Recent Trends in Fertility and Nuptiality in China

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The State Family Planning Commission of China has conducted two large-scale fertility surveys, in 1982 and 1988, covering sample households containing 1 million and 2 million persons, respectively. These surveys obtained lifetime histories, including age at first marriage and at each birth for female members of the households from ages 15 to 67 in the first survey and from 15 to 57 in the second. The data provide detailed information on the extraordinary decline in the rate of childbearing in China (by 60% from 1970 to 1980). Because rising age at marriage played a significant role in this decline, the effect of changes in the pattern of entry into marriage on childbearing since 1980 was examined. There was a sharp increase in overall fertility (the total fertility rate) from 1980 to 1982; after falling to slightly below the 1980 level in 1985, the rate rose in 1985 and 1986 to well above that of 1980. A major factor in this arrested and partially reversed decline was a boom in marriage that followed a relaxation in 1980 of locally administered restrictions on marriage before the officially designated desirable age. In fact, the total fertility rate of married women (summed over duration of marriage rather than age) averaged much lower in the mid-1980s than in 1980. The summary rate of bearing second children increased markedly in the 1980s when calculated by age of women, but declined when calculated by duration of marriage, given the inflated number of recently married women.

D RAMATIC CHANGES IN THE RATE OF CHILDBEARING IN the population of China are well known to nonspecialists as well as specialists in population studies. Changes since 1950 can be summarized by two measures of fertility (Fig. 1), the total age-specific fertility rate (TAFR, commonly called simply the total fertility rate or TFR). It records the total number of births that would occur per woman in a hypothetical group subject at each age to the rate of childbearing experienced in a given calendar year. Thus at the fertility rate at each age in China in 1963 women would bear an average of more than seven children in a lifetime and at 1985 rates would bear only slightly above two children per woman. (The other measure, the total duration-specific rate, or TDFR, is the total number of births that would occur per ever-married woman in a

hypothetical group of newly married women subject at each duration since first marriage to the duration-specific rate of a given calendar year. It will be discussed further below.) The TFR is a preferred measure of fertility for many purposes because it is independent of the age composition of the population, as is the expectation of life at birth as a measure of mortality. The total fertility rate followed a nearly level trend until 1970, except for the abrupt decline from 1958 to 1961 associated with the crisis induced by the economic policies of the so-called "Great Leap Forward," the peak in 1963 associated with the return of normalcy, and a smaller diversion around 1967 associated with the Cultural Revolution.

From 1970 to 1980 the TFR fell by 60%, the most rapid decline ever recorded in a large low-income population. This precipitous fall was caused mostly by the vigorous antinatalist campaign initiated by the government in the cities in the mid-1960s and in the whole country in 1970, incorporating the slogan "later, longer, fewer": later marriage, longer intervals between births, and fewer children. Forceful measures that included incentives and disincentives to promote these goals were initiated by local authorities. In 1979 the program was intensified with the introduction of the well-known "one child" policy. Couples were encouraged to sign a pledge to have only one birth and were strongly pressured to avoid a second birth, and especially not to go beyond the second. In the year following the introduction of this intensified policy, the TFR reached its lowest level to that date, but then rose in 1981 and 1982 before falling again between 1983 and 1985, and finally rising in 1987 to match the low achieved in 1980.

Until recently a solid basis for calculating the recent sequence of TFRs in China existed only for years up until 1981, because the requisite accurate and detailed data were collected in a very large-scale retrospective fertility survey conducted in 1982 by the State Family Planning Commission (1). This survey (the National One-per-Thousand-Population Fertility Sampling Survey) obtained detailed lifetime fertility histories from 310,000 women from 15 to 67 years of age in sample households containing more than a million persons. Because of the very careful design and conduct of this survey, and the precise knowledge of dates in the Chinese population, accurate fertility rates, rates of first marriage by age, and other primary data from 1950 to 1981 can be taken from the extensive tabulations of the results of this survey. There is much interest in fertility changes since 1981, but no source of detailed data comparable to the 1/1000 survey for 1982 and later has been available. In 1988 the Family Planning Commission carried out a successor survey with a sample actually twice as large (2/1000) as the 1982 survey. The results of the 1988 survey have not yet been published, but we have had access to a 10% sample of the data.

Data from the 1988 survey allow us to analyze the changes in fertility since 1981, the last year fully covered in the 1982 survey. In

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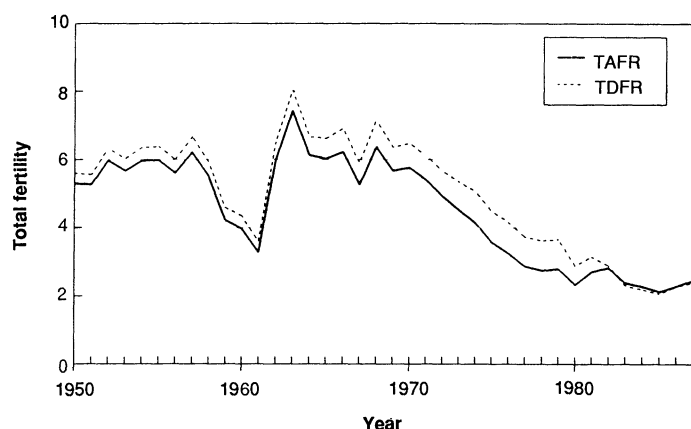
Fig. 1. Total age-specific and duration-specific fertility rates in China, 1950–1987. Total age-specific rates are the average total number of children per woman that would be born according to the fertility rates at each age in the given period. Total duration-specific rates are the average total number of children that would be born per ever-married woman according to the marital fertility rates at each duration since first marriage in the given period.

particular, we see strong effects of changes in the pattern of age of entry into marriage on the TFR and also on the aggregate rate of having first, second, third, and higher order births.
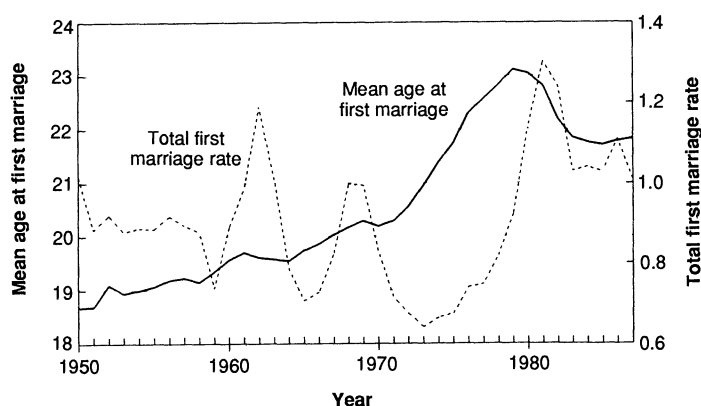
Nuptiality and Fertility in China, 1950–1981

The effect of marriage trends on fertility in China from 1950 to 1981 (2), in brief summary, were: (i) the mean age at first marriage for women in China rose from less than 19 in 1950 to more than 23 in 1979, resulting in a reduction of about 100 million in the number of births that would have occurred with no change in age at marriage, even if it is assumed that each couple had the same number of children that they would have had with no change in age at marriage. (ii) The accelerated increase in age at marriage after 1970 was the result of administrative measures introduced as part of the later, longer, fewer antinatalist program. The policy favored a minimum female age at marriage of 23 in rural areas and 25 in cities. The legal minimum age was not changed from the lower legal limit of 18 years established in the early 1950s, but after 1970 couples needed permission from local authorities to marry, and permission was often withheld for women younger than the age stipulated in the policy. (iii) In 1980 the legal minimum was raised from 18 to 20

Fig. 2. Mean age at first marriage and total first marriage, China, 1950–1987. The total first marriage rate is the sum of the first marriage rates at each age in the given period. Because almost all women have married no later than age 35, if age of entry were stable from year to year, TMR in China would be about 1.0. It differs by more than a small margin because age at marriage has varied.
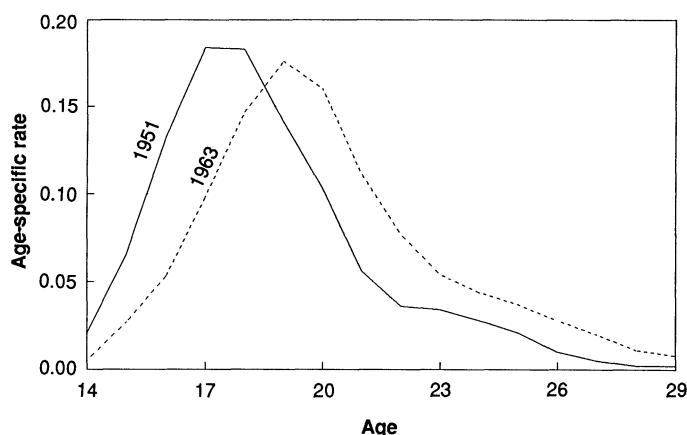
years; however, the legal minimum was not strongly enforced before or after this change in the law. For example, more than one-third of the women reaching 18 in 1959 married before the legal minimum. As age at marriage rose the proportion marrying before 18 fell to only 3.5% among women reaching 18 in 1978. But when the marriage law of 1980 increased the legal minimum to 20 years, the proportion of marriages before 20 actually increased, from 12.5% for women reaching 20 in 1980 to 17.9% for women reaching 20 in 1983. The more consequential change in 1980 in the control of age at marriage coincident with the new law was a relaxation of the bureaucratic restraint on marriage before age 23 (or 25) that had been imposed in the 1970s. The result of this relaxation was a boom in marriages. The total first marriage rate (the sum of rates of first marriage in a given period from the youngest to the oldest age of first marriage) in 1981 was 41% higher than that in 1979. The increase in the number of newly married couples led to an "echo" in the form of more first births. The increase in the number of marriages is the major cause of the upturn in the TFR in 1981 and 1982.

An alternative aggregate measure of fertility is the total duration-specific fertility rate or TDFR (Fig. 1). It records the average number of children that would be borne by a group of newly married women subject at every year of duration since first marriage to the rate of childbearing at that duration in the period in question. In China female entry into first marriage is virtually complete. In the 1982 census the listed proportion of women ever married is above 99% at each age above 30. With little imprecision the number of women in a given generation reaching age 50 can be considered equal to the number of ever-married women reaching 50. Imagine ascertaining the average number of children ever borne by women reaching 50 in a given year. If the slight effect of differential mortality of women of different prolificity is ignored, the average number born is the total fertility rate (TAFR) of this cohort. If the average number of children ever borne by ever-married women reaching age 50 is determined, it is equal to the total duration-specific (TDFR) of this cohort, if there is no childbearing outside of marriage. In China the number of births outside of marriage is negligible, and the number of women and the number of ever-married women at age 50 are essentially equal, since only three or four per thousand remain single. Thus for a cohort (women born in the same year) TAFR and TDFR are virtually equal.

When the age schedule of entry into first marriage remains unchanged for many years, the distribution of ever married women at each age by duration since first marriage also remains fixed. In China this relation implies that if the pattern of nuptiality were to remain constant, TDFR and TAFR would be virtually equal each year. Instead TAFR was less than TDFR in every year from 1950 through 1981. This difference was created by the changes in the age pattern of marriage that occurred in these years. When, as in China, entry into marriage is virtually complete, the total rate of first marriage (the TMR, defined above) of each cohort is almost 1.0. In fact, the annual period value of TMR was less than 1.0 in 28 out of 30 years from 1950 through 1979 (Fig. 2). Persistently low TMR was the result of a persistent increase in the mean age of first marriage. When age at marriage increases, the number of marriages (and the TMR) is reduced below the number that would have occurred with constant age at marriage, even when all women in each cohort ultimately marry. A simplified example shows the logical basis of this effect. Suppose that by edict all women marry on the birthday when they reach age 22. Suppose that on 1 January 1990 the edict is altered to require marriage on attaining 23. No marriages would take place in 1990. Those already 22 are already married, and those who reach 22 wait until 1991. TMR drops from 1.0 to zero, and then returns to 1.0. The average TMR for the decade would be

Fig. 3. First marriage rates by age, cohorts in China reaching 14 in 1951 and 1963. These cohorts experienced most of their marriages during relatively undisturbed years in the 1950s and 1960s. The earlier cohort was nearly completely married before the crisis years of 1959–1961; the later cohort began marrying after this crisis had passed and had passed the major ages of marriage before the restrictive measures of the 1970s had much effect. The two curves illustrate the kind of change in pattern when age at marriage increases in response to general social transformation.

0.9, although all members of every cohort marry. In a more realistic context, an increase of 1 year in the mean age at first marriage implies the loss of one normal annual quota of marriages over a period of a few years, even when entry into marriage remains complete. (A decline of 1 year in the mean implies the addition of 1 year's quota.) Between 1970 and 1978 mean age at first marriage increased by a little more than 2 years. This change implies the loss of two complete "crops" of first marriage in about 8 years, or a reduction of the TMR by about 25% of its normal value, which is about 1.0 in China. (The average value of TMR from 1970 to 1978 was, in fact, 0.723.)

The effect of changes in the age pattern of entry into marriage on fertility is most simply visualized in a population (like that of China in recent years) in which the fertility is strongly limited at later ages and durations of marriage by contraception and abortion. In such a population, fertility rates by duration of marriage are not much affected by differences in age at marriage. Women married at 20, 21, 22, or 23 have about the same number of births in the first 5 or 10 years after marriage. With strong limitation of
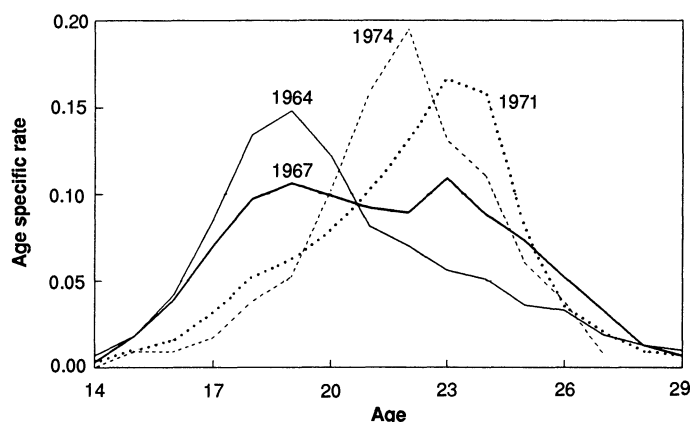
fertility, by the time the women reach a duration where the later marriers might be less capable of childbearing, fertility is severely restricted by contraception and abortion. In short, in such a population, TDFR is not much influenced by changes in the mean age at first marriage. Let us assume, then, that the value of TDFR in a given recent year is independent of recent changes in nuptiality.

Under this assumption, age-specific fertility rates are affected by recent changes in age at marriages. The fertility rates of young married women at early durations of marriage are the same as if age at marriage had not changed, but if the mean age at marriage has risen, there are fewer young married women, and therefore age-specific fertility rates are lower than they would be with constant age at marriage.

The effect of recent changes in marriage on fertility is shown succinctly by a comparison of the two total fertility rates that appear in Fig. 1. If age at marriage had been constant, the two total rates would have the same. From 1950 until 1982, TAFR was less than TDFR, precisely because the upward movement of age at marriage reduced the annual number of marriages even as entry into marriage remained virtually universal. In fact, the ratio TAFR/TDFR is an approximate measure of the reduction in TAFR caused by the recent changes in age at marriage, when, as in China, almost all women marry (*3*). Multiplication of this ratio for each year by the annual number of births gives an estimate of the reduction in the number of births caused by the rising age of marriage. From 1950 to 1970, the reduction was about 8%, or about 47 million births; from 1971 to 1980, the reduction was about 19%, or about 53 million. Altogether in the three decades after the founding of the People's Republic, rising age at marriage reduced the number of births by about 100 million.

Effect on Marriage of Government Intervention, 1970–1987

The total first marriage rate was below 1.0 from 1951 until 1979 except for two upward excursions associated with recovery from the crisis of 1959–1961 and the Cultural Revolution (Fig. 2). The general prevalence of a TMR of less than 1.0 was the result of the general upward trend of the mean age of first marriage shown in Fig. 2. The concerted longer, later, fewer policy instituted on a nationwide basis in 1970 led to an accelerated increase in the mean age at first marriage, accompanied by very low values of TMR. In 1979, the mean age at marriage did not increase, and TMR rose to 1.0, the value expected when marriage is universal for each cohort, and mean age at marriage is not changing. When the program of withholding the required permission to marry until the bride was 23 (25 in urban areas) was relaxed in 1980, there was a rush to marriage among women less than the former permissible age. The TMR rose to 1.14 in 1980, 1.30 in 1981, 1.24 in 1982, and remained above 1.0 through 1987. Rates above 1.0 are possible when women at different ages marry in the same year rather than sequentially. A fall in the mean age at first marriage has this effect, as does, for example, the demobilization of a large army providing grooms at the same time for brides at a substantial range of ages. The end of severe restriction of marriage before the required minimum was analogous to demobilization in producing more marriages at all ages from about 20 to 22. Also the mean age at first marriage fell by 1.41 years from 1979 to 1985.

The dominant influence of bureaucratic intervention in the changing pattern of age at marriage after 1970 is evident in Figs. 3 and 4. Figure 3 shows the rates of first marriage in a cohort that began entering marriage soon after 1950, and in a cohort that began

Fig. 4. First marriage rates by age, cohorts reaching age 14 in different specified years, 1964 to 1974. These irregular curves show how the age pattern of entry into marriage was affected in different degrees and different ways by government intervention in the choice of age at marriage.

marriage in the 1960s just after the effects of the crisis period of 1959–1961 were over. Each cohort experienced a fairly smooth sequence of marriage rates; in the later cohort, however, there were fewer marriages at the youngest ages (less than 18) and more at older ages (over 21). This kind of shift in pattern is what one would expect when later marriage is the effect of general social and economic change. The effect on the marriage pattern of successively later cohorts of the imposition and removal of restrictions on marrying before age 23 are shown in Fig. 4. The oldest cohort (14 in 1964) had reached age 20 before the restrictions were imposed. The next cohort shown was 17 in 1970; the sharp reduction in marriages at ages 18 to 22 is clearly visible; especially significant is the pronounced peak at 23. Just 4 years later, the cohort reaching 14 in 1971, which experienced all of its marriages under bureaucratic restraint until reaching 23 in 1980 when the restrictions were eased, had sharply reduced marriage rates at younger ages and a single peak rate at the prescribed minimum. The youngest cohort shown was 20 when restraints on marriage at ages less than 23 were softened. Up to age 19 its marriage rates are less than the next older cohort, but from 20 through 22 the marriage rates are much higher and from 23 through 25 much lower. These changes from cohort to cohort are not what one would expect when later (or earlier) marriage is the effect of general social and economic change, but are rather explained as the effect of official intervention in the determination of age at marriage.
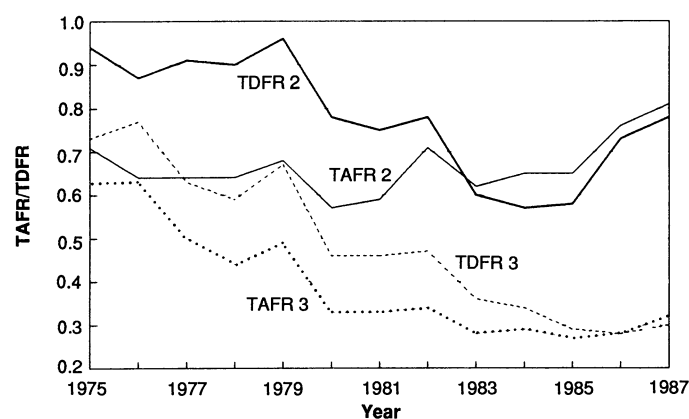
Fertility in China Since 1981

The TAFR reached a temporary minimum in 1980 after the introduction of the one-child policy, rose in 1981 and 1982, fell to a new minimum in 1985, and then increased in 1986 and 1987 to a value a little higher than in 1980 (Fig. 1). The TDFR also rose from a temporary minimum in 1980, but resumed its decline after only 1 year, fell to a new low in 1985, and rose in 1986 and 1987 to a value still well below the level in 1980. Specifically, TAFR in 1985 and 1987 was 92% and 106% of TAFR in 1980, whereas TDFR in the latter 2 years was 72% and 83% of TDFR in 1980. The ratio TAFR/TDFR rose from 0.806 in 1980 (0.767 in 1979) to a little more than 1.0 in 1983 and later years. The trend in the total age-specific fertility rate in the 1980s was generally horizontal, compared to the steep decline in the 1970s; however, the total

Fig. 5. Total age-specific and duration-specific rates of second and third order births. TAFR2 is the sum of the age-specific rates of giving birth to a second child during a given period; the other measures are analogously defined. The different time paths of the age and duration rates show the strong effect of the marriage boom after 1980 on the occurrence of second and third births.

duration-specific fertility rate continued to fall in the early to mid-1980s, with a mild upturn in 1986 and 1987.

The failure of the total age-specific rate to continue the steep fall of the 1970s certainly means that there were many more births than if the decline had continued. Indeed the ratio of the birth rate in 1987 to the birth rate in 1980 was larger than the corresponding ratio of TAFRs, because high fertility in the 1960s led to an increase in the proportion of women at the ages of highest fertility. There has also been speculation that such factors as less stringent enforcement of the one-child policy, and greater perceived advantages of second and third births in the rural areas because of the economic reforms beginning in the late 1970s, contributed to an increase in the birth rate. We shall next examine the total rates of bearing first, second, and third children, calculated as the sum of birth rates of a given birth order at each age of woman, and at each duration since first marriage for ever-married women (TAFR1, TAFR2, TDFR1, and so on). Because a first birth is almost universal for married couples in China, the total duration-specific marital fertility rate for birth order one has remained very close to 1.0. For the 10 years 1978–1987, TDFR1 had an average value of 0.993 (4). The universality of first births creates a very tight relation between the total age-specific first birth rate and the total marriage rate of the preceding year. For 1978–1987 the average ratio of TAFR1 to TMR(t-1) was 1.00. Because of the boom in marriages in these 10 years, the average value of TAFR1 was 1.037, compared to 0.762 from 1970 to 1978.

The total fertility rates by age and duration of marriage for second and third births are shown in Fig. 5. TAFR2 is higher in every year from 1981 to 1987 than in 1980 and 43% higher in 1987. By this measure it does appear that the one-child program was having ever less effect. In contrast, TDFR2 fell steeply after 1982 to a minimum in 1984 27% below 1980 and then rose in 1986 and 1987 to within 1% of the level in 1980. By this measure, married couples had a strongly diminished propensity for a second birth in the mid-1980s, with an upturn after 1985 but not returning to the marital second birth rate before 1980. The continuation of a total duration-specific rate of bearing a second child lower or at least no higher than in 1980 shows that the effect of the one-child policy was not in fact greatly weakened (5).

The total age-specific rate of bearing a third child declined to a minimum 17.5% below 1980 in 1985 and then returned almost to the 1980 level in 1987. TDFR3 reached a minimum 40% below 1980 in 1986 and rose very slightly in 1987. The very different sequences of birth order total rates by age of mother and duration of marriage are the result of the boom in marriages that began when permission to marry before a recommended minimum was softened in 1980. In 1980 TDFR2/TAFR2 was 1.37; in 1987 the ratio was 0.952. In both years, the same total number of second births entered into TDFR2 and TAFR2; the reason why TAFR2 rose by 43% and TDFR2 fell slightly is that in 1987 the number of married women at durations at which second births occur was greatly inflated by the boom that began in 1980. The number of women at ages at which second births normally occur was not inflated, just the number of married women. The denominators of duration-specific rates were increased by the high marriage rates, the denominators of age-specific rates were not.

Conclusions

Fertility in China since 1950 has been continuously affected by changes in marriage. The moderate rise in age at marriage from 1950 to 1970 produced a moderate reduction in the number of births that would have occurred if age at marriage had remained

unchanged. The more rapid increase in age at marriage that followed the antinatalist policies of 1970 produced a more pronounced reduction during the 1970s in the number of births that would have occurred with no change in age at marriage (and the same number of births at each duration for each couple). The policies of 1970 included measures to encourage limitation of marital fertility by the use of contraception and induced abortion, policies that culminated in the one-child norm introduced in 1979. The birth rate and the total age-specific fertility rate have not continued the decline of the 1970s, and the total second order birth rate has risen by more than 40% in the 1980s. We have shown that the total marital fertility rate by duration since first marriage did continue to decline at least until 1985, and that for married women the rate of bearing second and third children diminished (except for an upturn in the total second birth rate in 1986 and 1987). A major element in the undiminished or rising fertility calculated by age (as the TAFR) or for the whole population (as the birth rate) is the marriage boom that began when the government in 1980 relaxed the locally administered restrictions on marrying before an officially recommended age.

REFERENCES AND NOTES

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4. This value of TDFR1 implies that at the rates of first birth at each marriage duration in this decade, only 0.7% of married women would remain childless. This low a rate of sterility is inconsistent with data from some other populations. See, for example, J. Trussell and C. Wilson [*Pop. Stud.* 39, 269 (1985)], where an estimate of 4.6% sterile is found from records in 14 English parishes from the mid-16th to the early 19th centuries. The 1982 census of China confirms a very low proportion childless: 1.47% among ever-married women 40 to 49. Actually, the average TDFR1 of 0.993 is slightly augmented by the decline in the mean duration of the interval between marriage and first birth in recent years. We have calculated this mean (for intervals of no more than 3 years) from 1970 to 1984 using data from the 1988 fertility survey. From 1976 to 1984 the average interval fell by about 1 month, or 0.083 years. Thus the average decrease in interval length was about 1% of a year annually, which would augment the TDFR by about 1%, just as the TMR is diminished by an increase in the mean age at marriage. Thus the TDFR1 with no change in the interval from marriage to first birth would be about 0.983, quite consistent with the 1.47% childless of ever-married women 40 to 49 reported in the 1982 census.
5. N. Luther, G. Feeney, and W. Zhang [*Pop. Stud.* 44, 341 (1990)] come to similar conclusions on the basis of parity progression ratio.

Thermodynamics of Surface Morphology

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Classical thermodynamic descriptions of surfaces treat surface orientation as a thermodynamic degree of freedom and thus allow for the possibility of reversible changes in surface morphology as a function of temperature or impurity concentration. The existence of these transitions has been confirmed experimentally. Advances in surface diffraction and imaging techniques now make it possible to characterize such transitions quantitatively in terms of the atomic structure, and particularly in terms of the behavior of steps on surfaces. Statistical mechanical models can be used to analyze the observations to determine the fundamental energetic parameters governing the observed thermodynamic behavior.

THE MORPHOLOGY OF SOLID SURFACES, THAT IS, THEIR structure on a scale of nanometers to micrometers, is the governing factor in a number of practical processes, including crystal growth, epitaxy, and etching. As a first step in developing a quantitative understanding of any of these processes, it is necessary to understand the equilibrium morphology of the surface. The profiles of two silicon surfaces [extracted from scanning tunneling microscopy (STM) data] (Fig. 1) illustrate the extent to which equilibrium thermodynamics can influence surface morphology (*1, 2*). Both of these morphologies represent equilibrium configurations, with the difference being only the net crystallographic orientations of the surfaces. The stepped surface in Fig. 1A is defined by its net crystallographic orientation and can be considered a single

thermodynamic phase. In contrast, the faceted profile in Fig. 1B contains regions of two distinct orientations and must be considered the coexistence of two thermodynamic phases.

The classical thermodynamic formalism for describing such surface morphologies and associated phase diagrams was put in place by Gibbs (*3*) and fully developed by Herring (*4*). Attempts to develop atomic models to calculate the surface free energies needed for thermodynamic prediction began as early as the 1920s (*5*), but little progress was made in extending them to nonzero temperature until the 1960s. Although recognized only in retrospect, Gruber and Mullins (*6*) developed the crucial insight that the thermal evolution of the surface free energy is governed by the wandering of steps (that is, linear boundaries across which the surface height changes by one or more atomic layers). Since then, statistical mechanical theories describing the surface free energy in terms of step behavior have been extensively developed (*7*). However, rigorous experimental tests of these theories only became possible in the 1980s, as more sophisticated surface preparation procedures, diffraction measurements, and new imaging techniques were developed.

In this article we show how experimental observations of steps can be used to test theoretical predictions about the orientational dependence of surface free energy, which governs the orientational phase diagrams of a surface. The extension of the underlying atomic models to provide a semiquantitative understanding of thermodynamic transitions observed on real surfaces is then illustrated by examples of reversible changes in surface morphology.

Theoretical Background

In this section we review how step properties are related to thermodynamic properties of surfaces. Crystallographic orientations of high symmetry (low–Miller index surfaces) will generally repre-

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