existing set of data and compare the various methods. The final section will summarize the findings and implications of the paper.

**The problem of shrinkage**

The decline in human stature with age is well recognised. Part of this decline is due to a birth cohort effect – previous generations were on average shorter than more recent generations\(^1\) – and part is due to the physiology of aging in the individual. Historical cross sectional samples of heights of individuals in the past for a finite period of time, such as convicts in a nineteenth century prison, are likely to include a wide range of ages. Their analysis will typically show a marked decreased in the average height of the older members of the sample population. This age-related shrinkage in stature is a confounding problem for the economic historian who wishes to use the mean height of a population sample ordered by birth cohort to plot the trend over time in the

\(^1\) Average human stature increased about 1cm per decade over the century from the 1850s for many countries of Western Europe (Eveleth and Tanner, 1990; Floud, 1994; Steckel, 1995).
average height. Because the height of older subjects in the sample is less than their maximal attained height, inclusion of these subjects may bias downward the estimated trend. The effect of any downward bias on the estimated trend depends on the age of the subjects and how many there are in a particular birth cohort period. Until age 55 years or older the magnitude of the decline in the individual is barely noticeable and within the bounds of daily fluctuations and measurement errors (Cline et al., 1989). The cumulative effects of age-related shrinkage of many such subjects for a specific birth cohort in a sample might however produce a mean that was statistically different from that obtained if using a sample of the same birth cohort that had been measured at an earlier age. The practical question for the economic historian using anthropometric data is to decide what proportion of older subjects might be too many to retain without adversely affecting the trend estimate. Another question is the age at which to exclude subjects. Most economic historians choose a cautious approach, excluding those older than 49 years. Some even opt for 45. An effect of this decision is to reduce the sample size, which might affect the reliability of the estimates. Another effect is to move forward in time the earliest viable birth cohort estimations, which shortens the period for which we can obtain viable estimates of mean heights and limits how far back in time we can project a series without finding more data for younger subjects at the time of measurement for the earlier birth cohort periods.

An alternative to discarding the older subjects is to adjust their measured height to the height they had obtained before their stature began to decline. To do so, we need an algorithm to estimate the maximal attained height knowing the measured height and age at measurement. There have been quite a few attempts to derive estimates of stature lost with age motivated by various concerns, including forensic identification, adjustment of drug regimes for height-age combinations and other concerns.

Galloway (1988) put forward a simple model for use in forensic anthropology, which used a sample of 550 white individuals from southern Arizona aged between 50 and 92 years. Their stature was measured and they were asked to report their present

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2 The downward bias due to age might be cancelled by a survivor bias. Past studies have shown that on average a taller person has lower mortality than a shorter person (Waaler, 1984; Fogel, 1994; Steckel, 1995). For US white army veterans, the increase in height and weight (frame size) explained almost half of the secular mortality decline 1914-1988 (Costa, 2004).
height and their height at 25, which was assumed to be their maximal height. From her regression estimates she concluded that decline in stature did not begin until 45 years, with a lost of 0.172 cm/year for men and 0.155 cm/year for women. The mean lost of height was approximated by the formula (1):

\[
\text{Max loss (cm)} = 0.16 \times (\text{age} - 45) \tag{1}
\]

Galloway’s model is a straight line slope. Two longitudinal have produced more complex estimates of age-related change in stature. Cline and associates (1989) used data from the Tucson (Texas) epidemiological study of obstructive lung disease between 1972 and 1985. A total of 1763 white non-Mexican Americans were monitored, of whom 754 men were measured on average 5.71 times, making for 4305 observations. Chandler and Bock (1991) used data from the Busselton (Western Australia) population studies group, which measured 3329 individuals of “predominantly northern European descent” at least three times between 1966 and 1981. There were 1544 men in the study, with 6876 observations, making for an average of 4.4 observations per subject. Both studies concluded the rate of change in height with age was linear, but the cumulative effect increased quadratically with age. Based on their observations, they set 40 years of age as the base year for age-related decline in stature. Equation 2 is the general form where \( y \) is the stature measured, the intercept is the height at 40 years, \( x \) is age and \( x^2 \) is age squared:

\[
y = B_0 + B_1 x + B_2 x^2 + \text{error} \tag{2}
\]

The motivation for each study was slightly different. Cline et al. sought to find the age at which stature begins to decline and derive equations to estimate the maximum height of subjects using measured height and age. They used simple linear regression and curve-fitting, from which they derived the following equation to adjust height for men:

\[
\text{Max Ht} = \text{Standing Height} + 3.277 - 0.1652(\text{age}) + 0.00209(\text{age})^2 \tag{3}
\]

Chandler and Bock sought to estimate the rate of change in height explained by age and determined the relative proportion of the decline that could be attributed to individual aging and the proportion attributed to secular changes associated with the birth cohort. They used a Bayes-form marginal maximum likelihood (MML) method. Their reported equation sought to estimate the change in height compared with 40
years of age. This equation was transformed to obtain the following equation for estimating height at 40 years before the onset of decline:

\[ \text{Max Ht} = \text{Standing Height} + 0.0642(\text{age}-40) + 0.00017(\text{age}-40)^2 \]  

(4)

The analytical focus on individual longitudinal changes therefore enables these studies to remove the secular trend and leave only the intra-individual age change. Chandler and Bock observed that the residual for individuals was quite large, which indicate unobserved effects on stature other than age after controlling for the secular trend. Neither longitudinal study controlled for occupations, socioeconomic status and so on, factors that might account for some of the observed variance. Both studies and the one here using archival data are mixed method longitudinal studies because the subjects entered the study frame at different times, at different initial ages, and were measured with varying frequency. Our estimation approach is similar to the Cline method. The next section will describe the data set we are using for this experiment.

**Chinese immigrant data**

The height data are from the immigration-control certificates that governed the entry and residency of Chinese in Australia after 1901, the Certificate of Domicile (Figure 1) and the Certificate Exempting from Dictation (CEDT), as it was rename from c.1906. After the Australian Federation in 1901, all non-white residents were required to obtain a CEDT as evidence of their prior residence in Australia before departure. Without the CEDT, on their return to Australia they would be subject to a dictation test in English (later, any European language), which should they fail they would be prohibited from landing and returned to China regardless of how long they had lived in Australia (Morgan, 2006b). This was the primary control device for the policy known as the ‘White Australia Policy’ that governed immigration from Federation to 1966. Each CEDT shows the name, age, height and date of the certificate. Another form, the Statutory Declaration, which included other personal information and which was submitted at the time of the application, is also available for some subjects.

INSERT Figure 1 about here
All holders of these CEDTs were southern Chinese from the Guangzhou (Canton) region in Guangdong Province who were resident in Sydney or country New South Wales between 1901 and the 1940s (NAA Series ST84/1). We have 18,997 CEDTs, which include 10,779 for two or more exits. These repeat visits are in fact duplicate records for an individual, which would be discarded in most anthropometric studies, but were collected due to a quirk in the filling system that did not allow us to filter out duplicates during initial collection. The counts are summarised in Table 1: 43.3 percent made one trip for which we have a valid CEDT, but more than half (53.1 percent) made 2-5 visits to China (1-4 repeat trips). Less than one percent made more than six visits. The Chinese at measurement were aged from their teens to the late 70s. The final data set will be smaller than indicated in Table 1 based on the analysis process outlined below.

From the 10,779 observations with two or more exits, we selected a subsample for further analysis. Each set of duplicates was examined to ensure they were genuine matches, and any doubtful matches were removed. We have matched supplementary data for 1027 subjects obtained from the Statutory Declaration series (SP42/1), but

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3 The CEDT (and the earlier Certificate of Domicile) was known as a Form 21. To obtain it, an applicant completed a Statutory Declaration, a Form 22, which included information about their previous occupations, places of residence, martial status, property holdings, and frequency of past visits to China. In most offices of the NAA the forms are filed together. For reasons that remain unclear, at the Sydney NAA the CEDT are in series ST84/1 arranged in a serial file ordered by year and folder number, while the Form 22 is held in a separate series SP42/1. The separation of the forms into distinct archive series prevented us from controlling for duplicates at the time of entry, despite our awareness of duplicates. We are matching the two series to obtain information about occupations, assets, and frequency of travel.

4 The matches were first made with the SPSS identify duplicate cases routine using the criteria of name, estimated year of birth and age ordered to sequence the duplicates. Next, each record was visually inspected. For common Chinese names there was risk of a false match, even more so when there were >5 duplicates. Records were excluded where there were multiple records for the same year but with different CEDT numbers, the height of the subject varied implausibly between years or the years of exit were too close together to enable a round trip between Australia and China. This may have excluded Chinese businessmen who made frequent business (short) trips to the Pacific islands.
time constraints do not permit including variables such as occupations and assets in this analysis. The primary data used here for estimations contain 2650 observations for 984 individuals who made up to seven trips, with an average of 2.7 trips, and were aged between 30 and 73 years. During the course of several estimation experiments we further reduced the sample. One panel used 102 individuals observed 297 times for whom at least one observation was at the age of 40 years. Another panel used 2027 for 817 subjects aged 39 years or older measured on average 2.7 times.

**Estimated age effect coefficients**

Conceptually the task is fairly straightforward, though the estimation is less so. We have a pooled set of repeat height observations at different times from which we want to estimate the coefficients that might approximate the change in stature. Figure 2 shows a schematic outline of the data and the estimation problem. Each individual has two or more height observations, but these occur at different times. All subjects are observed twice, but less than one-third of the sample was observed three or more times, the problem of attrition common with such data sets (Frees, 2004). The panel is thus ‘unbalanced’. After we have derived an equation that allows us to fit a curve that approximates the rate of decline, shown in Figure 2 in purple, we can estimate, for example, the original height at 40 years of a subject aged 58, shown as a backward projection line in red. A subsample of 49 observations from our dataset is shown in Figure 3.

Insert Fig 2 about here

Insert Fig 3 about here

The estimation procedure was messy – we swapped between Excel, SPSS and STATA. We found it difficult to work with the full set, so we picked up 102 subjects who had an observation at 40 years. This gave us 297 observations, with a minimum of two, a maximum of seven and an average of 2.9 observations per subject. Using the random-effect GLS regression procedure (STATA command: ‘xtreg’), we estimated the coefficients for the quadratic equation (Eq. 3 above). The parentheses are the

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5 I am switching from SPSS to STATA and have yet to master many aspects of the software, which has contributed to the undoubted errors and clumsiness in the paper.
Standard Errors with \( t \) or \( z \) stats significance as asterisks (* 10%, ** 1%, *** 0.1%).

The panel estimated results are show below (Eq. 5):

\[
H_{t\_at\_40} = H_{t\_measure} + 2.586388 - 0.173149*age + 0.0027124*age^2
\]
\[
(1.540233)^* (0.674897)** (0.0007257) ***
\]

\( R^2 \): within =0.3735, between = 0.3146, overall 0.3457

Almost identical results were obtained using a pooled analysis under OLS estimation (Eq. 6 below).

\[
H_{t\_at\_40} = H_{t\_measure} + 2.700662 - 0.1790668*age + 0.0027836*age^2
\]
\[
(1.622606)^* (0.0711827) * (.0007657) ***
\]

\( \text{Adj} R^2 = 0.3413 \quad \text{F 77.68} \)

Using a panel approach with the whole sample 2560, \( \text{xtreg height age age}\_2\):

\[
H_t = 164.17 \quad + \quad 0.1983149*age \quad + \quad 0.0027124*age^2
\]
\[
(0.658847)*** (0.0266809)*** (0.000275)***
\]

\( R^2 \): within = 0.3557, between = 0.02201, overall = 0.0303

Next, the 2560 observations were reduced to 2027 for 817 individuals to obtain a sample aged 39 years or older with an average of 2.5 observations. This removed all multiple observations that took place for subjects younger than 39 (there were quite a few multiple observations for subjects who dropped out of the data set before they had reached 40 years of age). A dummy variable was included for subjects age >40 years, leaving an omitted group of 126 persons aged 39-40 years.

\[
H_{t\_at\_40} = H_{t\_measure} + B1.x + B2.x^2 + D_u>40 + \text{error}
\]
\[
= H_{t\_measure} + 0.5271653 - 0.0493104*age + 0.0009145*age^2 - 0.0132215
\]
\[
(1.122049) (0.0447112) (0.0004181)^* (0.1159197)
\]

\( R^2 \): within = 0.1843, between = 0.0492, overall = 0.1041
The regression coefficients for panel_102 (Eq. 5) and OLS_102 (Eq. 6) were for all practical purposes identical when plotted or used to adjust height-for-age status. Assuming a mean of 165cm, Figure 4 plots the estimates curves for the height-age relationship for the age 40 to 80 years for Galloway (Eq. 1), Cline et al. (Eq. 3), Chandler and Bock (Eq. 4), Panel_102 (Eq. 5) and Panel_2027 (Eq. 8). Galloway is a straight line linear decline from age 45 years. The Chandler- Bock plot is similar to that for Panel_102, though Panel_102 estimates make more severe corrections for age-related stature decline from about 61 years of age and crosses Galloway at 80 years. The more conservative corrections are the equations for Cline et al. and Panel_2027. The Panel_2027 estimated corrections are larger than Cline et al. between ages 40 and 59, but thereafter the adjustments are more conservative than the Cline et al. estimates. Next, we explore the effect of different adjustment coefficients for height on the estimated height trend for data containing many elderly subjects.

Application of competing coefficients
The choice of adjustment coefficients will affect the derived secular trend for a height series that includes a significant proportion of older subjects. Four sets of correcting coefficients will be explored in this section: Cline et al., Chandler and Bock, Panel_102 and Panel_2027. Which coefficients to use is possibly a personal choice rather than merely technical: to err on the conservative side of any upward adjustment or choose the more radical adjustment and risk over adjusting. Either choice has implications for the extent of the adjustment made to the population mean height and the conclusions that are drawn from the adjusted time series of heights.

Several data sets containing varying proportions of Chinese older than 50 years are available. For this paper I will use by way of example the data from the recent Morgan (2009) study using Chinese imprisoned in colonial Australia from the second
half of the nineteenth century to the early twentieth century. Many Chinese had come to Australia during the gold rush of the 1850s. The sample comprised 1492 southern Chinese (details in Morgan, 2009). After restricting the age to those older than 23 years and removing extreme-low outliers, 1382 subjects were used for estimation. The first step was to apply the newly derived coefficients to adjust for age each of the reported heights of the prisoners. Next, a time series of adjusted mean heights was created ordered by year of birth. From these means, we can compare the relative degree of adjustment for the series according to year of birth of those in our sample. This is shown in Figure 5 (5-year moving average) and Figure 6 (9-year moving average). As we would expect from the plot of the height-for-age curves (Fig 4), the adjustments using the Cline et al. and Panel_2027 coefficients are similar as are those for Chandler-Bock and Panel_102. Departures between the series are most obvious for those born before 1815, but these differences initially are barely significant in a practical sense and probably reflect the attrition in the database (observations decline sharply for those born before 1818).

The final step in our comparison of the adjustment coefficients is to re-estimate the decal regressions using the new coefficients and compare these with the previous estimates (Morgan, 2009). Figure 7 shows the time-only regression estimates for decal change in stature. All show upward adjustment of height as we move back in time (the subjects increasingly are older than 40 years) compared with the original height series estimate. Most interesting is that the adjustments using the Chandler-Bock and the Panel_102 coefficients produce the same estimates across most of the time range. The Cline et al. and Panel_2027 estimates are similar except for a small divergence for 1810-19. We added occupation dummies for the estimations in Figure 8, with miners the control group. Here we see differentiation in the estimate secular trend for

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6 Following common practice, data for older Chinese were removed from the analysis in several previous studies (Morgan, 2004, 2006a), but retained in the database. Adjusted height data for some of the southern Chinese was used in Baten, Ma, Morgan and Wang (2009).
Chandler-Bock and Panel_102 for the 1810-19 decade, but otherwise the height trend is more or less the same for all series, though the absolute estimated height varies slightly from Figure 7.

How big a difference does the use of adjustment for age make? This data set of Chinese imprisoned in colonial Australia is quite small, containing only 1492 records, and any attrition due to age constraints or other problems with the data will adversely affect estimations in various ways. The main concern is to retain as many records as possible to strengthen the robustness of estimates of mean height and to extend those estimates as far back in time as the data will allow. To estimate the height trend the subjects younger than 24 years were removed. This left an adult data set of 1382 subjects born between the 1790s and the 1890s; were we to restrict the age to those 49 years or younger – as is typical in anthropometric history – we are left with 1080 subjects, the earliest of whom were born in the 1810s (Table 2). Moreover, there are only 26 subjects for that decade, which compromises the robustness of any estimates. This is apparent in Fig 9, which adds to Fig 8 an estimate of the original series for those aged 24-49 years. Those born in the 1810s according to the 23<age<50 restriction are 1.8cm shorter than those born in the 1830s, an improbable change. We therefore would abandon the estimates for the 1810s as potentially unreliable, especially in view that the inclusion of unadjusted subjects >49 years (original series without restriction) increases the mean height nearly 1cm for the 1820s. In effect, we have lost one decade of estimates and raised doubts about the following decade.

A step not taken here in this paper is to undertake a step analogous to a controlled experiment of the coefficients using two subsamples. The idea is this that for the same birth cohort years, to draw two samples, one aged older than 40 years and the other in their prime, 25-40 years, but obviously measured at different times. The estimated
adjusted height trend for the population measured when they were older than 40 years will be compared with estimate for the sample measured when they were in their prime years. Since both sub-groups were from the same population and birth cohort sample, the variance between the estimates for the adjusted elderly and the unadjusted prime-age populations will indicate the accuracy of the adjustment measures, others thing being equal, and perhaps enable us to say something about the interaction effects between height and longevity on age-related adjusted height series.

**Conclusion**

Repeat height observations for Chinese immigrants resident in Australia during the first four decades of the twentieth century were used to simulate a longitudinal study of the effects of age on human stature. The aim of the experiment was to derive Chinese-specific coefficients for the rate of age-related shrinkage for a population born in the second half of the nineteenth century. These coefficients would not only take into account any genetic-specific effects of aging among the Chinese, but would also capture effects on stature among the aging that might be attributed to the typical heavier manual occupations that the population would be engaged in compared with those of European descent measured in the second half of the twentieth century.

The results of the experiment indicate the coefficients obtained from the studies of European populations are more or less practical for estimation of the original attained stature of Chinese before the onset of age-related shrinkage. The results also show that adjustment for height enabled the retention of estimates for an earlier decade than would otherwise be lost or their robustness called into question. Further tests to control for occupations and other characteristics may refine the estimated coefficients, but they are unlikely to make a big difference upon the result achieved here. The ‘experiment’ has shown the benefits of attempting to adjust archive-derived height data for Chinese older than 49 years, the upper limit of the age anthropometric historians usually include, as a means to preserve scarce data for the estimation of secular trends in stature.
Acknowledgements: Collection of data at the NAA in Sydney was supported by a Faculty of Economics and Commerce Research Grant, University of Melbourne, as part of a project on welfare and human capital in nineteenth century China. For research assistance, I thank Fiona Herron (data collection in Sydney) and Dan Luo (panel analysis using STATA, Nottingham).

References


Table 1: Preliminary estimates of repeat exits (duplicate CEDTs)

<table>
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<tr>
<th>Repeat Trips</th>
<th>Persons</th>
<th>Percent</th>
<th>Cumulative Percent</th>
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<td>8218</td>
<td>43.3</td>
<td>43.3</td>
</tr>
<tr>
<td>1</td>
<td>3745</td>
<td>19.7</td>
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<tr>
<td>2</td>
<td>3745</td>
<td>19.7</td>
<td>82.7</td>
</tr>
<tr>
<td>3</td>
<td>1762</td>
<td>9.3</td>
<td>92.0</td>
</tr>
<tr>
<td>4</td>
<td>834</td>
<td>4.4</td>
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</tr>
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</tr>
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<td>6</td>
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<tr>
<td>9</td>
<td>23</td>
<td>.1</td>
<td>99.8</td>
</tr>
<tr>
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<td>100.0</td>
</tr>
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<td>18997</td>
<td>100.0</td>
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</tr>
</tbody>
</table>

Source: NAA, Sydney, ST84/1 Series, boxes 1-240.

Table 2: Comparison of Chinese prisoner data retained when including older subjects and when restricted to mature adults 24-49 years of age

<table>
<thead>
<tr>
<th>Year of birth decade</th>
<th>Age &gt;23 years</th>
<th>23 &lt; Age &lt; 50</th>
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<tbody>
<tr>
<td></td>
<td>Count</td>
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<tr>
<td>1790-99</td>
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<td>1800-09</td>
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<td>1810-19</td>
<td>94</td>
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<tr>
<td>1820-29</td>
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<td>1830-39</td>
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<tr>
<td>Total</td>
<td>1382</td>
<td>40.21</td>
</tr>
</tbody>
</table>

Share of data (%) 92.6 72.4

Source: PROV Series 515 (see Morgan, 2009, for details)
Fig 1 Wong Bow J2482, Certificate of Domicile (Form 21)
Source: NAA, J2482 1906/16
Fig 2 Schematic outline of the data and estimation problem

Figure 3 Recorded heights by age for a subsample of 49 observations from the sample of 2560 observations
Source: See Table 1
Figure 4 Rate of change in stature based on selected coefficients (assumed initial height 165 cm).
Source: Derived coefficients; see text.
Fig 5 Mean relative adjustment (cm) by year of birth of subjects (5-year moving average)
Source: Morgan, 2009; derived coefficients, see text.

Fig 6 Mean relative adjustment (cm) by year of birth of subjects (9-year moving average)
Source: Morgan, 2009; derived coefficients, see text.
Fig 7 Trend in Chinese prisoners’ stature, time only
Source: Morgan, 2009; see text.

Fig 8 Trend in Chinese prisoners’ stature, with occupation dummies (control group, miners)
Source: Morgan, 2009; see text.
Fig 9 Secular trend in Chinese stature using alternative adjustment coefficients and age groups
Source: Morgan, 2009; see text.