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Rice Price Fluctuations and Fertility in Late Tokugawa Japan

The population of Japan neither grew nor declined during the last half of the Tokugawa era. This has been interpreted as indicating that the society had reached Malthusian limits of subsistence. Marxist thought transformed the misery that Malthus regarded as an absolute and immutable condition of human existence into the result of exploitation by a feudal elite. This singular marriage of intellectual traditions was sufficiently powerful that for many decades it went unchallenged.

The challenges that have arisen are well known. At the most general level, a society depressed and destitute is an unlikely crucible for Japan's extraordinary and atypical economic development since the late nineteenth century. The principal evidence, however, has come from many detailed and often quantitative studies of Tokugawa society. There were many improvements in agriculture, the level of mortality appears to be lower than one would expect of peasants living on the edge of starvation, and the failure of the population of the country as a whole to grow conceals considerable variations within different regions.[1]

As the evidence against the older view began to be developed, there was perhaps a notion that the older and more speculative approach must eventually bow to the newer and more quantitative one, a sense of progress

We are grateful to Professor Shigeo Akashi for supplying us with the numerical values of the famine index plotted in his paper. We gratefully acknowledge comments on an earlier version of this paper from Laurel Cornell, Patrick Galloway, Akira Hayami, Masaru Iwahashi, G. William Skinner, and two anonymous reviewers for the *Journal of Japanese Studies*.

1. Thomas C. Smith, *The Agrarian Origins of Modern Japan* (Stanford: Stanford University Press, 1959). Susan B. Hanley and Kozo Yamamura, *Economic and Demographic Change in Preindustrial Japan, 1600–1868* (Princeton: Princeton University Press, 1977). Hayami Akira, "Population Change," in Marius B. Jansen and Gilbert Rozman, eds., *Japan in Transition* (Princeton: Princeton University Press, 1986), pp. 280–317.

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and inevitability best captured in Hanley and Yamamura's "quiet transformation" paper of 1971.[2] Time and experience with the difficulties of quantitative work have tempered this view, and the appeal of speculative reasoning has not entirely subsided. Thus Hanley recently expressed sharp pessimism over the available quantitative evidence,[3] and a recent review by Totman might be read as indicating a standoff.[4]

In the meantime, studies of the historical demography of Europe have plunged deep into the statistical study of economic and demographic time series. The motivating idea has been that the relation between movements in prices, taken as an indicator of food supply, and subsequent movements in birth and death rates can be used as indicators of the operation of the two Malthusian checks to population growth. If death rates rise following a rise in prices, the positive check (to use the now somewhat quaint Malthusian jargon) is indicated: any tendency to population increase strains food supplies and so leads to a rise in the death rate. If on the other hand birth rates fall following a rise in prices, the preventive check is operating: social mechanisms are restraining population numbers and avoiding the misery of Malthusian subsistence.[5] This characterization is too pat, but it does indicate the general thrust.

This European work was anticipated in a remarkable but little-noticed paper by Uemura, who studied the relationship for Japan as a whole using Osaka rice prices and birth rates estimated from early Meiji data.[6] The present paper continues this line of work, exploring the relation between year-to-year fluctuations in rice prices and estimated birth rates in 13 Meiji

2. Susan B. Hanley and Kozo Yamamura, "A Quiet Transformation in Tokugawa Economic History," *Journal of Asian Studies,* Vol. 30, No. 2 (February 1971), pp. 373–84.

3. Susan B. Hanley, "A High Standard of Living in Nineteenth Century Japan: Fact or Fiction?" *Journal of Economic History,* Vol. XLIII, No. 1 (March 1983), p. 183.

4. Conrad Totman, "Tokugawa Peasants: Win, Lose, or Draw?" *Monumenta Nipponica,* Vol. 41, No. 4 (1986), pp. 457–76.

5. An extensive and recent review of the literature, as well as highly relevant comparative material, is given in Patrick R. Galloway, "Basic Patterns in Annual Variations in Fertility, Nuptiality, Mortality, and Prices in Pre-industrial Europe," *Population Studies,* Vol. 42, No. 2 (July 1988), pp. 275–302 and insert. See also, by the same author, "Differentials in Demographic Responses to Annual Price Variations in Pre-revolutionary France: A Comparison of Rich and Poor Areas in Rouen, 1681 to 1787," *European Journal of Population,* Vol. 2 (1986), pp. 269–305, and "Population, Prices, and Weather in Preindustrial Europe" (Ph.D. diss., University of California, Berkeley, 1987), pp. 4–9. Without going into much further detail, we may mention for general background Michael W. Flinn, *The European Demographic System* (Baltimore: The Johns Hopkins University Press, 1981), and E. A. Wrigley and R. S. Scofield, *The Population History of England: 1541–1871* (Cambridge, Mass.: Harvard University Press, 1981).

6. Uemura Shōji, "Kinsei ni okeru hōkyō-jōtai to shusshō-sū shusshō-seihi," *Osaka daigaku keizaigaku,* Vol. 27, No. 4 (1978), pp. 66–85.

prefectures. The results confirm Uemura's work for Japan and present remarkable similarities to Galloway's results for Europe.

The Iwahashi Rice Price Series

Rice was the staple crop of pre-industrial Japan, so that it is reasonable to expect that rice prices are important economic indicators. Higher prices indicate shorter supply, which in turn indicates lower stocks in peasant households.[7] We use the 13 rice price series given in Iwahashi's study of price history in early modern Japan.[8]

There are three basic sources of rice prices for Tokugawa Japan: local market prices recorded at the village level, records of merchants, and the *kokudai-nedan.*[9] While merchant and local market prices are rarely available for long periods without gaps, the *kokudai-nedan* are frequently available in long, unbroken series. Iwahashi analyzed available price data for many regions of Japan and found that in many cases the *kokudai-nedan* are consistent with merchant and local market prices. Cases where agreement was poor may have reflected efforts on the part of authorities to set prices to their own advantage. In any case, Iwahashi selected only those cases where agreement was good for his final price series.

The earliest series, for Hiroshima, begins in 1620, and all series begin by the early eighteenth century. They extend, in unbroken annual series, until a few years before the Meiji Restoration. The exact spans, together with various other information on the series, are shown in Table 1.

7. The relation of rice prices to the condition of harvests is investigated in Akashi Shigeo, "Kinsei-kōki keizai ni okeru kahei, bukka, seichō: 1725–1856," *Keizai kenkyū,* Vol. 40, No. 1 (January 1989), pp. 42–51. Using data kindly provided by Akashi, we have calculated median detrended Osaka rice prices (see below) for years in which his famine index assumed the values 0, 1, 2, and 3 or 4. These medians are, respectively: 92.2, 98.7, 100.9, and 122.9. The relation is consistently positive, as expected, indicating higher prices for years of more severe famine conditions. Rice price data are of course far more widely available than quantitative indicators of harvest conditions and may be a superior measure of economic conditions to the extent that rice stores can be carried over from one year to the next.

8. Iwahashi Masaru, *Kinsei Nihon bukkashi no kenkyū* (Tokyo: Ōhara Shinsei-sha, 1981), pp. 459–65.

9. The Tokugawa government periodically carried out cadastral surveys, on the basis of which the productivity of the land of each village was set at a certain annual number of *koku* of rice. See Smith, *Agrarian Origins,* Chapter 1. Tax rates, expressed as a percentage of this figure, were then set each year according to harvest conditions, and villages would remit the designated quantity of rice to their *ryōshu.* While taxes were denominated in units of rice, direct payment in rice would have involved a good deal of unnecessary transport, so there came into effect a system in which a portion of the taxes owing were paid in money. This required an exchange rate, the *kokudai-nedan,* between rice and money, which was set by the *bakufu* in *bakufu*-controlled territories and by local *daimyō* elsewhere.

Table 1
Summary Information on Iwahashi Rice Price Series

Prefecture	Name of Series	Rate	Months	Years	Ref.
Yamagata	Dewa (G)	.0038	October	1697–1862	196
Fukushima	Aizu (G)	.0038	Fall/Winter	1643–1857	217
Kanto Region	Edo (G)	.0033	December	1652–1863	172
Nagano	Shinshū (G)	.0032	October	1691–1863	213
Aichi	Nagoya (G)	.0022	Oct-Dec	1645–1867	209
Shiga	Ōmi	.0014	Oct-Jan	1739–1867	282
Kyoto	Fukuchiyama	−.0001	December	1696–1867	292
Osaka	Osaka	.0011	Oct-Dec	1701–1867	273
Hyogo	Banshū	.0011	October	1701–1867	287
Hiroshima	Hiroshima	.0045	December	1620–1858	225
Yamaguchi	Bōchō	.0035	December	1704–1867	296
Saga	Saga	.0032	December	1702–1861	249
Kumamoto	Kumamoto	.0036	November	1688–1867	74

Note: (G) indicates gold-based price series. The "rate" column shows the estimated average annual growth rate for the commoner population for the period 1804–81 (approximated from data for Tokugawa provinces), used in the calculations described below. The last column gives the page reference in Iwahashi's book for the season of the rice prices.

The price series are expressed in two different units of account. At the beginning of the Tokugawa era, coins in circulation were valued in terms of a standard unit of silver, the *momme*. This system remained in effect in parts of the country, but the gold-based *ryō* introduced by the Tokugawa government was adopted in Edo and surrounding areas.[10] The price series for Dewa, Aizu, Edo, Shinshū, and Nagoya are expressed in the gold currency, the series for the remaining prefectures in the silver currency. Although the silver unit was used in Osaka, Iwahashi has produced a corresponding series in the gold unit using the Osaka market exchange rate between gold and silver.[11] The months of the year to which the prices refer are shown in Table 1. For the most part, they are autumn, and thus post-harvest, prices.

Estimating Annual Birth Rates from Meiji Age Data

We use single-year age distributions for each prefecture at the end of 1886 to derive an estimated annual series of crude birth rates. The estimation involves the use of an average level of infant mortality, and since actual infant mortality levels undoubtedly fluctuated from year to year, our

10. E. S. Crawcour and Kozo Yamamura, "The Tokugawa Monetary System: 1787–1868," *Economic Development and Cultural Change*, Vol. 18 (1972), p. 490.
11. Iwahashi, *Bukkashi*, pp. 459–65.

estimates must be regarded as crude birth rates net of these infant mortality fluctuations. This rather technical point turns out to be important for the interpretation of our results, and we shall return to it in the discussion below.

The source of the single-year age distributions are household registers, maintained at the village level, indicating year of birth of each individual in the household. This material is described in detail by Hayami.[12]

> In 1872 the Meiji government initiated a household registration system which required that all inhabitants register their household circumstances at an appropriate level of local administration. Thereafter, for reasons of marriage or migration, the register was amended and the government was able to count the population on the basis of this "Registered Population" (*honseki-jinkō*). . . .
>
> The present study uses as its principal source the invaluable Table of Households and Population of Imperial Japan (Nihon Teikoku Minseki Kokōhyō: hereafter NTMK), which was compiled first in 1886. It has been almost entirely overlooked as a source for the demographic study of Japan. Among its many virtues, the NTMK lists the population at each age for each prefecture in Japan and how many of those persons at each age were marrying, using as the basis the *honseki-jinkō*. . . .
>
> It is astonishing, therefore, that this valuable data source of *honseki-jinkō* (NTMK) has been entirely overlooked in demographic research so far.

By traditional Japanese reckoning, a child is aged one at birth, advances to age two at the first subsequent new year, age three at the next new year, and so on. Since the age distributions refer to the end of 1886, persons born in that year are classified as age one, persons born in the preceding year as age two, and so on. The Japanese ages are thus equivalent to Western ages plus one, but for the difference between the Western and Japanese calendars. This difference turns out to be important for our work, and we adjust for it by the method described in the following section.

We begin by computing reverse survival estimates of annual crude birth rates for the period 1807–86 using (i) the prefectural age distributions, (ii) an average life table for the period, and (iii) an average population growth rate for the period. Mortality was high and declining slowly during this period. Based on Tokugawa village level studies, Kitō indicates an e_0 of slightly under 30 years for the seventeenth century, values in the

12. Hayami Akira, "Another Fossa Magma: Proportion Marrying and Age at Marriage in Late Nineteenth-century Japan," *Journal of Family History,* Vol. 12, Nos. 1–3 (1987), p. 60. The age distribution data are given in *Meiji 19 nen Nihon teikoku minseki kokō-hyō* (Tokyo: Naimushō, 1887).

mid-30s for the eighteenth century, and values in the late 30s for the nineteenth century.[13] Okazaki gives values of the expectation of life at birth (both sexes combined, by averaging) ranging from 35.3 for 1866 to 37.8 for 1886, obtained by extrapolating backward from official Japanese life tables for 1891–98 and later periods.[14] The consistency of these results suggests an average level of about 35 years during the period, with an upward trend of not much more than five years over 80 years. We generate the L_x values with an expectation of life at birth of 35 years using the Brass one parameter logit model with the Brass General standard schedule of mortality.[15]

Following Saitō,[16] we use Tokugawa data for the commoner population of 48 provinces (provinces judged to have particularly bad data are omitted from the calculation) to obtain a population total for 1804 (data from Sekiyama[17]) and Meiji data for the same provinces to obtain a corresponding total for 1881. This yields the average annual growth rates shown in Table 1.

We then calculate the crude birth rate estimate for each prefecture in year 1886-x as

$$\frac{P(x)/L_x}{P\exp\{r(x+1/2)\}}$$

where P(x) denotes the number of persons aged x, and P the total number of persons, from the 1886 age distribution; L_x the life table survivorship values; and r the growth rate. The numerator here represents the reverse-survived number of births in the given year, the denominator the reverse projected number of total population at mid-year.[18]

13. Kitō Hiroshi, *Nihon nisennen no jinkōshi* (Tokyo: PHP Kenkyū-jo, 1983), p. 146; see also Table 20, p. 114.

14. Okazaki Yōichi, "Meiji-Taishō-ki ni okeru Nihon jinkō to sono dōtai," *Jinkō mondai kenkyū*, Vol. 178 (1986), pp. 5–7.

15. See William Brass, *Methods for Estimating Fertility and Mortality from Limited and Defective Data* (Chapel Hill: Laboratories for Population Statistics, 1975), on the logit model. We used the standard values given in K. Hill and T. J. Trussell, "Further Developments in Indirect Mortality Estimation," *Population Studies*, Vol. 31, No. 2 (1977), pp. 314–34.

16. Saitō Osamu, "Jinkō hendō ni okeru nishi to higashi—Bakumatsu kara Meiji e," in Odaka Kōnosuke and Yamamoto Yūzō, eds., *Bakumatsu-Meiji no Nihon keizai* (Tokyo: Nihon Keizai Shinbun-sha, 1988), pp. 29–47.

17. Sekiyama Naotarō, *Kinsei Nihon no jinkō kōzō* (Tokyo: Yoshikawa Kōbun-kan, 1958), p. 117.

18. It is interesting to note that this reverse survival calculation was made for the total population of Japan nearly 50 years ago by Morita. See Morita Yūzō, *Jinkō zōka no bunseki* (Tokyo: Nihon Hyōron-sha, 1944).

Crude birth rates reflect the combined influence of fertility, as represented by age-specific birth rates, and age distribution. We are concerned only with short-term fluctuations in fertility, however, and because age distribution and total population change only slowly, short-term fluctuations in crude birth rates correspond closely to short-term fluctuations in fertility.

Our focus on short-term fluctuations likewise makes it unnecessary to obtain precise mortality estimates for reverse survival, or to take account of long-term trends in mortality. While the level of our crude birth rate estimates may err on this account, the short-term fluctuations will be faithfully represented. Short-term fluctuations are relatively unaffected for the simple reason that any two successive single-year birth cohorts experience nearly the same mortality.

The same applies to short-term fluctuations in adult and child mortality. It does not apply to short-term fluctuations in infant mortality, however, and this is why we find it necessary to refer to our estimates as "net" of short-term fluctuations in infant mortality. Since it is impossible to estimate year-to-year fluctuations in infant mortality for Japan at the national or prefectural level during this period, rises in infant mortality are indistinguishable from declines in fertility, and vice versa. Infant mortality is exceptional because of the extreme concentration and greater variability of mortality in infancy. Because of this, very high infant mortality in any given year will substantially reduce the size of cohort born in this year, with relatively little effect on earlier and later cohorts.

Since we derive crude birth rate series for prefectures, we must consider their interpretation in the presence of migration. Migration will affect the results only insofar as it changes the shape of the age distributions, and this will occur only to the extent that net migration at each age differs from zero. This is of course possible even in the presence of substantial migration if subpopulations are simply trading equal numbers of persons at equal ages. It is only net migration, in this context, that counts.

Even where net migration differs significantly from zero, and so changes the shape of the age distribution, the effect on the year-to-year changes in the estimated crude birth rates will generally be small because members of two adjacent single-year birth cohorts will experience similar migration. Heavy migration into or out of a prefecture during any period will tend to affect persons at any given age very much the same as it affects persons at the immediately surrounding ages.

This theoretical consideration is supported by the empirical evidence of the crude birth rate series for various prefectures. In examining plots for a catholic selection of a dozen prefectures (not shown here), we find very similar patterns in the crude birth rate series in all cases except

Tokyo, Osaka, and Hokkaido. This undoubtedly reflects substantial net in-migration to these three prefectures. This is consistent with relatively small effects on other provinces to the extent that the corresponding out-migration is distributed among many provinces and so is relatively low in each.

Lunar Calendar Adjustment

Year of birth for 1873–86 refers to the Western calendar, but previous years refer to the Japanese solar-lunar calendar.[19] In this calendar, normal years are either 354 or 355 days long, but leap years, which occur every two or three years, are either 383 or 384 days long. Leap years are thus roughly 13 months, as compared with 12 months for non-leap years. Leap years between 1800 and 1872 are shown in Table 2.

The effect of the longer leap years is suggested by plotting the estimated crude birth rates for Japan as a whole and circling the points corresponding to leap years. When this is done, it is found that 17 of the 24 leap years are local maxima (that is, have crude birth rate values greater than those for the preceding and following years), as compared with only 2 leap years that are local minima.

The simplest way to adjust for the effects of the lunar calendar before 1873 is to multiply the number of persons in leap year birth cohorts by 12/13.[20] When this is done, however, and we plot the results with leap year values circled, we find that 12 of the 24 leap years have now become local minima, as compared with 2 leap years that are local maxima. This suggests that the adjustment has overshot the mark, leaving leap year values that are too small. We suspect that this is due to seasonal variation in numbers of births and infant deaths, but available data on seasonal patterns are insufficient to confirm or refute this.

The same pattern of reversal of maxima and minima occurs in the Nōbi region (prefectures of Aichi, Gifu, and Mie), convincing us that the simple adjustment is unsatisfactory. As an alternative, we calculate three averages for the years 1807–72, the average estimated crude birth rate for leap years, for all years, and for non-leap years. We then adjust leap year values downward using the ratio of the first two of these averages, and the non-leap years upward using the ratio of the second two of these averages. This results in adjusted values in which leap years are reasonably evenly distributed as to local maxima and minima. It also adjusts values for the pre-1873 solar-lunar calendar period so as to be comparable with the subsequent Western calendar period.

19. Masao Uchida, *Nihon rekijitsu genten* (Tokyo: Yūzankaku Shuppan, 1975).
20. Hayami, "Fossa Magma," uses this procedure.

Table 2
Lunar Adjustment of Estimated Crude Birth Rates for Japan, 1807–86

Year	ECBR	ADJ	Year	ECBR	ADJ
1807	34.5	35.0	1847	32.4	32.9
1808*	34.7	33.8	1848	32.9	33.4
1809	31.5	32.0	1849*	34.1	33.2
1810	31.5	32.0	1850	31.2	31.7
1811*	34.2	33.3	1851	29.5	29.9
1812	31.4	31.9	1852*	33.3	32.5
1813*	32.9	32.0	1853	32.5	33.0
1814	30.7	31.2	1854*	32.6	31.8
1815	30.2	30.6	1855	31.6	32.1
1816*	31.4	30.6	1856	31.5	32.0
1817	29.4	29.8	1857*	31.9	31.1
1818	30.6	31.1	1858	31.5	32.0
1819*	32.7	31.9	1859	29.2	29.6
1820	31.3	31.8	1860*	28.5	27.8
1821	29.9	30.3	1861	25.1	25.4
1822*	33.1	32.2	1862*	26.4	25.7
1823	31.0	31.4	1863	27.8	28.2
1824*	31.9	31.1	1864	31.9	32.4
1825	32.0	32.5	1865*	32.7	31.8
1826	29.8	30.3	1866	29.8	30.3
1827*	31.4	30.6	1867	30.2	30.6
1828	31.5	31.9	1868*	32.3	31.5
1829	29.7	30.2	1869	28.1	28.5
1830*	32.6	31.8	1870*	27.4	26.7
1831	29.4	29.8	1871	27.7	28.1
1832*	31.3	30.5	1872	29.9	30.3
1833	28.3	28.7	1873	33.2	33.2
1834	27.4	27.8	1874	33.2	33.2
1835*	28.7	28.0	1875	33.7	33.7
1836	27.6	28.0	1876	36.1	36.1
1837	23.0	23.4	1877	34.3	34.3
1838*	26.3	25.6	1878	34.9	34.9
1839	27.6	28.0	1879	35.1	35.1
1840	29.2	29.6	1880	34.3	34.3
1841*	29.9	29.2	1881	34.9	34.9
1842	28.8	29.3	1882	34.3	34.3
1843*	32.1	31.3	1883	34.3	34.3
1844	30.9	31.4	1884	32.4	32.4
1845	32.6	33.1	1885	31.2	31.2
1846*	28.9	28.2	1886	29.9	29.9

Average ECBR (total, leap, other): (30.51, 31.31, 30.06)
Adjustment factors (leap, other): (0.9746, 1.0151)
Note: Averages for 1807–72 only; * signifies lunar leap year.

The effect of the lunar calendar adjustment is shown in Table 2, which shows the estimated crude birth rate series for Japan as a whole for 1807–86 before and after the lunar adjustment.

Rice Prices and Birth Rates in 13 Regions

In the course of earlier research, we compared the plot of the estimated crude birth rate series for the Nōbi region for the years 1807–86 with the Iwahashi rice price series for Nagoya.[21] Comparison of these plots suggested an inverse correlation between short-term fluctuations in rice prices and fertility, with a one-year lag: net fertility declines (rises) the year following a sharp rise (decline) in rice prices.

The direct comparison of the time series is obscured by the inverse nature of the correlation and by the confounding of short-term and long-term fluctuations in both series. The inverse correlaton is simply handled graphically by inverting the rice price scale. To focus on short-term fluctuation we detrend both series by taking ratios of observed values to centered seven-year moving averages. The rice price series is thus detrended by calculating

$$100 \frac{RP(t)}{[RP(t\text{-}3) + RP(t\text{-}2) + \ldots + RP(t+3)]/7}$$

The estimated crude birth rate series is detrended in the same way.

We tried a number of alternative detrending procedures before settling on this one. Weighted moving averages produced results very similar to simple unweighted averages, whence we decided to stick with the latter. We also tried and compared five, seven, nine, eleven, and thirteen-year moving averages. Visual inspection of the given and moving average series suggested that seven terms were required for adequate smoothing, but that more than seven terms did not smooth more effectively.

The first and last three years of the series are lost in this detrending process. Since our estimated crude birth rates run from 1807 to 1886, the detrended series runs from 1810 to 1883. The original rice price series all begin before 1807 and end at the years (all before 1886) indicated in Table 1.

The simplest way to see the correlation between rice prices and fertility

21. Griffith Feeney and Hamano Kiyoshi, "Demographic Aspects of the Nōbi Region through Meiji Statistics," revision of paper prepared for the Second Workshop of the Nōbi Regional Project, Nagoya, January 6-10, 1988. We were at this time unaware of Uemura's earlier work along the same lines.

change is to plot the two detrended time series and compare them. This is done in Figure 1, which shows the detrended crude birth rate series for Yamagata prefecture together with the detrended Dewa rice prices. To facilitate visual assessment of the inverse correlation, the rice price scale (at right) is inverted and rice prices are plotted with a one-year lag (i.e., the rice price for any given year is plotted above the horizontal scale mark for the following year). The crude birth rate and rice-price scales are chosen to equalize the observed variance in the two series.

The correlation between the two series is most visible in those years in which the series make sharp upward or downward moves, as for example 1817, 1834, and 1837 (the Tempō crisis), and 1851 and 1854.

The same data may be scatter plotted as shown in Figure 2. Here each point corresponds to a particular year. The vertical coordinate of the point gives the deviation from 100 of the detrended crude birth rate for this year, the horizontal coordinate the deviation from 100 of the detrended rice price for the preceding year. While there is considerable scatter to the points, there is also a clear negative correlation.

We have made similar plots for each of the 13 Iwahashi rice price series, relating the detrended rice price series to the detrended crude birth rate series for the corresponding prefecture. The Yamagata/Dewa case shown in Figures 1 and 2 exemplifies one of the stronger correlations between rice prices and population change. At the other extreme, Figures 3 and 4 show the time series and scatter plots for Saga, the case in which the correlation is weakest.

We now ask what quantitative effect a given deviation in the rice price series has on the following year's detrended crude birth rate. Since our detrended series are ratios of the value for any given year to an average of this and surrounding values, the detrended values fluctuate about 100. Subtracting 100 from these detrended values thus gives the per cent deviation of each annual value from the average level for the surrounding period.

Since the expected effect of a zero deviation in rice price is a zero deviation in the detrended crude birth rate, the regression line is constrained to go through the origin and the regressions have the form DNCBR(t) = Beta.DRP(t-1), where DNCBR denotes the deviations of the detrended net crude birth rate from 100 and DRP the deviations of the detrended rice price series from 100. The coefficient Beta applied to the per cent deviation in the rice price index thus gives the corresponding per cent deviation in the detrended crude birth rate (an "elasticity" in economic jargon).

We have carried out these regressions for each of the 13 cases noted above using a robust method that consists of repeated applications of weighted least squares, with the weights at each iteration chosen to down-

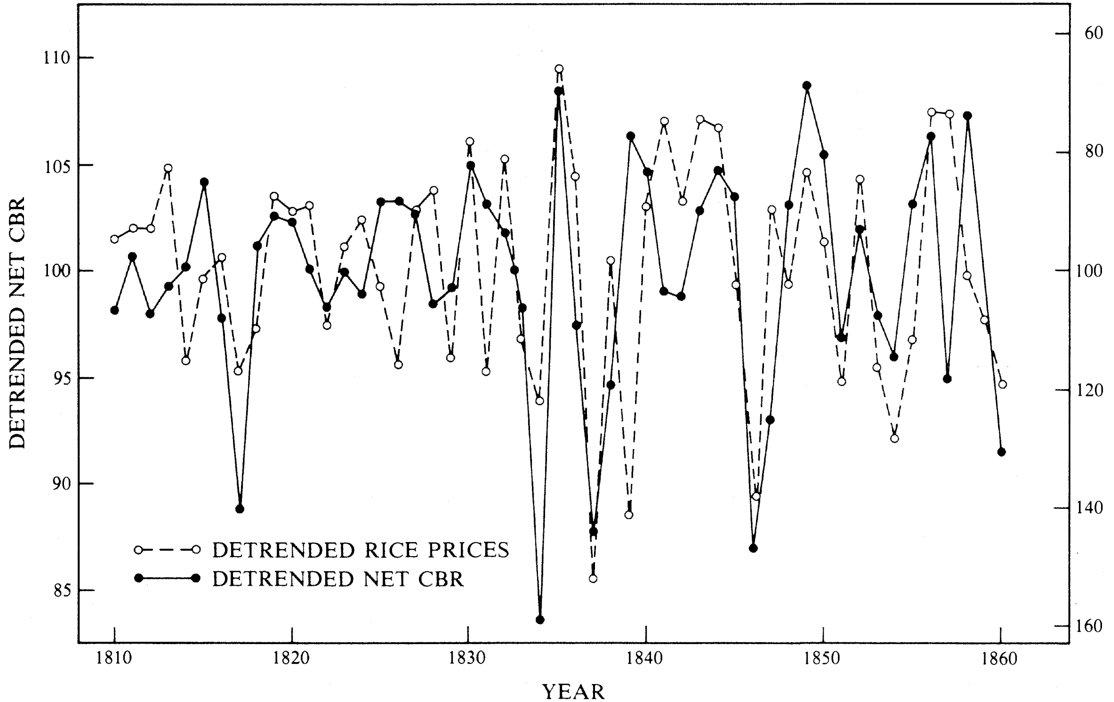

Figure 1
Time Series Plot: Detrended Rice Prices and Fertility Change Indices for Yamagata Prefecture

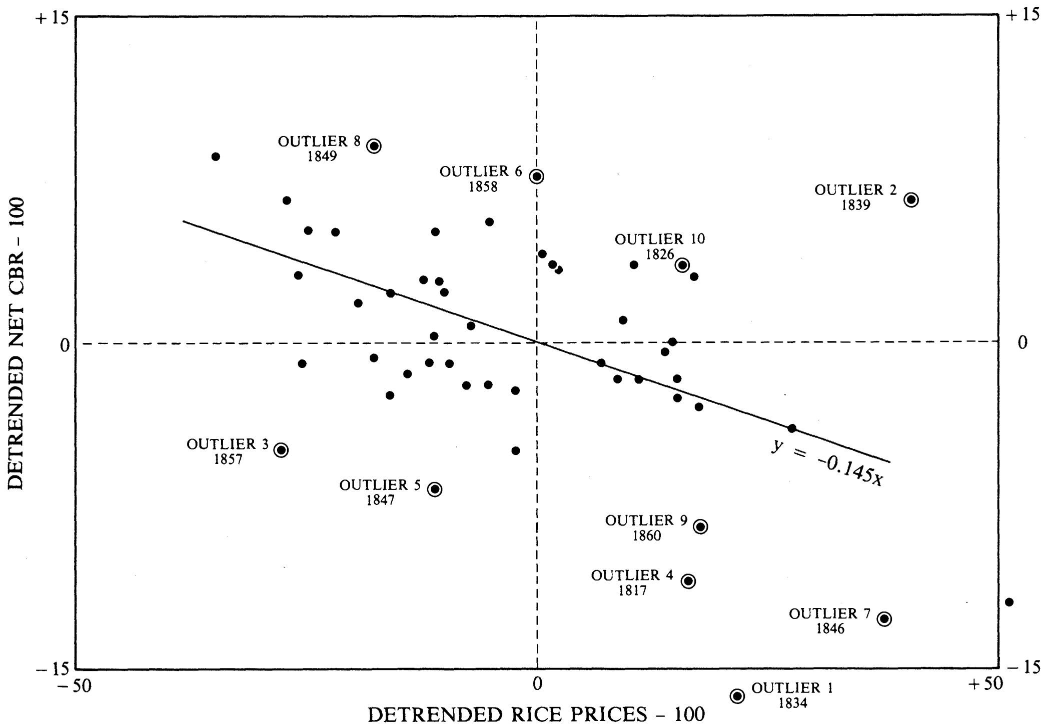

Figure 2
Scatter Plot: Detrended Rice Prices and Fertility Change Indices for Yamagata Prefecture

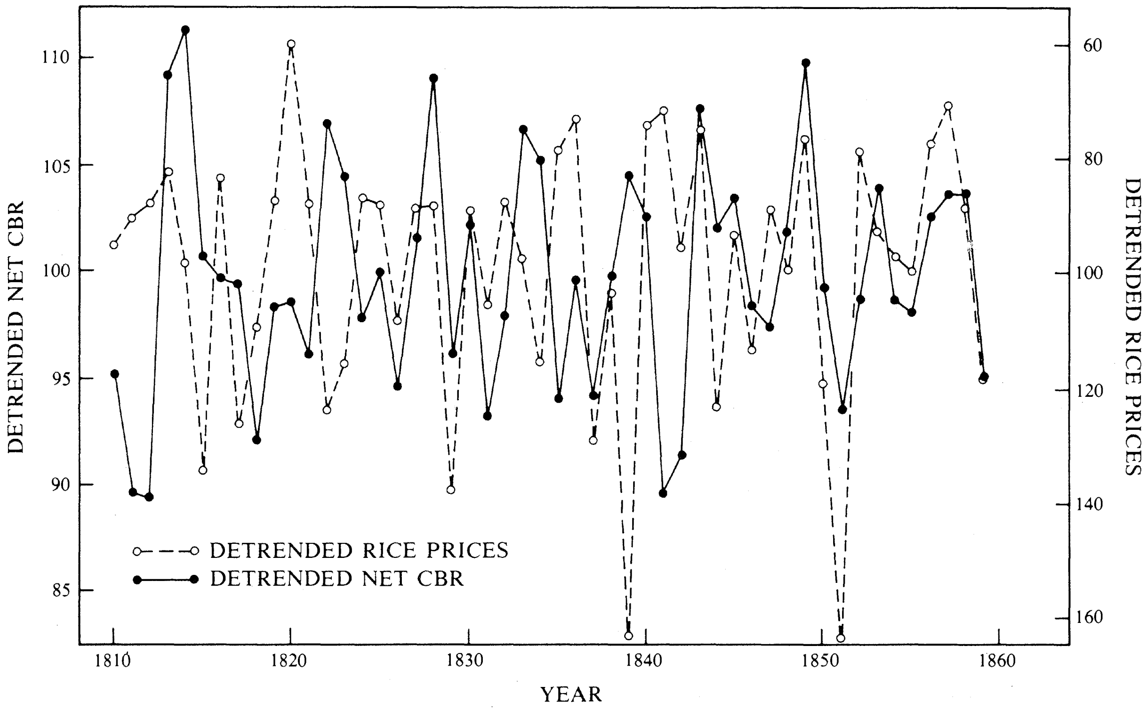

Figure 3
Time Series Plot: Detrended Rice Prices and Fertility Change Indices for Saga Prefecture

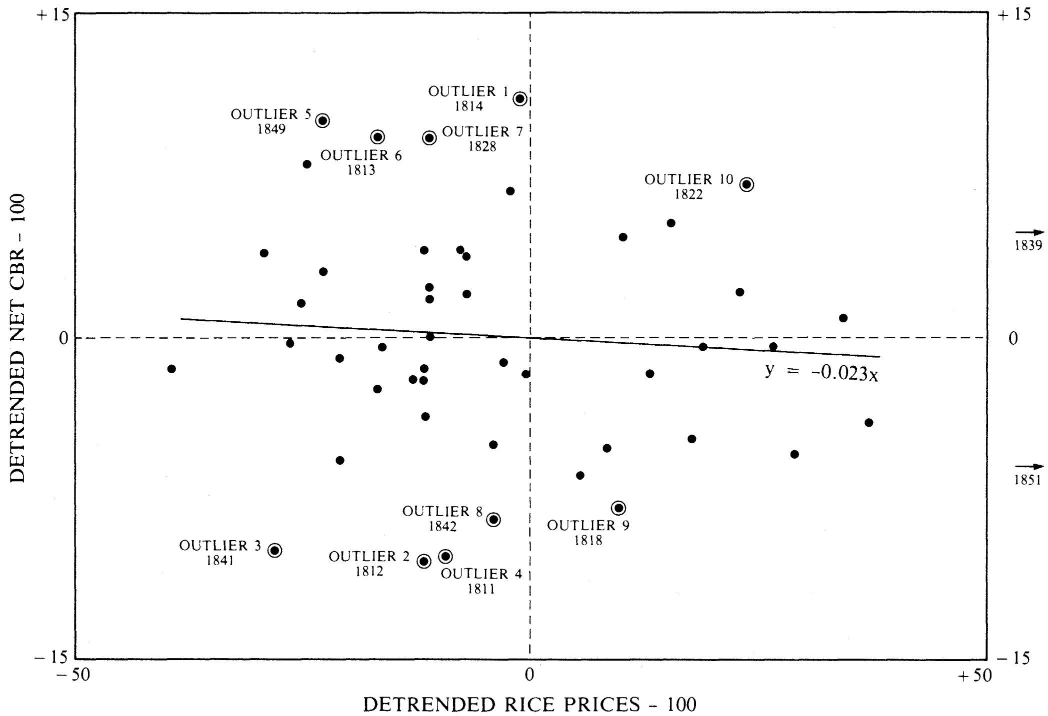

Figure 4
Scatter Plot: Detrended Rice Prices and Fertility Change Indices for Saga Prefecture

weight observations with large residuals.[22] Table 3 shows the values of the regression slope at successive iterations for each of the 13 cases, labeled by the name of the prefecture. We see that the results of the robust regression are similar to those given by simple least squares. Aichi is the only case in which there is a substantial difference between the original least squares slope and the final weighted least squares slope. We conclude that these data are not afflicted with any obviously extreme outliers. Note that, with the exception of Fukushima and Kyoto, the slopes increase or remain constant with each iteration.

An ancillary result of the procedure is the weight assigned to each observation, the smallest weights indicating the most extreme outliers. The ten most extreme outliers have been identified as such in Figures 2 and 4. There is little in the pattern of the outliers to attract attention. They are reasonably evenly scattered above and below the fitted line and to the right and left of the zero point on the horizontal axis.

It is instructive to order the 13 cases according to the strength of the relationship as measured by the regression coefficient. For this purpose the regressions were rerun using only the years 1806–57 (for the rice price series, 1807–58 for the detrended crude birth rate series), 1857 being the last year in the shortest rice price series (Aizu), so that the regressions cover comparable time periods.

The results are shown in Table 4. The columns show, in addition to the estimate of the regression slope Beta, its standard error, the t-statistic, the significance probability, and the proportion of variance explained.[23] All the regressions except Saga are highly significant.

The dispersion of the coefficients between prefectures is notable, for rice played much the same role in every prefecture, and we therefore expect the relationship to be similar everywhere. Here is the stem and leaf of the distribution, drawn sideways for typographical convenience, and (since all coefficients are negative) without the signs.[24]

22. Frederick Mosteller and John W. Tukey, *Data Analysis and Regression* (Reading, Mass.: Addison-Wesley Publishing Company, 1977), pp. 356–65. The value of the parameter C was 6, and five iterations were performed in all cases.

23. See any standard statistics text. We have referred to George W. Snedecor and William G. Cochran, *Statistical Methods*, 7th edition (Ames: The Iowa State University Press, 1980), Chapters 9 and 10.

24. The stem-and-leaf plot is a way of drawing the histogram of a distribution by writing down the distributed values, separating common from variable digits. Thus the "7" at the far left in the diagram above indicates the value -0.007, the 2 at the far right the value -0.212. The device was invented by the statistician John Tukey. See John W. Tukey, *Exploratory Data Analysis* (Reading, Mass.: Addison-Wesley Publishing Co., 1977), Chapter 1, or Mosteller and Tukey, *Data Analysis and Regression*, Chapter 3.

Table 3
Regression Coefficients at Successive Iterations of Robust Regression: 13 Meiji Prefectures

	Iteration				
Prefecture	LS	1	2	3	4
Yamagata	−0.138	−0.142	−0.144	−0.144	−0.145
Fukushima	−0.094	−0.081	−0.072	−0.067	−0.065
Kanto Region	−0.115	−0.117	−0.118	−0.119	−0.119
Nagano	−0.046	−0.047	−0.048	−0.048	−0.049
Aichi	−0.159	−0.184	−0.194	−0.199	−0.199
Shiga	−0.099	−0.104	−0.105	−0.105	−0.105
Kyoto	−0.132	−0.111	−0.101	−0.097	−0.095
Osaka	−0.120	−0.129	−0.131	−0.132	−0.132
Hyogo	−0.134	−0.141	−0.144	−0.145	−0.145
Hiroshima	−0.105	−0.113	−0.117	−0.118	−0.118
Yamaguchi	−0.185	−0.184	−0.183	−0.183	−0.183
Saga	−0.020	−0.023	−0.023	−0.023	−0.023
Kumamoto	−0.098	−0.099	−0.099	−0.099	−0.099

Note: The second column shows ordinary least squares estimates of the regression coefficient for the regression of detrended crude birth rates on detrended rice prices one year lagged. The following columns show the coefficients resulting from four iterations of robust regression (Mosteller and Tukey, *Data Analysis and Regression*, pp. 356–65).

Table 4
Regression Results: 13 Meiji Prefectures

Prefecture	Beta	SE	t	p	%VE
Yamaguchi	−0.212	0.026	8.0	<.001	0.55
Aichi	−0.194	0.022	8.7	<.001	0.56
Yamagata	−0.144	0.028	5.2	<.001	0.32
Hyogo	−0.142	0.034	4.2	<.001	0.24
Kanto Region	−0.138	0.030	4.6	<.001	0.28
Hiroshima	−0.135	0.027	5.0	<.001	0.31
Kyoto	−0.133	0.028	4.7	<.001	0.26
Osaka	−0.116	0.029	4.0	<.001	0.25
Shiga	−0.093	0.028	3.3	.003	0.19
Nagano	−0.090	0.036	2.5	.002	0.09
Kumamoto	−0.070	0.027	2.6	.002	0.13
Fukushima	−0.065	0.027	2.4	.002	0.08
Saga	−0.007	0.032	0.2	>.500	0.00

SE: standard error t: t-statistic
p: significance probability %VE: variance explained
Note: Ordinary least squares regressions on data truncated to period for which all rice price series are available, 1806–57.

STEM AND LEAF OF REGRESSION COEFFICIENTS

00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21
7						5	0		0		6		3	2					4		2
									3				5	4							
													8								

Most of the values lie in the range -0.06 to -0.14, with a clear concentration on the upper limit of this range, but we have a low outlier for Saga, with a coefficient of 0.007 and two high outliers for Yamaguchi and Aichi, with coefficients of -0.212 and -0.194, respectively.

How should we interpret this dispersion? It may be due merely to random variation, and indeed it is not so great as to force any other conclusion. Nonetheless, the sharp separation of the outliers leads us to consider whether the variability of the Betas may be due to variability in the quality of the rice price and population data. To test this possibility we regress the detrended crude birth rates for each prefecture on the Osaka rice price series. If rice prices in a particular prefecture are a poor indicator of actual economic conditions, we may get a higher correlation of birth rates with the Osaka price than with the local price. The choice of Osaka is of course dictated by its status as the principal national rice market.

The results of these regressions are shown in Table 5, with the explained variance figures from the previous regressions repeated for convenience in comparison. The next to last column shows the per cent variation in crude birth rates explained by the regression on the Osaka rice prices, the last column the comparable figure (from Table 4) for the regression on the local area prices. Prefectures are grouped according to whether the variance explained by the Osaka regression is less than (first group) or greater than (second group) the original regression. Within groups, cases are ordered by the value of the Beta coefficient shown in the first column.

The explained variance improves substantially for several prefectures, most notably for Fukushima (Aizu price series) and Nagano (Shinshū price series). As it turns out, both of these rice price series are for relatively sparsely populated mountain areas in their respective prefectures. Since both prefectures had a concentration of population in plain areas, the Aizu and Shinshū price series may provide a poor representation of the supply of rice in Fukushima and Nagano as a whole. This would explain why the birth rate series are more strongly related to the Osaka than to the local price series.[25]

25. We are indebted to Iwahashi for several conversations clarifying these points.

Table 5
Osaka Rice Price Regression Results: 12 Meiji Prefectures

Prefecture	Beta	SE	t	p	%VE Cf
Aichi	−.203	.035	5.8	<.001	39 < 56
Yamaguchi	−.197	.033	5.9	<.001	41 < 55
Yamagata	−.115	.033	3.5	.001	18 < 32
Kanto Region	−.106	.030	3.6	<.001	18 < 28
Shiga	−.105	.036	3.0	.005	15 < 19
Kumamoto	−.031	.021	1.5	.150	5 < 13
Kyoto	−.170	.030	5.8	<.001	36 > 26
Fukushima	−.167	.030	5.6	<.001	31 > 8
Nagano	−.159	.035	4.6	<.001	24 > 9
Hyogo	−.146	.031	4.7	<.001	30 > 24
Hiroshima	−.132	.026	5.1	<.001	34 > 31
Saga	−.039	.043	0.9	.360	2 > 0

SE: standard error t: t-statistic
p: significance probability %VE: variance explained
Cf: VE from Table 4 above
Note: Same as regressions in Table 4, but with Osaka rice price series used in all regressions.

The overall level of the coefficients in the Osaka regressions is roughly the same as that in the regressions on the local area series, as indicated in the following stem-and-leaf plot.

STEM AND LEAF OF OSAKA RICE
PRICE REGRESSION COEFFICIENTS

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
		1							5	5		2	6	9	7	0		7	3		
		9							6												

This might at first seem to indicate that it is pointless to relate the various prefectural fertility series to the local rice prices, because the single Osaka series does just as good a job overall of explaining the variation in the fertility series as the local price series. In fact, however, this overall similarity results from a mixture of two very different groups of cases, one in which the local price series do a better job of explaining prefectural fertility variation, and one in which the Osaka series do better.

It is interesting to note that the prefecture of Saga is an outlier here, as it was in the local area regressions, in the sense of having very low Betas. Here, however, it is joined by Kumamoto as well. We shall return to the discussion of these cases in the following section.

The Time Pattern of Rice Price Effects on Birth Rates

The extensive work of Lee and Galloway prompts us to carry out a series of what are called "distributed lag" regressions for comparison with their results.[26] This means simply that the detrended crude birth rate for year y is regressed not only on the rice price for year y-1, but, using multiple regression, on the rice prices for several prior years. Following Lee and Galloway, we regress the detrended crude birth rate for year y with the rice prices for years y, y-1, y-2, y-3, and y-4. The results are shown in Table 6 and plotted in Figure 5. Unlike our earlier univariate regressions, these are conventional (rather than robust) least squares estimates. Results significant at one and five per cent by the usual t-test are signaled by one and two asterisks, respectively.

Most of the one-year lag coefficients are highly significant. Nagano is one exception, with a relatively large coefficient with little statistical significance. It was noted in the last section that the rice price series for Nagano and Fukushima may be unrepresentative of economic conditions in their respective prefectures, however, and we have therefore rerun the lagged regressions for these two cases using the Osaka rice price series. This brings the coefficients for both cases in line with the general pattern. For Nagano, the one-year lag coefficient jumps to -0.296, which is highly significant, and the zero- and four-year lags fall to low and insignificant values. For Fukushima the one-year lag coefficient rises to -0.163 and the remaining coefficients fall. These results confirm the earlier diagnosis of the unrepresentativeness of the rice price series for Nagano and Fukushima.

The result is that the pattern is universal but for the curious exception of Saga, which persists as an outlier through all the analyses. Does this mean that the relationship that exists elsewhere does not exist in Saga, or simply that the quality of the Saga data is lower? Having no good reason to suppose the former, we looked for indications of poor data quality. Since both the rice price series and the estimated birth rate series are highly inter-

26. Galloway, "Basic Patterns," p. 285, and Ronald D. Lee, "Short-term Variation: Vital Rates, Prices, and Weather," in Wrigley and Schofield, *Population History of England,* Chapter 9, pp. 356–401; see also Appendix 16, "Econometric Procedures," pp. 739–40.

27. Since there is a high correlation both between Iwahashi's 13 rice price series and between the estimated crude birth rate series for the 13 corresponding prefectures, we looked for evidence that the series for Saga and Kumamoto departed from this pattern. Specifically, we used the median polish technique of Tukey to extract year and prefecture effects and examined the table of residuals from this fit. See Tukey, *Exploratory Data Analysis,* Chapter 11, or Mosteller and Tukey, *Data Analysis and Regression,* Chapter 9. Though the analysis may be carried out by hand, we used the computer program given in Donald R. McNeil, *Interactive Data Analysis* (New York: John Wiley & Sons, 1977), p. 116.

Table 6
Lagged Regression Results: 13 Meiji Prefectures

	Coefficient and (beneath) Standard Error for Rice Price in Indicated Year				
Prefectures	Year 0	Year −1	Year −2	Year −3	Year −4
Yamagata	−.031 .038	−.131** .036	−.023 .036	+.037 .035	−.026 .038
Fukushima	−.067 .041	−.100** .037	+.044 .037	+.058 .037	−.084* .041
Kanto Region	−.019 .040	−.135** .042	+.023 .040	+.078* .040	−.033 .041
Nagano	−.134* .058	−.105 .057	−.022 .057	+.021 .057	−.161** .058
Aichi	−.054 .037	−.146** .040	−.008 .043	+.013 .041	−.028 .042
Shiga	+.034 .031	−.094** .031	−.065* .033	−.057 .033	+.012 .036
Kyoto	+.020 .045	−.143** .048	−.006 .049	−.026 .049	+.018 .051
Osaka	−.014 .033	−.125** .036	−.058 .040	−.041 .039	−.044 .040
Hyogo	+.064 .044	−.120** .042	−.067 .043	−.004 .045	+.045 .048
Hiroshima	+.018 .036	−.094* .037	−.018 .038	+.031 .036	+.074* .037
Yamaguchi	−.003 .035	−.189** .036	−.047 .037	+.032 .037	+.004 .038
Saga	+.047 .032	−.047 .032	−.025 .031	−.060 .032	.105** .033
Kumamoto	+.002 .034	−.094* .038	−.019 .038	−.080* .040	+.001 .041

*significant at 5% level **significant at 1% level
Note: See text for explanation.

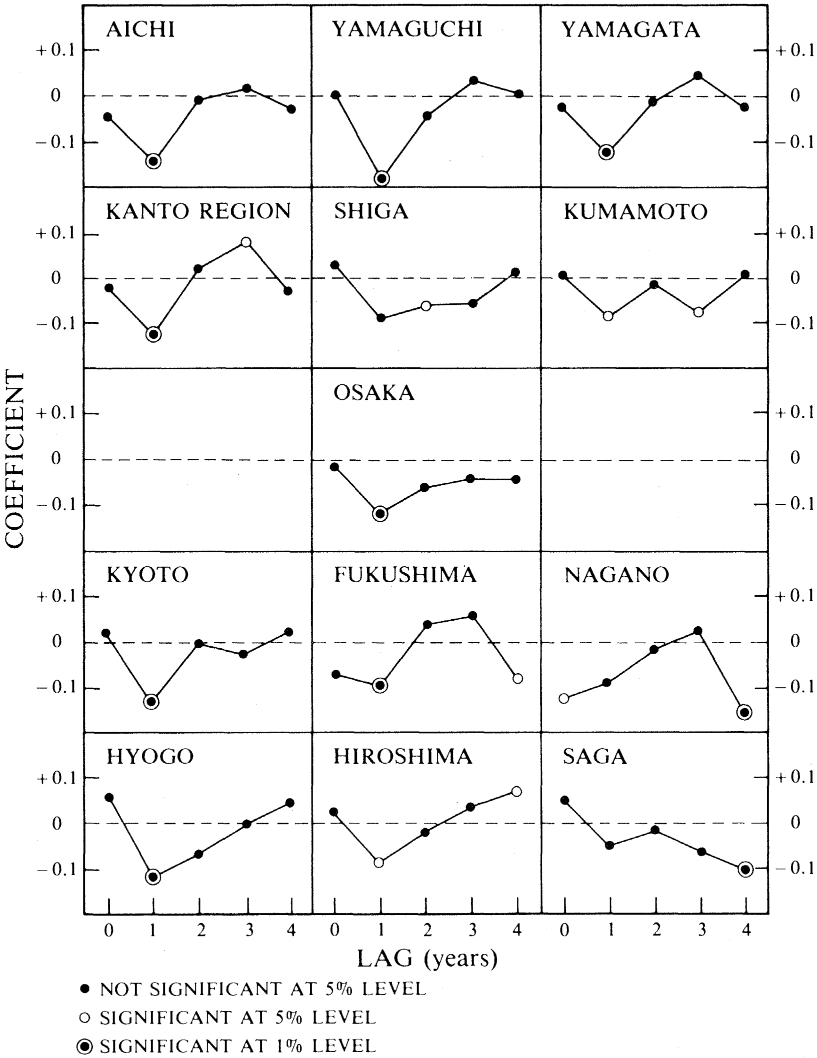

Figure 5
Patterns of Fertility Response to Rice Price Changes for 13 Prefectures

correlated between regions, the approach was to see whether the series for Saga stand out in any way from the remaining provinces.[27] The results of this inquiry are negative, however, and in the face of highly consistent results everywhere else, the results for Saga remain mysterious.

Looking at the significance for the coefficients for lags of other than one year, we find seven coefficients significant at five per cent and two significant at one per cent out of a total of 52 coefficients, roughly four times the numbers we would expect by chance, suggesting that the lagged terms are playing a role. The prefectural plots shown in Figure 5 are ordered as in Table 5. The six plots at the top of the figure correspond to prefectures for which the regression using the local rice price series explains more variance than the regression using the Osaka series. Since we infer from this fact that the rice price series for these prefectures are better data, we place more weight on these cases. Conversely, the six plots at the bottom of the figure correspond to cases in which the Osaka regressions explain more variance, upon which we place less weight.

Four out of the six prefectures in the first group show a consistent down-up-up-down pattern of lag coefficients. The exceptional cases are Shiga and Kumamoto. One prefecture in the second group, Fukushima, shows the same pattern. The persistence of the pattern suggests a real effect, despite the minimal significance level of the coefficients.

By contrast, the second group of prefectures, those in which the Osaka rice price series explains more variance, shows no such common pattern, tending to support the notion that these rice price series are less than faithful reflections of real economic conditions.

It is interesting to compare these results with those of Uemura for Japan as a whole.[28] Using reverse survival to estimate a crude birth rate series, but without adjustment for the lunar calendar in effect before 1873, and detrending using five-year moving averages, he estimates a series of regression equations including zero-, one-, and two-year lags for Japan as a whole using the Osaka rice price series. He obtains very high one-year lag coefficients for the early nineteenth century, on the order of 0.250, and much lower values for the later part of the century. The overall value for 1813–59 is 0.195 (Table 5, right panel, p. 73), very close to the highest values we obtain. He also analyzes sex ratios at birth in relation to rice price fluctuations and concludes that males experience especially high infant and child mortality during poor harvest years (p. 79).

Broadly comparable results for 14 European cases are given by Galloway.[29] Comparison of the lag coefficient plots in Figure 5 with Galloway's

28. Uemura, "Kinsei ni okeru hōkyō-jōtai to shusshō-su shusshō-seihi."

29. Galloway, "Basic Patterns," Appendix Table 1.

plots for Europe[30] reveals interesting similarities and differences. In both Europe and Japan, (i) the zero-year lag coefficient is close to zero, (ii) the one-year lag coefficient drops sharply negative, and (iii) subsequent coefficients first rise and then fall. In Galloway's European cases, however, the rise occurs all at once with the two-year lag coefficient, whereas in our Japanese cases the rise occurs over two years, peaking with the three-year lag coefficient.

The patterns are sufficiently consistent in both cases to look for an explanation. G. William Skinner[31] has suggested that the gentle rise in the Japanese coefficients is consistent with a mean birth interval of about three and one half years. If this explanation is correct, then the European pattern would correspond to mean birth intervals roughly one year lower. Extensive evidence on European mean birth intervals indicates that they are indeed some two and one half years.[32]

Galloway and Lee[33] find a European lag pattern for Japan for the period 1886–1940 using crude birth rates from registration data and a wholesale price index series. If it is indeed a difference in birth interval distributions that accounts for the different lag patterns, this would suggest shorter birth intervals during the Meiji period, and hence a decline from the longer Tokugawa intervals. We are not aware of any statistical evidence on Meiji birth intervals, however, and have no other reason to suppose that birth intervals might have been declining.

We are not inclined to press these interpretations of the lag patterns very far, however, because of a technical deficiency in regression specification. Because of the typical pattern of the distribution of intervals between births, fluctuations in births in any given year induce fluctuations in subsequent years. Thus a rise in births in year y tends to induce first a slight fall and then a rise in births in subsequent years, confounding the rice price effects. So far as we are aware, none of the work carried out thus far controls for this auto-correlation in the birth series.[34]

30. Ibid., Figure 1(A), p. 286.

31. Personal communication. On evidence for long birth intervals in late Tokugawa Japan, see G. William Skinner, "Reproductive Strategies and the Domestic Cycle among Tokugawa Villagers," paper prepared for the Panel on Household Structure and Fertility in Asia, 40th annual meeting of the Association for Asian Studies, San Francisco, March 26, 1988.

32. Flinn, *The European Demographic System, 1500–1820,* Table 3, pp. 112–16, antepenultimate-penultimate intervals.

33. Patrick R. Galloway and Ronald D. Lee, "Some Possibilities for the Analysis of Aggregate Historical Demographic Data from China," paper presented at the Workshop on Qing Population History, California Institute of Technology, Pasadena, California, August 26–31, 1985.

34. While this is a solvable statistical problem, it requires some technical innovation. One approach would be to model explicitly the birth series using demographic models that

Why Do Birth Rates Respond to Changes in Rice Prices?

The observed response of fertility to changes in rice prices might be due to fluctuations in natural infant mortality, to infanticide, to abortion, or to some form of contraception. By "natural" infant mortality here we mean infant mortality not due to infanticide, so that infant mortality in the usual sense is the sum of natural infant mortality and infanticide.

Infant mortality is a possible mechanism because our estimates of birth rates are necessarily net of year-to-year variations in infant mortality about the average level. The life table used in constructing our crude birth rate series (e_0=35 years) shows an infant mortality rate of 22 per cent. What appears in our series as a two per cent fall in the birth rate, from 100 to 98 births, say, might in fact be due to a rise in infant mortality resulting in two additional deaths, 24 instead of 22, say.

Infant mortality fluctuations of this magnitude are certainly possible, and we cannot rule out this explanation of the observed correlation. This would of course be consistent with the picture of peasants living at the extreme margin of existence, with poor harvests regularly calling into effect the Malthusian "positive check" of higher mortality. As a counter to this possibility, however, we observe that essentially the same correlation is observed in European historical data, in which the birth series, derived from contemporary records of baptisms, should be independent of infant mortality fluctuations.[35]

Infanticide was practiced in Tokugawa Japan, as we know from the number and nature of contemporary references to the practice.[36] This does

incorporate birth interval distributions, on which see Griffith Feeney, "Population Dynamics Based on Birth Intervals and Parity Progression," *Population Studies,* Vol. 37, No. 1 (March 1983), and "Parity Progression Projection," in International Union for the Scientific Study of Population, *International Population Conference, Florence 1985,* Vol. 4 (1985), pp. 125–36.

35. On the other hand, the European fertility series, based on records of baptisms, might suffer the same difficulty. Since most infant deaths occur very shortly after birth, and hence possibly before baptism, and since infants dying before being baptized will be excluded, birth rates calculated from these data might in fact be just as "net" of year-to-year fluctuations in infant mortality as our reverse survival estimates. The low infant mortality rates calculated from English data, for example, are evidence of substantial omission of infant deaths, and it is certainly possible that the number of omissions fluctuates from year to year with the level of infant mortality. On the English data see E. A. Wrigley, "Mortality in pre-industrial England: the example of Colyton, Devon, over three centuries," in D. V. Glass and Roger Revelle, eds., *Population and Social Change* (London: Edward Arnold, 1972), pp. 243–73.

36. See Irene B. Taeuber, *The Population of Japan* (Princeton: Princeton University Press, 1958), pp. 29–30. The principal source, cited by Taeuber, is Takahashi Bonsen, *Nihon jinkō-shi no kenkyū,* Vol. 1 (Tokyo: Sanyūsha, 1941), Vol. 2 (Tokyo: Nihon Gakujutsu Shinkōkai, 1955), and Vol. 3 (Tokyo: Nihon Gakujutsu Shinkōkai, 1962). See also Hanley and Yamamura, *Economic and Demographic Change,* Chapter 9; Thomas C. Smith, *Nakahara:*

not mean that it was practiced on a sufficient scale to have any appreciable effect on population movements, however, nor that it would explain the observed correlation between our rice price and birth rates series.

We have already seen that increasing deaths from 22 to 24 per hundred would create the appearance of a two per cent fall in our estimated birth rate, and similarly for a fall in deaths from 22 to 20 per hundred. While we do not slight the ghastly prospect of infanticide concretely imagined, it is at least conceivable that a community that sees 20 out of every 100 children born die naturally shortly after birth might not "return" two more if conditions seemed not only to portend this fate for the child in any case, but to threaten the survival of older children as well. If women bear five children on the average, two or even four infanticides in 100 births would mean a similar number for every 20 families. Many families would thus escape the eventuality altogether, and the few that committed it might do so only once.[37] It is certainly possible that infanticide accounts for the observed correlation.

Contemporary sources likewise indicate that abortion was practiced, but not what its incidence might have been. It is certainly possible that it could have been practiced sufficiently widely to account for the relatively small fluctuations in birth rates. As the same sources are relatively silent on any form of contraception, we may reasonably dismiss it as a significant factor.

This leaves us, however, with three possible routes through which the observed correlation might be effected, natural infant mortality, infanticide, and abortion. It is of course possible that all three operated, but we would like to be more specific, and it may be possible to glean further information from the pattern of time lag between rice price changes and birth rate effects.

Since the rice crop was harvested in the early autumn, a relative shortage of rice in any given year would be felt roughly during the last quarter of this year and the first three quarters of the following year. Natural infant mortality and infanticides occurring as a result might be supposed to occur uniformly over the same period, so that roughly one quarter of the effect would be felt in the same year, and three quarters in the following year. Households would presumably stave off natural mortality, however, and

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Family Farming and Population in a Japanese Village, 1717–1830 (Stanford: Stanford University Press, 1977), Chapter 5; and G. William Skinner, "Infanticide and Reproductive Strategies in Two Nōbi Plain Villages, 1717–1869," paper prepared for the Workshop on Population Change and Socioeconomic Development in the Nobi Region, Stanford University, March 15–18, 1987.

37. These figures are far lower than some of the extreme numbers indicated for particular areas, but these would be wildly improbable as applied to the population at large.

perhaps also foreswear infanticide, as long as possible, and could do so by consuming more food during the beginning of the period of shortage. This could easily push the effects of a shortage of rice in one year entirely into the following year.

Abortions, in contrast, affect numbers of births only with a six- to nine-month lag, so that the effects of high rice prices in one year would not be observed until after the first quarter of the following year, at the earliest, and would continue through the second quarter of the following year. Effects would thus be divided roughly equally between the two years following the price rise.

The regression results in Table 6 and Figure 5 show a very strong effect on the one-year lag and weak and erratic effects for all other lags, and so point toward natural infant mortality and infanticide and away from abortion as the mechanism behind the correlation.

It is perhaps worth noting, finally, one factor that definitely cannot account for the observed correlation between rice prices and birth rates: marriage. While delayed marriage and non-marriage certainly influenced the overall level of fertility,[38] year-to-year fluctuations in marriages cannot effect similar year-to-year fluctuations in birth rates. The simple, formal argument for this conclusion was given by Carlsson.[39] Because of the strong smoothing effect of varying intervals between marriage and first and higher order births, year-to-year fluctuations in numbers of marriages do not result in similar fluctuations in numbers of births.[40]

Conclusion

Was Tokugawa society in the first half of the nineteenth century a model of Malthusian misery resulting from the positive check of mortality on population growth? Or was it a model of Malthusian vice, with the draconian preventive checks of abortion and infanticide keeping population numbers down and so providing a basis for economic growth? Does it in fact make a difference? Abortion and infanticide are hardly happy alternatives to epidemic and famine, and it is not difficult to find evidence of exploitation in either case. Nonetheless, a society that consciously limits population growth by abortion and infanticide—taking the dirty work on itself, as it were, rather than leaving it to nature—is undeniably differ-

38. Hanley and Yamamura, *Economic and Demographic Change,* Chapter 9 and *passim.*

39. Gösta Carlsson, "Nineteenth-century fertility oscillations," *Population Studies,* Vol. 24 (1970), pp. 413–22. Once the argument is understood, the conclusion is immediate from Figure 2, p. 417.

40. The distribution of intervals between marriage and first birth in Tokugawa Japan may be exceptionally concentrated because of a tendency to record marriages only upon the conception of a child, but this would not effect the smoothing effect of higher order births.

ent from a society that does not. It is hardly likely that the difference is insignificant.

The quantitative methods used in recent years to address such questions take agricultural commodity prices as indicators of food supply and look for statistical relationships between short-term fluctuations in prices, birth rates, and death rates. Rising death rates following a rise in prices, and falling death rates following a fall in prices, suggest the operation of a positive check. Falling birth rates following a rise in prices, and rising birth rates following a fall in prices, indicate a preventive check.

By this standard, we have found what appears to be powerful evidence of a preventive check, and this in turn tends to support the newer, progressive development view of late Tokugawa society. We have seen, however, that the estimated birth rate series might in fact be influenced by fluctuations in natural infant mortality (infant mortality exclusive of infanticide). Thus the observed correlation between prices and birth rates might really be a correlation between prices and (natural) infant mortality rates. This would indicate the operation of a positive check, which would be consistent with the older view of a society straining against the limits of subsistence. We are inclined against this possibility, on the grounds of the similarity of our results to those for many European countries, whose birth rate series are (probably) not subject to the same problems as those for Japan, but this is clearly not decisive.

It is perhaps worth noting, not just in self-defense, but for a realistic appreciation of the difficulty, that the prospects for resolving this particular statistical dilemma are poor. Resolution depends on knowing annual infant mortality rates during the Tokugawa era, and on this matter the *shūmon chō* registers, the principal contemporary sources, are necessarily silent because they record only surviving children.[41] There are of course other possibilities, including the *kakochō* death registers and the *kainin-kakiage-chō* pregnancy registers, but it is nonetheless our expectation that estimates of annual fluctuations in infant mortality rates will be difficult to come by.[42]

A more profound puzzle, and one probably more subject to eventual solution, is the smallness of the effects in question. This is not the place to enter into a discussion of the level of birth rates in late Tokugawa, but a

41. On the *shūmon chō* registers, see Hanley and Yamamura, *Economic and Demographic Change, passim;* Smith, *Nakahara,* Chapter 2; and L. L. Cornell and Hayami Akira, "The *Shūmon Aratame Chō:* Japan's Population Registers," *Journal of Family History,* Vol. 11, No. 4 (1986), pp. 311–28.

42. On the *kakochō* death registers, see Arne Kalland and Jon Pederson, "Famine and Population in Fukuoka Domain During the Tokugawa Era," *Journal of Japanese Studies,* Vol. 10, No. 1 (1984), pp. 31–72, and Ann Bowman Janetta, *Epidemics and Mortality in Early Modern Japan* (Princeton: Princeton University Press, 1987). On the *kainin-kakiage-chō* pregnancy registers see Kitō, *Nihon nisennen no jinkōshi.*

figure in the low 30s is likely to be better than a figure in the low 40s.[43] We have found a very systematic response of birth rates to rice prices, but the typical effect is a change of some five per cent in the birth rate. This would bring a value of 32.0 births per thousand women, say, up to 33.6 per thousand or down to 30.4 per thousand. But if changing rice prices explain why the birth rate moves up and down by a few points in the low 30s range, what explains why it is in the low 30s rather than in the low 40s? Natural infant mortality cannot explain this level effect, and a truly extraordinary incidence of abortion and infanticide would be required to account for it. Late and non-marriage are more likely candidates, but the indications here are inconsistent.[44] And if the preventive check of marriage operated to keep fertility low and population within the limits of subsistence, why was the check represented by the rice price-birth rate relation necessary?

However these matters turn out, we have conclusive evidence of a correlation between short-term fluctuations in rice prices and fertility. Uemura's results for Japan as a whole have been confirmed by our analysis of data for 13 provinces spread throughout the country. Saga stands out clearly as an exception, but for the remaining 12 prefectures, we find that a rise (fall) of 10 per cent in rice prices in one year tends to be followed by a fall (rise) of about 1.2 per cent in fertility in the following year, with strong statistical significance.

These results bear remarkable similarities to those for the nine European cases assembled by Galloway.[45] The magnitude of the fluctuations in the Japanese rice price series is somewhat smaller than for the European series, the magnitude of the crude birth rate fluctuations somewhat greater. The estimated effects of prices on birth rates are congruent, being somewhat stronger for Japan than for Europe.[46]

An important ancillary conclusion concerns the accuracy of both the Iwahashi price series and the 1886 age data. The rice price series are based on contemporary local records, the birth rate series on the 1886 age distri-

43. The median values of our estimated crude birth rate series for the 80-year period 1807-86 typically give values of 31 or 32 per thousand. For other indications see Hanley and Yamamura, *Economic and Demographic Change*, Chapter 8, and Smith, *Nakahara*, Chapter 5.

44. Hanley and Yamamura, *Economic and Demographic Change*, present evidence of massive fertility impact of marriage patterns, Chapter 9 and *passim*. Studies of other areas have shown little evidence at least of non-marriage, however. See Laurel L. Cornell, "Why Are There No Spinsters in Japan?" *Journal of Family History*, Vol. 9, No. 4 (1984), pp. 326–39. Contemporary census data on marital status leave no doubt that marriage was virtually universal among females during the last several decades of the nineteenth century, as shown in Griffith Feeney and Yasuhiko Saitō, "Progression to First Marriage in Japan: 1870–1980," NUPRI Research Paper Series No. 24 (Tokyo: Nihon University Population Research Institute, 1985), pp. 2–5.

45. Galloway, "Basic Patterns."

butions. Since there is no conceivable way in which errors in these two series could be correlated, the errors tend to obscure any relationship between them. The clarity with which the relationship is observed thus testifies to the accuracy of both series. This is particularly significant for the age data, where the fluctuations are much smaller, because the Meiji data have been so little regarded by Japanese demographers. That we should be able to discern a correlation involving movements of only a few percentage points in these numbers indicates age reporting far more accurate than we would otherwise have had any reason to expect. Hayami's characterization of these data as "a hitherto undiscovered Treasure Island awaiting exploitation"[47] is fully supported.[48]

It has been several decades now since quantitative approaches began to make an appearance in studies of Tokugawa society, and the results have perhaps not always met early hopes and expectations. Totman has observed acutely that "numbers measure outcomes but can only impute intent."[49] Imputing intent at the societal level is problematic by any means, however, and the challenge of good quantitative work is precisely to find the particular quantities that make the inference compelling. The coming decades promise a veritable explosion of new quantitative data on Tokugawa society. Though these data have certain inherent defects by conventional demographic standards, they are in other ways enormously more valuable, and the richly textured empirical work of Skinner gives a sense of how they may be exploited.[50] We think exciting times lie ahead, and with respect to the difficulties of making quantitative studies speak to the major issues, we suggest that, as Robert Frost once put it, "the only way out is through."

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46. Ibid., Table 1, lower panel. The comparison may be made using the coefficient of variation (standard deviation divided by mean) of the detrended series. The median value for Galloway's nine European grain price series is 0.23; the median value for the 13 Iwahashi rice price series is 0.18. The median value of Galloway's nine crude birth rates series is 0.044; the median for our 13 crude birth rate series is 0.053. The median value of the lag one coefficients for Galloway's nine cases (his Appendix Table 1) is 0.079; the median of the 13 lag one coefficients in Table 7 is 0.120.

47. Hayami, "Population Changes," p. 284.

48. It should perhaps be pointed out that these remarks apply only to the accuracy of age reporting. Underenumeration of the population is another matter. While underenumeration may vary from one age to the next, it will change very little from one single year to the next, and hence leave year-to-year fluctuations unaffected.

49. Totman, "Win, Lose, or Draw?" p. 462.

50. Skinner, "Infanticide and Reproductive Strategies," *passim*.