United Nations Expert Group Meeting on "Methodology and lessons learned to evaluate the completeness and quality of vital statistics data from civil registration"
New York, 3-4 November 2016

Evaluation of the Completeness of Birth Registration in China Using Analytical Methods and Multiple Sources of Data

(Preliminary draft)

Wei Chen
Center for Population and Development Studies
Renmin University of China
weichen@ruc.edu.cn

Abstract

Births are registered and birth data are collected in China by different government departments, and the completeness and quality of birth data are heavily affected by the one-child policy irrespective of the involving departments. In this paper, data from population census, primary school enrollment and household registration system are used to assess the completeness of birth registration in China by employing three types of methods—linear regression, Brass P/F ratio method, and Preston integrated approach. The three types of estimation derived from multiple data are highly consistent. Preston integrated approach is attractive and promising in application to the case of China where census age data are rather accurate over age 10 while there is varying degree of under-reporting at the very young ages.

One of the unfortunate and unexpected consequences of China's one-child policy is the deterioration of the quality of China's demographic statistics. Roughly since the early 1990s when Chinese government enforced the 'one-vote veto' system (*yi piao fou jue zhi*) for rigorously implementing the family planning policy, China's fertility suddenly dropped to below-replacement level on the one hand, and varying degree of birth under-reporting occurred in all sorts of demographic data collection on the other hand. Despite a lot of efforts done in evaluating completeness of birth report and fertility level, there has been no consensus on this issue in China. However, there are broadly two types of opinions regarding birth under-reporting and fertility. Many demographers in China believe that China has dropped into the low fertility trap since the late 1990s, while some others hold that China's fertility has not been that low. China's 2000 and 2010 population censuses obtained a total fertility rate (TFR) of 1.23 and 1.18 respectively, and all the annual population surveys in between also reported a TFR of 1.4 or lower. The low fertility trap school has based their argument on these census and survey data, believing that birth data were accurate; while those who believe China's fertility is not that low argues that these data are seriously under-reported. The purpose of this paper is to bring together multiple sources of data and various analytical methods to assess the completeness of birth report in China in the past decade.

Sources of Data Available for Estimating Birth Numbers

There are three government departments in China collecting birth data. Ministry of Public Security established household registration system (Hukou) in 1958 in which all household members are registered by date and place of birth, gender, ethnicity, marital status, educational level, and occupation. New born babies are required to report by their parents to the local police station within one month after birth, and are registered in the household's Hukou booklet. The National Population and Family Planning Commission (before 2012)/ The National Health and Family Planning Commission collects birth data through birth statistical form distributed to local levels. Data on married reproductive women regarding their use of all kinds of contraception and certificate of having an only child are also collected. The National Bureau of Statistics estimates and publishes population data including birth, death, migration, urbanization and age-sex structure of population. These data are derived from population census, mini-census (1% sample survey), and annual population survey (one per-thousand sample survey).

Births reported from Hukou system is the least complete among these three government departments. When reporting birth, parents need to present the baby's medical birth certificate (from public health department), birth permission (from family planning department), and parents' Hukou booklets (from public security department) to the Hukou registration department. Unauthorized births, resulting from the birth control policy, are thus unable to be registered. The fact that there is of no

much use of Hukou certificate until reaching around 6-7 years old for the purpose of going to primary school also leads to unwillingness of the parents to report birth timely. Births registered by the family planning department are slightly more complete than that registered by the Hukou registration department. Both individuals and the very low level of local government often under report births in order to avoid penalty resulting from being unable to meet the birth quota from higher level government. Birth numbers published by statistical bureau are typically much larger than those registered by the other two departments. The statistical bureau's estimates are based on census or sample surveys, making upward adjustment. However, the procedure involved in making their adjustment has never been made known. Some scholar argues that births published by statistical bureau are typically over-adjusted (Zhao and Chen 2011).

Another source of birth data that is not much noted is those collected through hospitalized delivery by Ministry of Health (before 2012)/ National Health and Family Planning Commission. Since hospitalized delivery rate has reached 98% or over only after 2010, no studies in China conducted in estimating fertility use the birth data from hospitalized delivery. Used to be covered are the hospitalized deliveries by Hukou registered local population, hospitalized delivery rate was only 50-70% in the 1990s, which increased to over 80% in 2004, over 90% in 2007 and nearly 99% in 2011. By improving hospitalized delivery rate to over 99% and covering births delivered by migrants, the birth numbers over 2011-2015 are largely the same as those published by the statistical bureau.

Some Chinese demographers have tried to estimate birth numbers from education statistics—number of students enrolled in primary schools (Zhai and Chen 2007; Chen 2009). Since 2000, primary school enrolment rate has exceeded 99%, virtually all children of school age are enrolled. When data of the enrolled children by age are available, it is possible to estimate birth numbers using reverse survival analysis. Since the enrollment rate is not 100%, birth numbers estimated from education statistics are not complete. But even in this case, the estimated birth numbers are larger than birth numbers from Ministry of Public Security, National Population and Family Planning Commission and National Bureau of Statistics. This approach has been challenged by some scholars (Cai 2009; Guo 2010) who believe that in many places the school enrollment was exaggerated or over-reported in order to obtain larger financial allocation from the central government, thus this approach tends to generate larger birth numbers than the actual numbers.

Another approach adopted by some Chinese demographers is to use Hukou registration data by age from which birth numbers are estimated by reverse survival method (Yang and Zhao 2013; Zhai et al. 2015). In the past decade, Hukou registration data have been substantially improved by correcting those double-counted, undeleted, or mis-registered. The total population from Hukou registration tends to be higher than that from the National Bureau of Statistics, but the gap has become

increasingly smaller. Since Hukou registration or identity card is needed for everyone to apply for citizenship or being covered in all sorts of welfare programs and socio-economic participation, a near complete coverage of the whole Chinese population has been reached, particularly for ages over 5. Thus birth numbers could be estimated using reverse survival method for the recent past. Hukou registration data (over age 5) are believed to be of the best quality among all sources of data available for estimating birth numbers in China.

Estimating Annual Number of Births over 2000-2009

Since no adequate data are available, particularly the education and Hukou registration data, for estimating annual births in the decade preceding the 2010 census (for this purpose we need education and Hukou registration data in the next 10 years), we will establish statistical relation by regression method between the 2000 census data of ages 0-10 and the corresponding education and Hukou registration data, then we assume those relations also hold between the 2010 census data of ages 0-10 and the corresponding education and Hukou registration data. Thus we plug into these regression equations the 2010 census data of ages 0-10, and arrive a more or less adequate estimate of the 2010 census age data 0-10, which then are reverse survived to 2000-2010.

Table 1 presents estimates of population at ages 0-10 in 2000 derived from various sources. Column (2) are just the 2000 census counts, while columns (3)-(5) are derived from data from 2010 census (population at ages 10-20), education statistics (primary school students at age 9 or 10) and Hukou registration (population at ages 10-20). Data from 2010 census, education statistics and Hukou registration have reverse survived to 2000 census time. This means that same cohort of population are recorded in different sorts of data collections. In a country like China which is largely closed to international migration, same cohort of population need to be roughly identical if the coverage is complete regardless the sorts of data collections. However, cohort members at the very young ages differ substantially across these data collections. For example, population at age 0 from education registration exceeds that from 2000 census by 2.8 million.

Table 1 Population at ages 0-10 in 2000: estimated from various sources of data (million)

Age	2000 census data	2010 census data	Education data	Hukou data
(1)	(2)	(3)	(4)	(5)
0	13.79	14.66	16.58	15.12
1	11.50	14.02	16.27	14.44
2	14.01	15.48	16.90	15.79
3	14.45	15.29	17.38	15.73
4	15.22	15.95	17.91	16.59

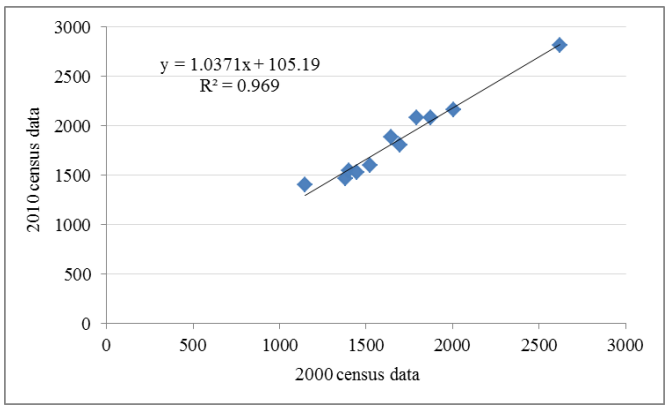
5	16.93	18.09	18.48	17.77
6	16.47	18.86	18.81	17.49
7	17.91	20.85	19.63	18.83
8	18.75	20.83	20.46	19.49
9	20.08	21.63	21.92	20.98
10	26.21	28.14	24.53	26.78

Source: 2000 and 2010 census data from census tabulations; Education and Hukou data from Ministry of Education and Ministry of Public Security (not published)

Some studies (Zhai and Chen 2007; Chen 2009; Yang and Meng 2013; Zhai et al. 2015) have evaluated quality of data from education and Hukou registration. They suggest that education and Hukou data are more complete than census data even the primary school enrollment and Hukou registration are not 100% complete. Using the three sources of data to assess the under-reporting rate of the 2000 census data, the rate derived from education data is the highest (15.8%) and that derived from Hukou data lowest (7.4%), while the rate based on the 2010 census data stands in between (10.0%). We assume that 2010 census has a similar rate of under-reporting with the 2000 census, then we establish linear statistical relations between the 2000 census data with respectively the 2010 census data, education data, and Hukou registration data (Figures 1-3). Using these regression equations, we arrive adjusted 2010 census data ages 0-10. The adjusted 2010 census ages 0-10 data are reverse survived to 2000-2010 to obtain the estimates of the annual number of births over this period.

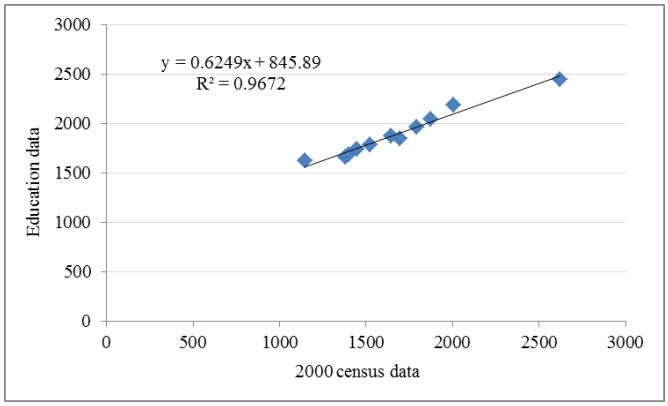
Data from Table 1 are fitted by linear regressions which are plotted in Figures 1-3.

Figure 1 The linear regression between 2000 and 2010 census data



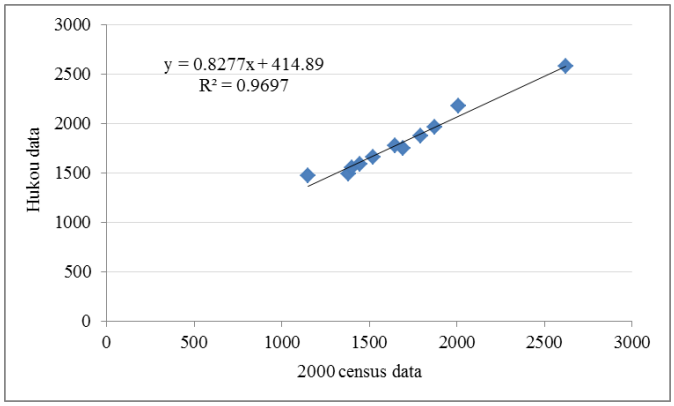
Source: Table 1.

Figure 2 The linear regression between 2000 and education data



Source: Table 1.

Figure 3 The linear regression between 2000 and Hukou registration data



Source: Table 1.

Results of linear regressions presented in Figures 1-3 show very high R-square (over 0.96). Estimates of annual number of births over 2000-2010 based on these regression equations and life table survival ratios are presented in Table 2. Birth numbers derived from the unadjusted 2010 census data at ages 0-10 and those published by the National Bureau of Statistics are also included in Table 2. In order to observe the trends and differences, data in Table 2 are again plotted in Figure 4.

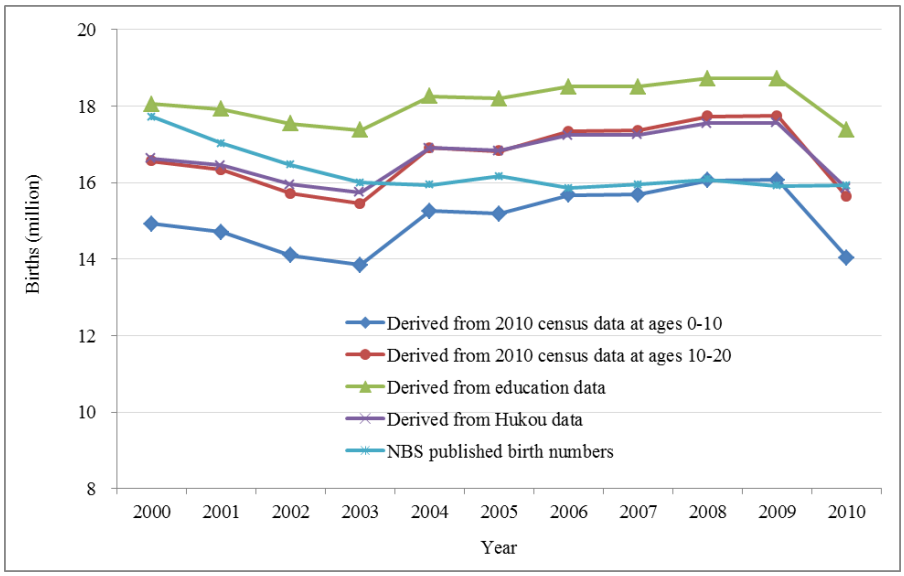
Table 2 Estimates of annual number of births, 2000-2010: derived from various sources of data (million)

Source of data	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Derived from 2010 census data at ages 0-10	14.92	14.70	14.10	13.85	15.26	15.18	15.67	15.69	16.05	16.07	14.03
Derived from 2010 census data at ages 10-20	16.56	16.33	15.70	15.44	16.91	16.82	17.33	17.35	17.73	17.74	15.63
Derived from education data	18.05	17.92	17.53	17.37	18.25	18.20	18.50	18.51	18.72	18.72	17.38
Derived from Hukou data	16.63	16.45	15.95	15.74	16.91	16.84	17.24	17.25	17.55	17.56	15.84
NBS published birth numbers	17.71	17.02	16.47	15.99	15.93	16.17	15.85	15.95	16.08	15.91	15.92

Source: 2010 census tabulation and author's own calculation.

Birth numbers derived from the unadjusted 2010 census data are the lowest, while birth numbers derived from education data are the highest. Birth numbers derived from the adjusted 2010 census data and Hukou registration data are very similar (Figure 4). It can be clearly seen from Figure 4 that the trend in annual births published by the National Bureau of Statistics is different from all other estimates.

Figure 4 Estimates of annual number of births, 2000-2010: derived from various sources of data (million)



Source: Table 2.

Reestimating the 2010 births

Figure 4 shows that there is a sudden and large drop in the birth number in 2010. This is a result of the age structure of the 2010 census population at ages 0-10. Because population at age 0 has 1.87 million fewer than the population at age 1, then using regression equation to estimate annual births would consequently result in such a drop. We thus need to reestimate the 2010 births.

Brass (1968; 1983) developed an indirect estimation method, known as P/F ratio method, to correct the mis- or under-reporting occurred in period fertility using information from cohort fertility (number of children ever born). The idea is simple. The fertility level implied by the number of children ever born reported by women at younger reproductive ages is used to adjust the reported period fertility which tends to be lower biased either because of the reference time error or the case like China where intentional hiding of births exists. The important assumption underlying the method is the constant trends and patterns of fertility over the last 15-20 years. China's fertility over 1995-2010 was more or less stable under the below-replacement level. Table 3 presents the estimation results of the P/F ratio method.

Table 3 P/F ratios calculated from cohort and period fertility from China's 2010

census

i	**Age group**	$P(i)$	$f(i)$	$\phi(i)$	$F(i)$	P/F **ratio**
1	15-19	0.0125	0.0059	0.0296	-0.0002	
2	20-24	0.2596	0.0695	0.3770	0.1822	1.4252
3	25-29	0.8440	0.0841	0.7973	0.5975	1.4126
4	30-34	1.2928	0.0458	1.0265	0.9249	1.3978
5	35-39	1.5235	0.0187	1.1201	1.0777	1.4136
6	40-44	1.6871	0.0075	1.1576	1.1318	1.4907
7	45-49	1.8366	0.0047	1.1810	1.1739	1.5645

Note: $P(i)$ are average parity of women at ages 15-19, 20-24,…, 45-49; $f(i)$ are age-specific fertility; $\phi(i)$ are cumulative fertility; $F(i)$ are estimated from the equation $F(i) = \phi(i-1) + a(i)f(i) + b(i)f(i+1) + c(i)\phi(7)$, arriving fertility equivalents of $P(i)$. The coefficients a, b and c are derived from Coale-Trussell fertility models.

The P/F ratios across age groups 20-24 to 35-39 are rather constant at 1.4, implying relatively stable fertility in China over the past 15 years. The average of the four ratios stands at 1.41, suggesting an under-reporting rate of over 40% in the period fertility in China's 2010 census. The cohort and period fertility in China's 2010 census are collected through the short form (10% of the whole population). Number of births estimated from the short form is 11.9 million. If inflating it by 41%, the 2010 birth number should be 16.78 million. This would yield a total fertility rate of 1.66.

Estimating the average annual number of births over 2000-2010

While fertility and birth data are subject to varying degree of under-reporting, age distribution data from population censuses, especially over age 10, are of much high quality. The purpose of this section is to reestimate China's births and fertility over the inter-censual periods between 1982 and 2010 using the census age distributions with an integrated estimation approach developed by Preston (1983).

The integrated estimation technique is derived from a generalization of stable population theory incorporating Brass's one-parameter logit mortality system that can be applied to any closed population, as shown in Equation (1):

$$\frac{e^{-\int_0^a r(x)dx}}{c(a)} = \frac{1}{b} + \frac{k}{b}\frac{q_s(a)}{p_s(a)} \qquad (1)$$

where *c(a)* is age distribution, *r(x)* is age-specific population growth rate, and $q_s(a)$ and $p_s(a)$ are survivorship functions from a standard life table. b is an estimate of the crude birth rate, and k adjusts the standard life table mortality curve to the level of mortality in the data of the population under study. In choosing the standard life table, we use the life tables of the 1982 census, as China's 1982 census is of the very

best quality, and is believed to better represent Chinese pattern of mortality than the model life tables.

Estimates of births and fertility for China's inter-censual periods 1982-1990, 1990-2000 and 2000-2010 are produced using the above integrated approach. The required data are census age distributions from two censuses for each inter-censual period. Application of the integrated procedure to China's fertility estimation is illustrated in Tables 4 and 5 for estimating fertility in the 2000-2010 inter-censual period. A line is fitted to the data points from the last two columns (points from ages 10-14 to 75-79, not including the points of the two extremes of the age groups which are believed to be less accurate), yielding the female equation

$Y = 76.396 + 44.149X$, implying

$b = \frac{1}{76.396} = 0.013090$ and $k = \frac{44.149}{76.396} = 0.57790$,

and the male equation

$Y = 75.217 + 45.326X$, with

$b = \frac{1}{75.217} = 0.013295$ and $k = \frac{45.326}{75.217} = 0.60261$.

Table 4 Chinese Female, 2000-2010

Age	$N(a)_{2000}$	$N(a)_{2010}$	$N(a)$	$r(a)$	$\int_0^a r(x)dx$	$c(a)$	$\frac{e^{-\int_0^a r(x)dx}}{c(a)}$	$\frac{q_s(a)}{p_s(a)}$
0	31329680	34470044	32874867	0.010	0.000	---	---	---
5	41849379	32416884	36932596	-0.026	0.010	0.011	84.868	0.0540784
10	60051894	34641185	46187366	-0.055	-0.016	0.013	80.984	0.0597694
15	50152995	47984284	49060651	-0.004	-0.071	0.015	93.050	0.0632462
20	46635408	63403945	54591123	0.031	-0.075	0.017	87.417	0.0682241
25	57371507	50176814	53693847	-0.013	-0.045	0.017	71.764	0.0753862
30	61953842	47616381	54470990	-0.026	-0.058	0.017	76.822	0.0833816
35	53005904	57634855	55288087	0.008	-0.084	0.018	86.354	0.0925701
40	38999758	61145286	49245407	0.045	-0.076	0.017	86.954	0.1044763
45	41581442	51818135	46512194	0.022	-0.031	0.015	75.809	0.1206473
50	30500075	38389937	34293873	0.023	-0.009	0.013	80.475	0.1445921
55	22308869	40229536	30393735	0.059	0.014	0.010	89.603	0.1831633
60	20029370	28832856	24164432	0.036	0.073	0.009	79.114	0.2453695
65	17231112	20364811	18754347	0.017	0.109	0.007	83.821	0.3576617
70	13137995	16568944	14787191	0.023	0.126	0.005	98.658	0.5557204
75	8752519	12573274	10547815	0.036	0.149	0.004	116.309	0.9623856
80	4785290	7455696	6022136	0.044	0.185	0.003	148.373	1.8168888
85+	2659218	4758898	3607797	0.058	0.230	0.002	204.533	

Note: $N(a)_{2000}$ and $N(a)_{2010}$ are population by age from 2000 and 2010 censuses; $N(a)$ in the 4th column is the average of $N(a)_{2000}$ and $N(a)_{2010}$.

Source: 2000 and 2010 census tabulations and author's own calculation.

Table 5 Chinese Male, 2000-2010

Age	$N(a)_{2000}$	$N(a)_{2010}$	$N(a)$	$r(a)$	$\int_0^a r(x)dx$	$c(a)$	$\frac{e^{-\int_0^a r(x)dx}}{c(a)}$	$\frac{q_s(a)}{p_s(a)}$
0	37648694	41062566	39330940	0.009	0.000	---	---	---
5	48303208	38464665	43197364	-0.023	0.009	0.013	76.188	0.0542455
10	65344739	40267277	51798193	-0.048	-0.014	0.014	74.172	0.0611322
15	52878170	51904830	52389993	-0.002	-0.063	0.016	86.150	0.0653082
20	47937766	64008573	55586517	0.029	-0.064	0.016	83.903	0.0710921
25	60230758	50837038	55401230	-0.017	-0.035	0.017	70.640	0.0787078
30	65360456	49521822	57075335	-0.028	-0.052	0.017	75.873	0.0866184
35	56141391	60391104	58240409	0.007	-0.080	0.018	85.019	0.0962545
40	42243187	63608678	52199206	0.041	-0.073	0.017	85.593	0.1097041
45	43939603	53776418	48692521	0.020	-0.032	0.015	76.353	0.1293549
50	32804125	40363234	36453148	0.021	-0.012	0.013	81.781	0.1600736
55	24061506	41082938	31816974	0.053	0.009	0.010	91.951	0.2122488
60	21674478	29834426	25537543	0.032	0.063	0.009	83.762	0.3032271
65	17549348	20748471	19104288	0.017	0.094	0.007	91.725	0.4747560
70	12436154	16403453	14328380	0.028	0.111	0.005	112.641	0.7918835
75	7175811	11278859	9073238	0.045	0.139	0.004	140.120	1.4776122
80	3203868	5917502	4422801	0.061	0.184	0.002	193.794	3.0639912
85+	1342707	2857250	2005561	0.076	0.245	0.001	299.375	

Source: 2000 and 2010 census tabulations and author's own calculation.

Results from implementing the integrated procedure in China's three inter-censual periods are presented in Table 6. The results suggest that fertility in China has decreased dramatically. A very large reduction of fertility occurred in the 1990s, and the downward trend continued into the 2000s although to a much less extent. Fertility patterns of this kind are already well established, but the levels are subject to a wide range of uncertainty. Results from this analysis show that the inter-censual TFR between 1990-2000 was far below replacement level, while the inter-censual TFR between 2000-2010 was just slightly over 1.5 which is markedly higher than the results from the 2000 and 2010 censuses.

Comparing our births and fertility estimates with those published by the NBS, our estimates of birth rate and number of births are only slightly higher for 1982-1990 and 2000-2010 inter-censual periods, but are markedly lower for the 1990-2000 inter-censual period than the NBS estimates. Some studies argue that the NBS over-estimated Chinese fertility in the 1990s, and our research presented further evidence to support this.

Table 6 Estimated Fertility with Comparison to NBS Published Fertility

Fertility measure	1982-1990	1990-2000	2000-2010
Estimated crude birth rate (per thousand population)	22.53	15.08	13.20
Published crude birth rate (per thousand population)	21.58	17.25	12.50
Estimated births (million)	23.91	17.76	16.86
Published births (million)	23.09	20.67	16.27
Estimated total fertility rate (Births per woman)	2.651	1.681	1.564

Source: Author's own estimation.

Since 1990, no officially published estimates of Chinese TFR are available as increasing numbers of under-reporting occurred in births and population at very young ages. However, the NBS still published the annual number of births and the crude birth rate based on the upward adjustment of the survey results. Our estimation results suggest that the NBS estimates for the 2000-2010 period are reasonable although slightly lower than ours, while the NBS estimates for the 1990-2000 period are apparently too high.

The estimated average number of births over 2000-2010, which stands at 16.86 million, are rather consistent with the results from the sections 1-2. Table 7 presents the averages of the estimated annual number of births over 2000-2009 from Table 2. The estimated number of births 16.86 million is very close to the number from row (2) and (4), and is also close the number from row (6) which is the average of the averages across rows (1) to (5). It is also similar to the number 16.78 million derived from the Brass P/F ratio method.

Table 7 Estimated average number of births over 2000-2009 from the regression method (million)

Source of data	Row	Average over 2000-2009
Derived from 2010 census data at ages 0-10	(1)	15.15
Derived from 2010 census data at ages 10-20	(2)	16.79
Derived from education data	(3)	18.18
Derived from Hukou data	(4)	16.81
NBS published birth numbers	(5)	16.31
Average	(6)	16.65

Source: Table 2.

Conclusion and Discussion

Using multiple sources of data and various estimation methods, this paper provides an evaluation of completeness of birth registration in China through estimating the annual or average number of births over 2000-2010. While birth data are collected by three government departments in China, the completeness of each tends to differ considerably. Li et al. (2010) suggested that birth registered by MPS and NPFPC were 60-80% complete in the 1990s. The NPFPC has stopped publishing its own birth data

since 2000, instead the birth data from the NBS were used in its annual population and family planning communique.

We use education data (primary school enrollment at age 9 or 10), Hukou registration data (ages 10-20) and 2010 census data (ages 10-20) to have estimated the under-reporting rate of the 2000 census data (ages 0-10), and reconstructed the 2010 census population at ages 0-10 under the assumption that the 2010 census has a similar under-reporting rate as the 2000 census using simple linear regression. With this, estimates of annual number of births over 2000-2009 are obtained. In estimating the 2010 births, we adopted the P/F ratio method. These estimates are again verified by using the integrated estimation approach to estimating the average number of births over 2000-2010. Surprisingly the above three types of estimation derived from different data and different methods are highly consistent. The average number of births over 2000-2010 stands at around 16.6-16.8 million. The average of the NBS-published annual estimates is only slightly lower than our estimate.

Despite that the above three types of estimation methods generated consistent and similar results, the integrated approach developed by Preston (1983) is more promising and of much higher value than other two methods in the case of China. The integrated approach is developed by generalizing the stable population theory. Population stability is a no more needed assumption, so is the assumption of population closed to migration. More noteworthy is that only population age distributions at two censuses are needed to estimate fertility and mortality. Population age distribution data are more easily available and of better quality than fertility or mortality data in most countries of the world. In addition, Preston (1983) performed analysis of sensitivity to various forms of error, and it appears to provide a fairly robust estimate of fertility. Virtually the only assumption is that population age distributions at two censuses are accurate, but what is very attractive is that the relative coverage completeness of the two censuses rather than the absolute coverage completeness matters. This means that even if the two censuses are not coverage complete, but if the extent and pattern of mis-reporting or under-reporting by age remain similar between the two censuses, this integrated approach will work perfectly. This advantage makes it promising to apply to the situation in China where census data are seriously under counted at the very early ages, and also to sub-regions subject to varying degree of under-reporting and migration.

Birth registration in China has been apparently affected by the one-child policy. Millions of births or children, more female than male, are deliberately under-reported in population censuses. Fertility policy is more important than estimation method for achieving accurate birth or population data in China. At the beginning of this year, China adjusted the one-child policy and started to implement a two-child policy. Since the vast majority of the Chinese population want to have two children, many of the second births, which would be illegal under the one-child policy, become legal under the two-child policy, and no more hiding is needed. It is hoped that the two-child

policy would do much help improving quality of birth or population data in China.

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