Estimating Subnational Total Fertility Rates in China

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Abstract

The county-level total fertility rate is an important indicator in studying the persistent low fertility and its spatial variations in China. Unfortunately, such data is not reported in the recent 2020 Chinese population census. We adopt a novel estimation framework proposed by Hauser and Schertmann (2020) and estimate 2020 county-level total fertility rates in China. This framework approximates TFR based on the observed population age structure, adjusted for women's lifetime fertility schedules and child mortality rates. We obtain data on the population age structure from the population census and under-five child mortality rate estimates from the maternal and child health surveillance system. We validate our estimation methods using province-level data from previous census years. Validation results show that, across four different TFR estimates, adjusting women's lifetime fertility schedule and child mortality rates improves the performances of the estimates. A preliminary analysis of the 2020 county-level estimates indicates there exist large within-province heterogeneity. Overall, our analysis demonstrates the robustness of the Hauser and Schertmann (2020) framework, especially when the under-enumeration of children is a concern.

Introduction

The period total fertility rate (TFR) is an important indicator in understanding fertility levels in a given place and time. However, calculating TFR requires detailed age-specific fertility rates in a given year, which is not always available, especially at the fine-grained geographic level. This lack of data hinders our ability to investigate subnational fertility trends and patterns and design place-based policies.

China's landscape of fertility rates demands a closer examination. China is known for its geographic heterogeneities in fertility rates. From the 1970s to the 2000s, China experienced a rapid nationwide decline in fertility rates. The economic, cultural, and social forces driving this decline are highly context-specific, and family planning policies have been tailored to local conditions. There is no one-size-fits-all explanation for fertility decline in China. Today, persistent low fertility has become a new reality. According to the 2024 World Population Prospects, China's total fertility rate has dropped to an average of one child per woman in 2023 (World Population Prospects, 2024). The National Bureau of Statistics of China arrived to the same conclusion, with the national level TFR at 1.3 children per woman in 2020 (National Bureau of Statistics of China, n.d.). Given this alarmingly low national average, how might fertility rates vary across different geographic places? This underscores the need for an updated understanding of subnational fertility patterns in China.

However, the study of recent subnational fertility in China was hampered by a data limitation: the 2020 population census only reported TFRs at the province level, which limited our ability to examine within- province fertility differences. Instead, only two county-level fertility indicators are reported: the average number of live births per woman aged 15 to 64, and the average number of surviving children per woman in the same age range. The former measures the total number of births a woman has ever given birth to, while the latter factor in the effect of mortality, and measures the average number of her surviving children at the time of the census. Although both indicators provide some insight into fertility levels, they are not ideal for tracking period fertility levels. This is because both indicators combine data from multiple cohorts—older cohorts may have completed their fertility, while younger cohorts have not yet done so.

In a series of publications, Hauser and Schertmann proposed several indirect estimations of TFR that rely on the age structure of a population (M. Hauer, Baker, and Brown 2013; Schmertmann and Hauer 2019). They consolidated these estimation techniques into a unified framework, which they presented in a 2020 article in *Demography* (Hauer & Schmertmann, 2020). The effectiveness of their methods was further validated using multiple human and non-human data.

Hauser and Schertmann's framework allows for estimating TFR without detailed age-specific fertility rates, making it particularly helpful in regions with limited data. However, the framework has not yet been applied by other demographers in the case of small-area fertility estimation. Its performance in China, a country with a large population but often criticized for its census data's large scale under enumeration (Cai 2013), also remains to be seen. In this study, we applied the framework of Hauser and

Schertmann (2020) to the study of subnational TFR in China. Our ultimate goal was to derive estimates of 2020 county-level fertility in China. We also use provincial-level data from earlier census years to validate the estimates.

A brief overview of the HS method

Hauser and Schertmann (2020) (thereafter HS) proposed a framework to estimate TFR without relying on age-specific fertility rates. Central to their framework is the idea that there exists an intrinsic relationship between a population's age structure and its fertility levels. Specifically for a given population age structure, the relationship between TFR and the child-woman ratio (the total number of children aged 0-4 by the total number of women aged 15-49) can be expressed as follows:

$$\mathrm{TFR}=\frac{1}{p}\times\frac{1}{s}\times\frac{C}{W}\ \ (1)$$

Equation (1) shows that converting the observed child-woman ratio to the total fertility rate requires two adjustments. The first adjustment *1/p*, accounts for the unequal distribution of fertility schedules across women's reproductive age. The second adjustment, *1/s*, accounts for child survival. Based on this premise, they proposed five approximations, with increasing data requirements, to derive estimates of TFR with varying levels of accuracy. For this analysis, we focus on the four non-Bayesian TFR estimates. These estimates offer straightforward formulas that can be easily mastered without any prior knowledge of Bayesian statistics. We summarize these four approximations as follows.

The first approximation assumes zero under-five mortality rates, and that women are uniformly distributed over the reproductive age. Given these two premises, the simplest approximation of TFR, which they named iTFR (implied TFR), can be expressed as follows:

$$iTFR=\frac{\beta-\alpha}{n}\cdot\frac{C}{w}=7\cdot\frac{C}{W}\ \ (2)$$

Where $\frac{C}{W}$ is the child-woman ratio. The multiplier 1/p=7 assumes fertility occurs uniformly across reproductive age groups.

The second approximation, xTFR (extended TFR), accounts for the uneven distribution of lifetime fertility over the reproductive age. That is, the multiplier *1/p* varies given the age structure of the women in reproductive ages. HS further derived a numeric estimation of the 1/p multiplier by examining the actual fertility schedules of 1,804 populations in Human Fertility Database. The xTFR is formally expressed as:

$$xTFR=(10.65-12.55\pi_{25-34})\cdot\frac{C}{W}\ \ (3)$$

HS further proposed two improved TFR approximations, iTFR^{+} and xTFR^{+} that adjust under-five child mortality (q5).

$$\mathrm{iTFR}^{+}=\frac{7}{1-0.75q_5}\cdot\frac{C}{W}(3)$$

$$\mathrm{xTFR}^{+} = \frac{10.65 - 12.55\pi_{25-34}}{1 - 0.75q_5} \cdot \frac{C}{W} (4)$$

The multiplier, $\frac{1}{1-0.75q_5}$ is the numeric form of child surviving multiplier 1/s in equation (1). It is derived by accounting for the logical and empirical relationships between life table variables in the Human Mortality Database.

These four non-Bayesian approximations have been shown to provide accurate estimations across a wide range of human and non-human populations (Hauer & Schmertmann, 2020). However, a caveat is that these indirect TFR estimations rely on accurate population age structures. In areas where young children are undercounted, these estimations may be less accurate.

The undercount of birth and young children in the Chinese population census has been a persistent issue. During the implementation of restrictive family planning policies in the 2000s and the early 2010s, parents had incentives to conceal births that exceeded the allowed limit. Consequently, it is generally believed that both the TFR and the total size of young children were likely underestimated. However, the 2020 population census is considered to be of much higher quality compared to the previous census. Additionally, with the relaxation of family planning policies, parents now have less incentive to hide excessive birth. Therefore, when evaluating the performances of TFR estimates at the provincial level, we expect the 2020 estimates to show better accuracy compared to the 2000 and 2010 censuses.

Data

We begin by evaluating the performance of these estimates using provincial-level population census data from China. This data includes information on both the population age structure and the total fertility rate (TFR), allowing us to validate our TFR estimates against the actual figures. Once we establish the validity of our estimates, we proceed to estimate the county-level fertility for 2020. We then apply the methods to the 2020 county-level population age structure. Below, we describe our data in detail:

Population Census

Although county-level fertility data are not reported, the Chinese Population Census Bureau publishes detailed provincial-level summary tables for the fifth (2000), sixth (2010), and seventh (2020) population censuses. These tables include each province's population age structure and total fertility rate. We rely on this data as our primary validation data. For each province, four sets of summary tables of different geographic scales are reported: the overall province, the city, the township, and the village levels. We therefore have 3(decennial census)×31(provinces) ×4 (geographic scales) = 372 data points in which we can compute iTFR and xTFR and compare these estimates with observed TFR.

Under-five child mortality estimates

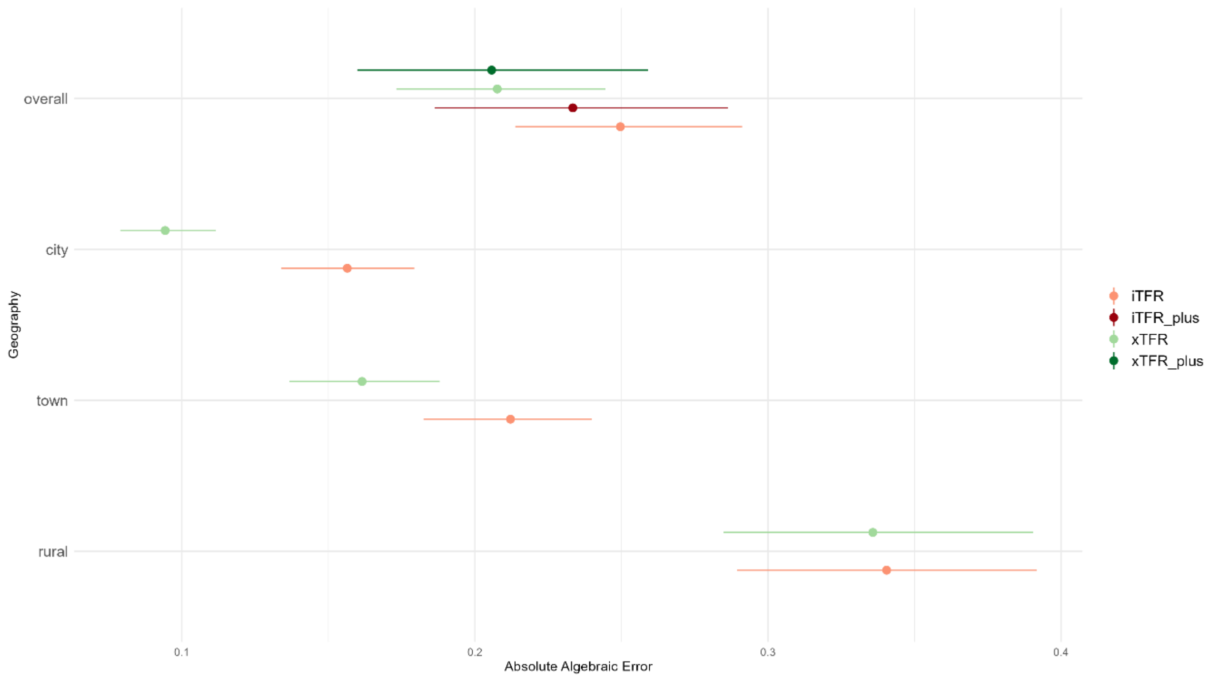
Two approximations, iTFR^{+} and xTFR^{+} require adjustment of under-five child mortality rates. The census-reported under-five child mortality rates in China have been criticized for under-reporting of infant and child mortality (Yang and Lu 2019). Therefore, we rely on alternative sources for these estimates. In addition to the census report, the Bureau of Health in China operates a maternal and child health surveillance system. This system establishes surveillance sites in every county, where incidences of child mortality are recorded and reported to the higher administrative levels within the Bureau of Health. While the raw child mortality data from this system is not publicly available, Wang et.al.,(2016) published estimations of county-level under-five mortality rates from 1996 to 2012 using data from this surveillance system. We rely on these estimates as our under-five child mortality data. Following the practices of Yang and Lu (2019), we compute province-level under-five child mortality rates from the estimate county-level mortality rates as follows: $U5MR_i = \frac{\sum_{j=1}^{k} P_{i,j} \times q_{ij}}{\sum_{j=1}^{k} P_{i,j}}$ where $P_{i,j}$ is the total number of children at county j in province i, and q_{ij} is the county-level estimates of under-five child mortality rates at county i in province j from Wang et.al.,(2016).

Preliminary Results

Validation results

Figure 1 presents the performances of the four TFR approximations of three census years (2000, 2010, 2020), breakdown by geographic scales. Since under-five child mortality estimates are only available at the provincial level, iTFR+ and xTFR+ were calculated solely for this scale. We computed the absolute algebraic error between these estimates and the reported provincial TFR. All four estimates fall within the acceptable error range. Notably, xTFR outperforms iTFR, suggesting adjusting for the unequal distribution of fertility schedule enhances the performances of the estimations. The additional adjustment of child survival also improves the performance of the estimates: both iTFR+ and xTFR+ outperform their non-adjusted counterparts (iTFR and xTFR). In addition, Figure 1 also reveals a geographic gradient of estimation errors, with the best performance in urban areas, followed by the township areas, and the worst performances in rural areas.

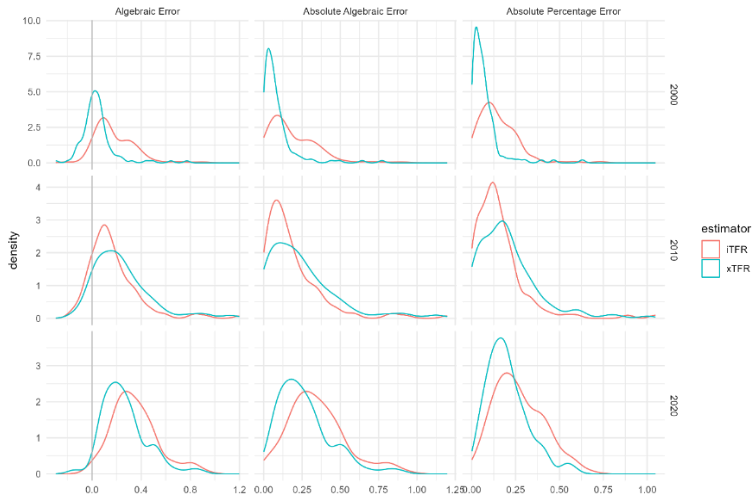
Figure 1. Absolute Algebraic Error of Four Estimates



Note: iTFR+ and xTFR+ are estimated only for the overall provincial scale for 2000 and 2010 census years.

Figure 2 further graphs the performances of iTFR and xTFR for all data points across three census years. We evaluate the performances of these two estimates against three criteria, the algebraic error, the absolute algebraic error, and the absolute percentage error. We found that for 2000 and 2020, xTFR are more concentrated and generally yield better performance than iTFR. However, for the 2010 census, the opposite is true, with iTFR showing better performance. Overall, we did not observe any salient trends in performance of these estimates across census years.

Figure 2. Performances of iTFR and xTFR by census years



2020 County-level TFR estimates

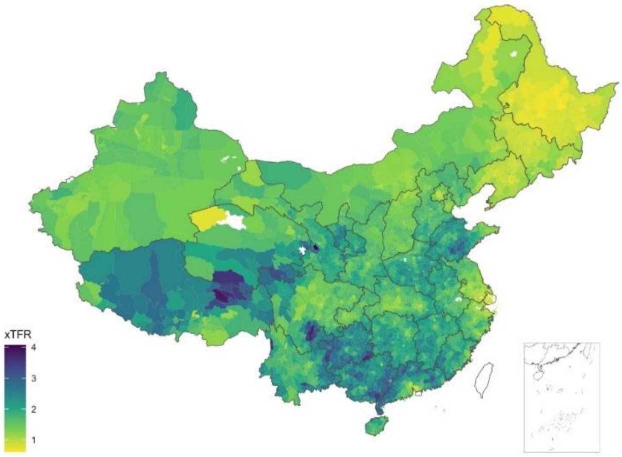
Because there are no estimates for 2020 county-level child mortality, we primarily use xTFR as our primary estimator of 2020 county-level TFR. For comparison purposes, we also calculated iTFR. Table 1 summarizes the county-level TFR estimates, with the last three columns showing the decomposition of the Theil index into within and between province differences. Notably, the county-level averages for both estimates are higher than the national report, with 1.75 at iTFR and 1.68 at xTFR. The theil index decomposition results show that while between-province differences are more pronounced, the within-province differences are also non-ignorable.

Table 1. Descriptive Statistics of county-level TFR estimates

	Summary Statistics		Theil index		
	Mean (SD)	Median [Min, Max]	Between	Within	Total
iTFR	1.75 (0.554)	1.72 [0.415, 4.36]	0.0291	0.0201	0.0492
xTFR	1.68 (0.528)	1.64 [0.496, 4.07]	0.0286	0.0192	0.0478

We further plotted the distributions of county-level xTFR (Fig 3). The results indicate an unequal distribution of fertility levels in China. Contrary to the typical east coast-west inland gradient, there appears to be a more pronounced south-north contrast in fertility levels. Past studies have suggested that cultural differences might explain some behavioral differences between southern and northern China. The spatial distribution of fertility rates seems to align with this explanation.

Figure 3. County-level 2020 xTFR



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