Assisted Reproductive Technology Use in the United States, a Demographic Assessment

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Abstract:

The percentage of births attributed to assisted reproductive technologies (ART) remains small, but has been steadily growing in the United States. Despite examples of differential access, use, and outcomes across racial/ethnic groups, knowledge about the social and demographic differentiation in ART is still limited. Prior estimates are based on sample data or are crude in their measurement. By contrast, the present project uses population data to estimate how ART has contributed to U.S. total fertility between 2010 and 2017 across age, race/ethnic, educational and marital status groups. Further, we use multivariate analyses to estimate the risk of an ART birth. Our results show that ART births are concentrated and more likely among women in their thirties, White and Asian women, married women, and women with more education. In addition to documenting trends with population data, our findings imply that current estimates obscure differences and may downplay unmet demand for ART services.

Extended Abstract

Background

According to the most recent data from the Centers for Disease Control and Prevention's (CDC) National ART Surveillance System, 182,154 assisted reproductive technology (ART) cycles were performed in 2015, up more than 30% from 2006, and ART births comprised about 1.7% of U.S. births in 2015 (Sunderam et al. 2018). Although scholars have noted that ART usage and outcomes vary considerably among racial/ethnic groups (e.g., Armstrong and Plowden 2012; Chin et al. 2017; Fujimoto et al. 2010; Greil et al. 2011; Humphries et al. 2016; Janitz, Peck, and Craig 2016; Kessler et al. 2013; Quinn and Fujimoto 2016), our knowledge about the social and demographic differentiation in ART use is limited. For example, the commonly used ART rate uses all women between ages 15 and 44 years as the denominator, thus, providing only crude information about the population at risk and information about who uses these services. A more detailed assessment of ART usage that connects patient groups with corresponding populations is critical for both assessing the hidden demand and for providing better access to underserved populations.

This paper is our first effort to quantify the percentage of births attributable to ART across age, race/ethnic, educational, and marital status groups using population data. Pairing birth record data from the United States National Vital Statistics System (NVSS) with demographic information gathered from the American Community Survey (ACS), we estimate the age-specific fertility rates for ART births at the population level, compare the impact of ART on total fertility rates across groups, and analyze these trends with multivariate analyses using population, rather than sample, data.

Research Questions: How has ART contributed to U.S. total fertility between 2010 and 2017? How have these trends varied by age, race/ethnicity, educational attainment, and marital status? How does the risk of ART births vary by group net of other factors?

Data: The numbers of births (total number and number due to ART) come from the National Vital Statistics System's (NVSS) birth certificate data, which is publicly available. Population counts by age, race/ethnicity, educational attainment, and marital status are from the publicly available American Community Survey (ACS).

Methods*:* Demographic analysis and multivariate negative binomial regression

Key Findings

Age-Specific Fertility Rates

Figure 1 shows the age-specific fertility rate by single year of age for ART and all births for the entire study period (2010-2017). Note that the two lines are shown in difference scales. The age patterns of fertility for all births and ART births are substantively different from one another. In the overall age-specific fertility rate curve, we observe a peak of births between 25 and 30 years of age and lower age-specific fertility rates past age 35 (e.g., skewed to the right). By contrast, for ART births, the age-specific fertility rate peaks in the mid-to-late thirties with a narrower spread and a skew to the left. However, ART births are not uncommon before age 35.

Table 1 includes the percentage of the age-specific fertility rates due to ART overall, by age, and across groups for each year. We observe an increasing proportion of births are attributable to ART over time and with age. Across all years, the percentage of births to women under 29 due to ART is below 1%. By contrast, births among women 30 and over have increased across the study period from 1.54% in 2010 to 2.19% in 2017. The increase is observed across board: from 0.95 in 2010 to 1.37% in 2017 for women 30-34, from 1.92% in 2010 to 2.82% in 2017 for women 35-39, from 4.02% in 2010 to 5.83% in 2017 for women 40-44, and from 17.29% in 2010 to 23.20% in 2017 for women 45-49.

Truncated Total Fertility Rates

Stratified analyses of age specific fertility reveal variation in the contribution of ART to overall fertility by race, education, and marital status. We find the percentage of the TFR for women over 30 due to ART has increased slightly over time from 1.56% in 2010 to 2.21% in 2017 (Figure 2, Panel A)[1]. Across all years, the percentage of the TFR of women over 30 due to ART is higher among married women compared with unmarried women (Figure 2, Panel B). As expected from prior research, the percentage of the TFR for White women over 30 attributable to ART was higher than observed for Black or Hispanic women, meanwhile the proportion of the TFR due to ART was similar among White and Asian women (Figure 2, Panel C). The percentage of the TFR to women over 30 due to ART increases with educational attainment across all years under study with a clear gradient (Figure 2, Panel D).

While the increasing number of ART-births trend is shared across all categories, social differentiation is also seen in the speed of change. The increases in the percent of the TFR due to ART is considerably steeper for married women relative to unmarried women. The relative increases across racial/ethnic groups are similarly uneven. Asian women appear to have the steepest increases, while the upward trends for Black women, Hispanic women, and women of other races have been shallow and relatively stable over time. Further, there are steeper increases among women with more than a four-year degree, a four-year degree and some college, while the changes observed for women with less than a high-school degree or a high-school degree/GED have remained relatively flat.

Multivariate Analyses of the Likelihood of ART Birth

Employing stepwise entry, the multivariate analyses reveal age, period, race, educational, and marital effects in the incidence rates of ART births (Table 2)[2]. Model 5 shows the main effects of race, education, age, marital status and period (year) on the incidence rates of ART births[3]. The findings are largely consistent with the descriptive analyses in Table 1 and Figure 2.

First, we find a significant effect of period (Model 5). Net of the other covariates, we show that in 2017 the incidence rate of ART births were 1.61 times those of 2010. Similarly, the incidence rates for 2016, 2015, 2014, and 2013 are significantly higher than the 2010 rates by a factor of 1.51, 1.27, 1.16, and 1.16, respectively. There were no significant differences between 2010 and 2011 nor 2012.

Second, net of the covariates, we show the incidence rate of ART births to women aged 30-34 and women 35-39 do not differ in the bivariate model (Model 1) nor when race (Model 2) or education (Model 3) are added. However, when marital status is incorporated into the model (Model 4), the incidence rate of ART births for women 35-39 is1.12 times that of women age 30-34. This finding holds when period is added in the full model (Model 5). By contrast, across all other models all other age groups have significantly lower incidence rates of an ART birth compared with the reference age group.

Third, Model 5 shows net of the covariates, Black women's ART incidence rates are .57 and Hispanic women's ART incidence rates are .67 times the incidence rates for White women. In model 2, we show no difference in the incidence rates of ART births between White women and Asian women nor women of other races. However, with the addition of educational attainment into the model (Model 3), we observe Asian women have higher incidence rates of ART births than White women, and this relationship persists net of additional covariates in model 5 where Asian women's incidence rates are 1.21 times that

[1] The patterns observed in the over 30 years of age TFR are similar as those observed across all ages.

[2]The multivariate models presented include women of all ages as parallel analyses only on women over 30 show no considerable differences.

[3] Year is entered as a categorical variable for Models 5 and 6. A linear term for year was also significantly associated with the incidence rate of ART births.

of White women. By contrast, we observe no differences in the incidence rate of ART births between White women and women of other races net of all covariates.

Fourth, with regard to the role of educational attainment, net of the covariates, we observe that women with more than a four-year degree have an incidence rate 2.08 times that of women with a four year degree. Women with less than a 4-year degree all have significantly lower incidence rates than women with a four-year degree. Finally, Consistent with the descriptive analyses, the effects of marital status are strong. Model 5 shows that net of age, race, education, and period (year), women who are married have an incident rate that is 5.72 times that of unmarried women.

Sensitivity Analyses

The sensitivity analyses revealed several important issues. First, in comparing the age-specific counts from the publicly available reports of NASS data to the counts from the NVSS data, we found discrepancies consistent with prior work (e.g., Moaddab et al. 2016; Thoma et al. 2014). Overall, NVSS captures between 41.2% (in 2010) and 50.0% (in 2016) of expected ART births (Supplemental Table 1)[4]. However, the age patterns observed in Figure 1 are mirrored in the NASS data (Supplemental Figure 2).

Second, there was general agreement between the differences across groups reported in Figure 2 and the parallel analyses done on births more likely to be reported as ART births (Appendixes 2-4). Notably, however, the proportion of the TFR due to ART among multiple births declines over time, rather than increases. This finding, however, is consistent with efforts since the 1990s to reduce occurrences of multiple births via IVF (Kulkarni et al. 2013; Martin, Osterman, and Thoma 2016; Penzias et al. 2017; Reynolds et al. 2003; The Practice Committee of the Society for Assisted Reproductive Technology and Practice Committee of the American Society for Reproductive Medicine 2006). In addition, although all three sub-population sensitivity analyses follow the same general stratification by marital status, education, and race, they have more volatility and less clear time-trends as observed in the full analyses. However, this is likely due to the small cell sizes rather than substantive differences in trends[5].

Implications

These analyses confirm that there are non-trivial differences in the concentrations and rates of ART births by age, race/ethnic, marital, and educational groups. Thus, the usual reporting of the percentage of births attributable to ART in the whole population obscures the large differences across groups. Uneven ART birth patterns further suggest that estimates and assumptions about the demand for ART services may be underestimated. For example, if barriers to access and use were diminished among racial and ethnic minority women or women with lower socioeconomic status, we might observe greater ART use in the population. Despite the overall low birth rates due to ART, ART use may be the difference in having children or being involuntarily childless for some women. Thus, quantifying unmet need and differential ART birth patterns presents an important first step in addressing access to these services.

Limitations

Prior research has found that ART births are underreported in the NVSS data (Moaddab et al. 2016; Thoma et al. 2014). However, this underreporting suggests that our estimates may under-estimate the impacts of ART in the population among younger groups of women and may present an upper-bound for women at older ages where ART may be over-reported. Preliminary sensitivity analyses of births that are more often reported as ART births do suggest the general trends we observe are robust to this issue.

[4] The 2017 NASS data are not currently available.

[5] Only descriptive analyses are provided because of known countervailing mechanisms that would skew multivariate analyses.

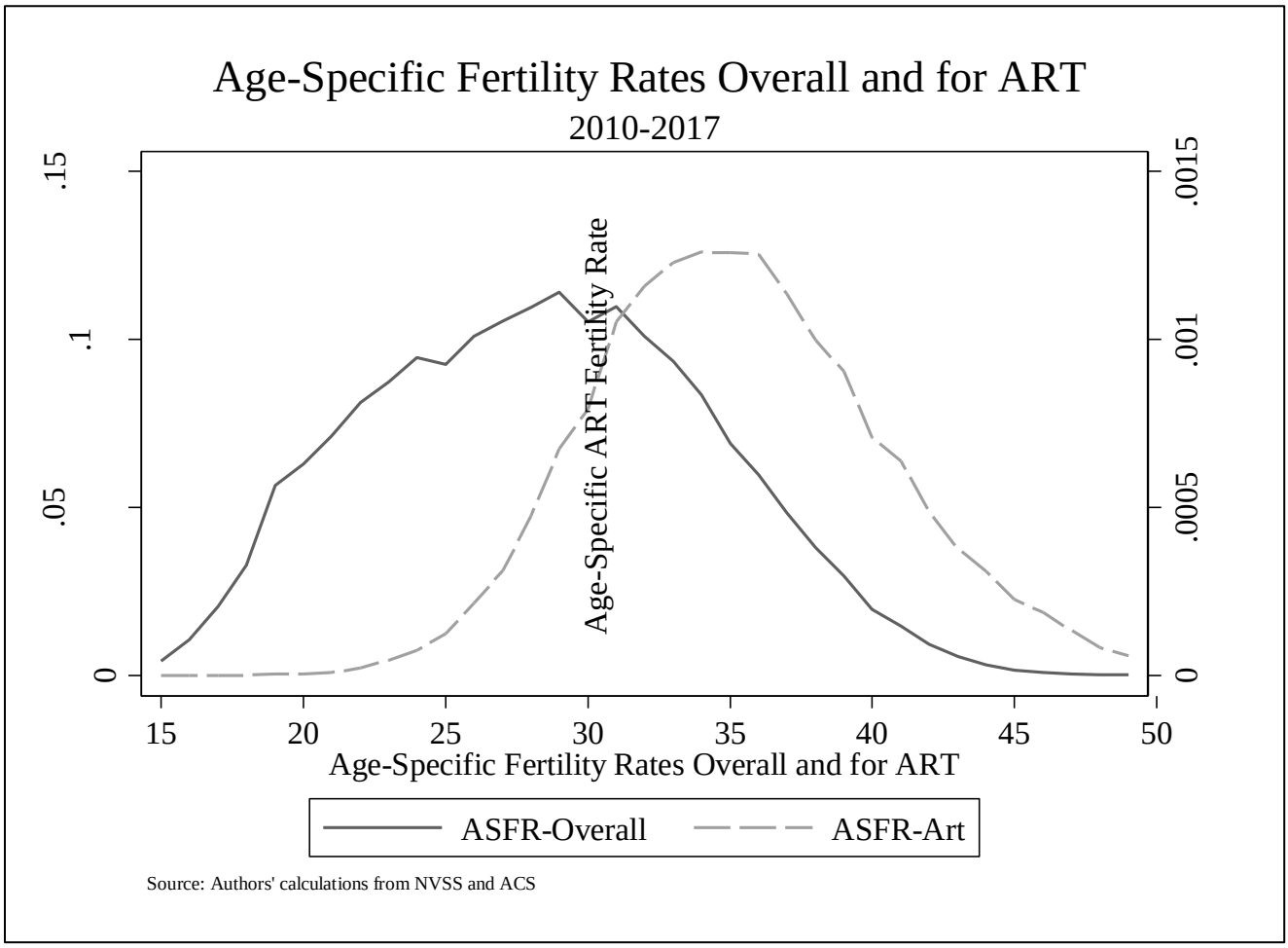
TABLE 1: PERCENTAGE OF BIRTHS DUE TO ART BY GROUP, AGE, AND YEAR

	2010	2011	2012	2013	2014	2015	2016	2017
Overall	0.70	0.68	0.79	0.81	0.82	0.86	1.01	1.12
Overall to Women 30 and Over	1.54	1.48	1.68	1.68	1.69	1.74	1.97	2.19
Age								
15-19	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00
20-24	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.05
25-29	0.31	0.31	0.34	0.33	0.33	0.32	0.37	0.40
30-34	0.95	0.94	1.04	1.03	1.07	1.09	1.22	1.37
35-39	1.92	1.86	2.13	2.13	2.13	2.19	2.49	2.82
40-44	4.02	3.72	4.49	4.62	4.62	4.76	5.36	5.83
45-49	17.29	16.50	18.30	19.23	18.64	19.04	22.49	23.20

Source: Authors' calculations from the NVSS birth certificate data.

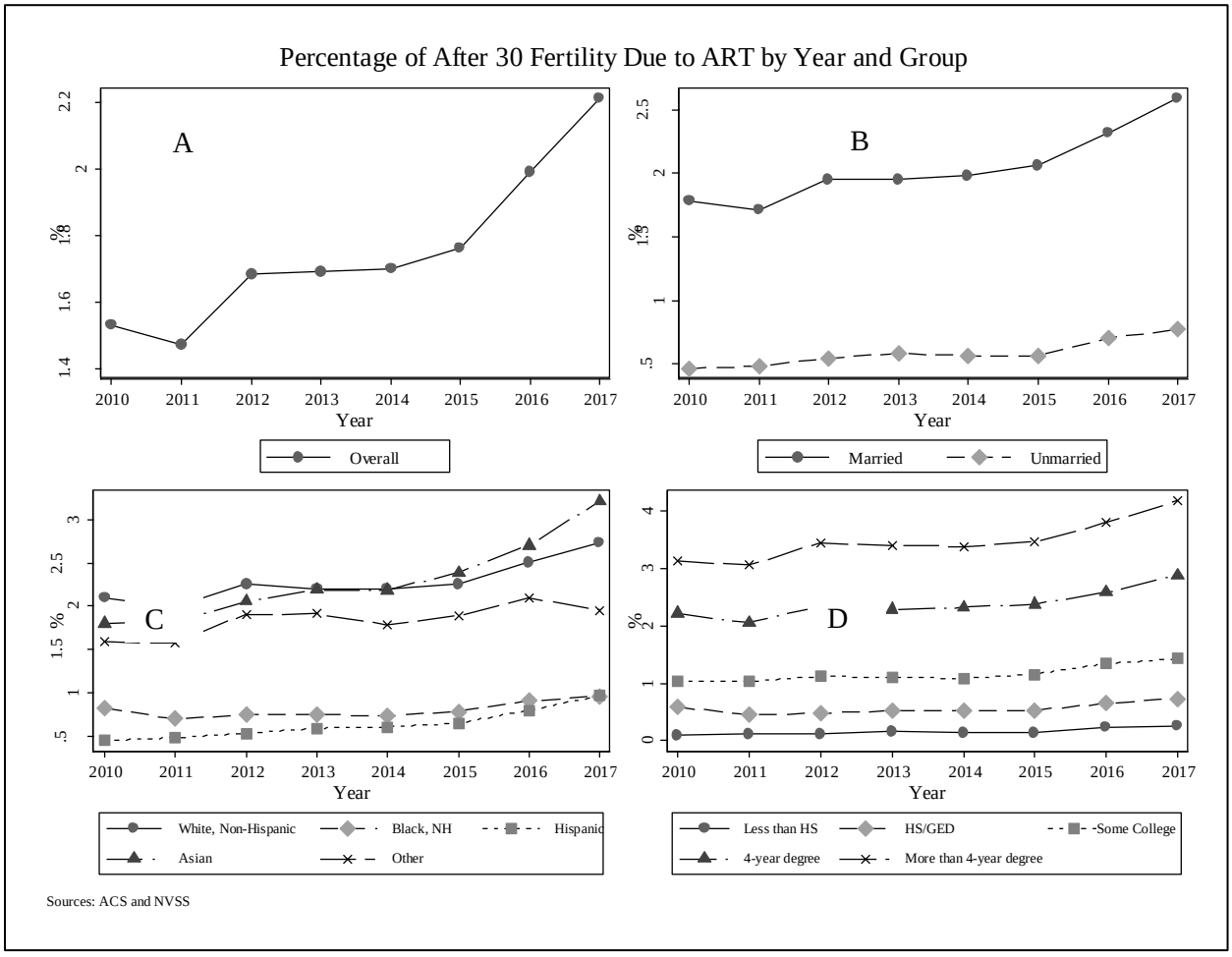
Note: Calculations for overall rates exclude cases with missing data on marital status or education. No substantive differences are observed due to the removal of these incomplete cases.

FIGURE 1: COMPARISON OF AGE-SPECIFIC FERTILTIY RATES OVERALL AND BY ART TOTALLED ACROSS ALL YEARS 2010-2017



Note: The scale for the ART ASFR rates are one-hundred times the ASFR overall rates.

FIGURE 2: PERCENTAGE OF AFTER 30 FERTILITY FOR WOMEN DUE TO ART BY YEAR AND GROUP



Notes:
After 30 fertility is defined as truncated total fertility after age 30.
Y-axis scales vary to best show patterns in the data.

TABLE 2: MULTIVARIATE NEGATIVE BINOMIAL REGRESSION ANALYSES OF THE INCIDENCE RATES OF ART BIRTHS BY AGE, RACE/ETHNICITY, EDUCATION AND INTERACTIVE TERMS

	Model 1		Model 2		Model 3		Model 4		Model 5	
Age (Ref= 30-34)										
15-19	0.01***	(0.00)	0.01***	(0.00)	0.03***	(0.01)	0.07***	(0.01)	0.08***	(0.01)
20-24	0.16***	(0.02)	0.15***	(0.02)	0.26***	(0.02)	0.23***	(0.01)	0.23***	(0.01)
25-29	0.52***	(0.05)	0.52***	(0.05)	0.62***	(0.05)	0.57***	(0.03)	0.58***	(0.03)
35-39	1.10	(0.10)	1.11	(0.10)	0.98	(0.07)	1.12*	(0.05)	1.12*	(0.05)
40-44	0.65***	(0.06)	0.66***	(0.06)	0.51***	(0.04)	0.71***	(0.04)	0.70***	(0.03)
45-49	0.25***	(0.02)	0.26***	(0.02)	0.20***	(0.02)	0.28***	(0.02)	0.28***	(0.01)
Race (Ref=White)										
Black			0.61***	(0.05)	0.60***	(0.04)	0.58***	(0.03)	0.57***	(0.03)
Hispanic			0.53***	(0.04)	0.57***	(0.04)	0.63***	(0.03)	0.62***	(0.03)
Asian/NHOPI			1.13	(0.09)	1.43***	(0.10)	1.24***	(0.06)	1.21***	(0.06)
Other			1.12	(0.10)	1.06	(0.08)	0.96	(0.05)	0.91	(0.05)
Education (Ref=4-year degree)										
Less than HS					0.18***	(0.01)	0.22***	(0.01)	0.21***	(0.01)
HS					0.19***	(0.01)	0.22***	(0.01)	0.22***	(0.01)
Some College					0.51***	(0.03)	0.53***	(0.02)	0.53***	(0.02)
More than 4-year degree					1.95***	(0.13)	2.07***	(0.10)	2.08***	(0.09)
Marital Status (Ref=Unmarried)										
Married							5.61***	(0.18)	5.72***	(0.18)
Year (Ref=2010)										
2011									0.99	(0.06)
2012									1.06	(0.07)
2013									1.16*	(0.07)
2014									1.16*	(0.07)
2015									1.27***	(0.08)
2016									1.51***	(0.09)
2017									1.61***	(0.10)
Constant			0.00***	(0.00)	0.00***	(0.00)	0.00***	(0.00)	0.00***	(0.00)
Ln dispersion parameter (alpha)			1.41***	(0.04)	0.89***	(0.03)	0.37***	(0.01)	0.34***	(0.01)
N			2079		2079		2079		2079	

p-values: * .05 ** .01 *** .001

Incidence risk ratios presented & standard-error in parentheses.

SUPPLEMENTAL TABLE 1: COMPARISON OF THE NVSS AND NASS ART BIRTH COUNTS

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
NASS Delivery[A, B]	28,378	32,505	39,901	42,612	49,954	53,134	64,703	Not Available
NASS Births[A,B, C]	37,101	41,879	50,696	53,187	61,189	63,772	75,413	Not Available
NVSS Births[C]	15275	17,840	21,871	24,596	28,609	30,012	37,690	36,065
% Delivery	53.8%	54.9%	54.8%	57.7%	57.3%	56.5%	58.3%	Not Available
% Births	41.2%	42.6%	43.1%	46.2%	46.8%	47.1%	50.0%	

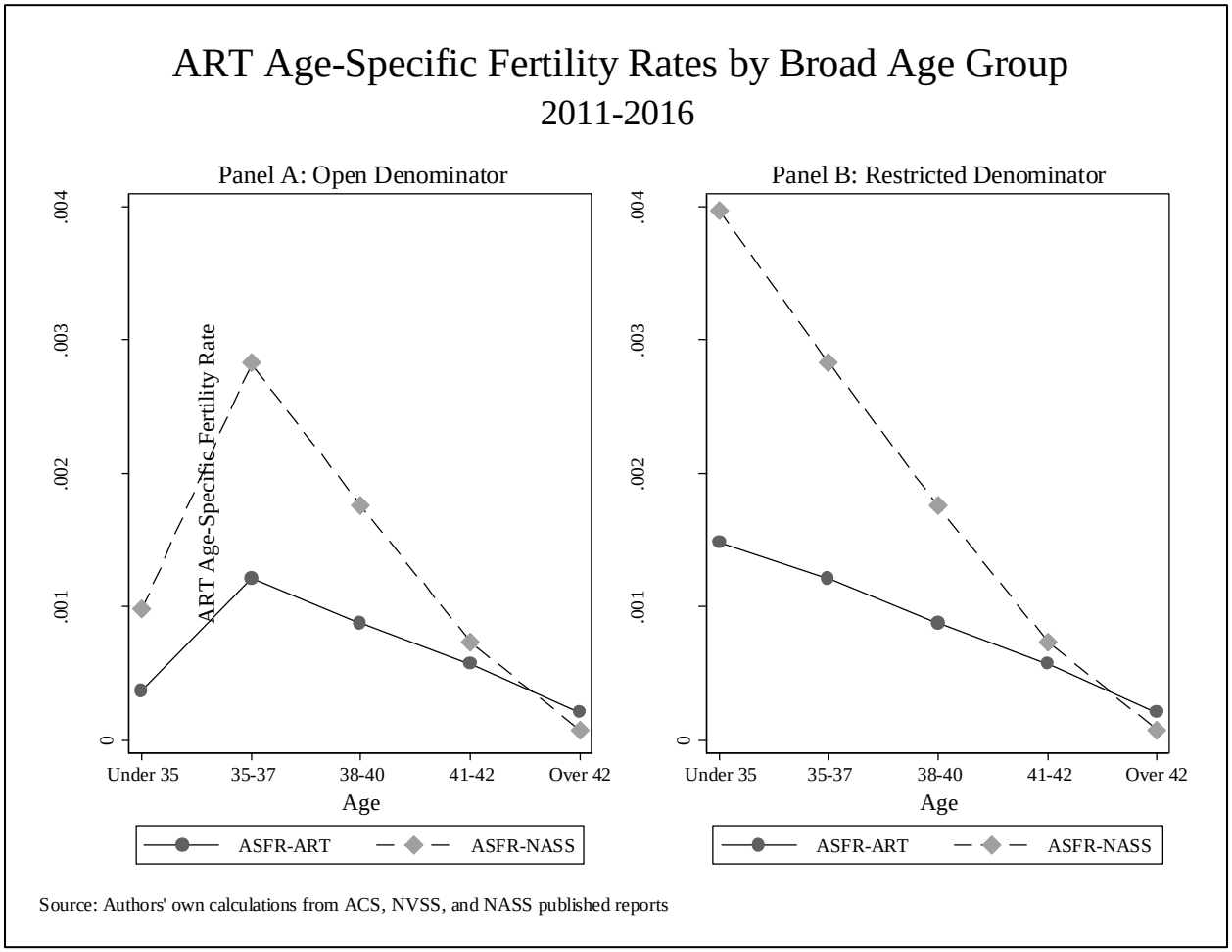
A. Counts from the NASS published reports were adjusted by the proportion of live births and deliveries occurring in states that report ART. This information is inferred from publicly released clinic reports, which include state-level information.

B. Estimates of the number of NASS births from 2011-2013 differ from those reported from Moaddab et al. (2016) as we excluded all states who do not report, rather than only those who did not report using the 2003 birth certificate data. Some states that transitioned to the use of the 2003 revision of the birth certificate did not report specific data on ART and are excluded in our estimates.

C. Estimates for 2011-2013 NVSS birth data differ slightly from those reported by Moaddab et al. (2016) as we exclude women 50 and over.

D. There is insufficient data in the 2010 reports to accurately estimate the number of live births (as opposed to deliveries) because insufficient data on the proportion of triplets and twins is provided. However, based upon the 2011-2016 data, we find there are few differences between the proportion of births and the proportion of deliveries in the reporting area of the NVSS data. As a result, we estimated the proportion of the deliveries that occurred within the reporting area using the publicly available clinic reports. We overlaid this proportion onto the total deliveries and births provided in the aggregate in the CDC reports.

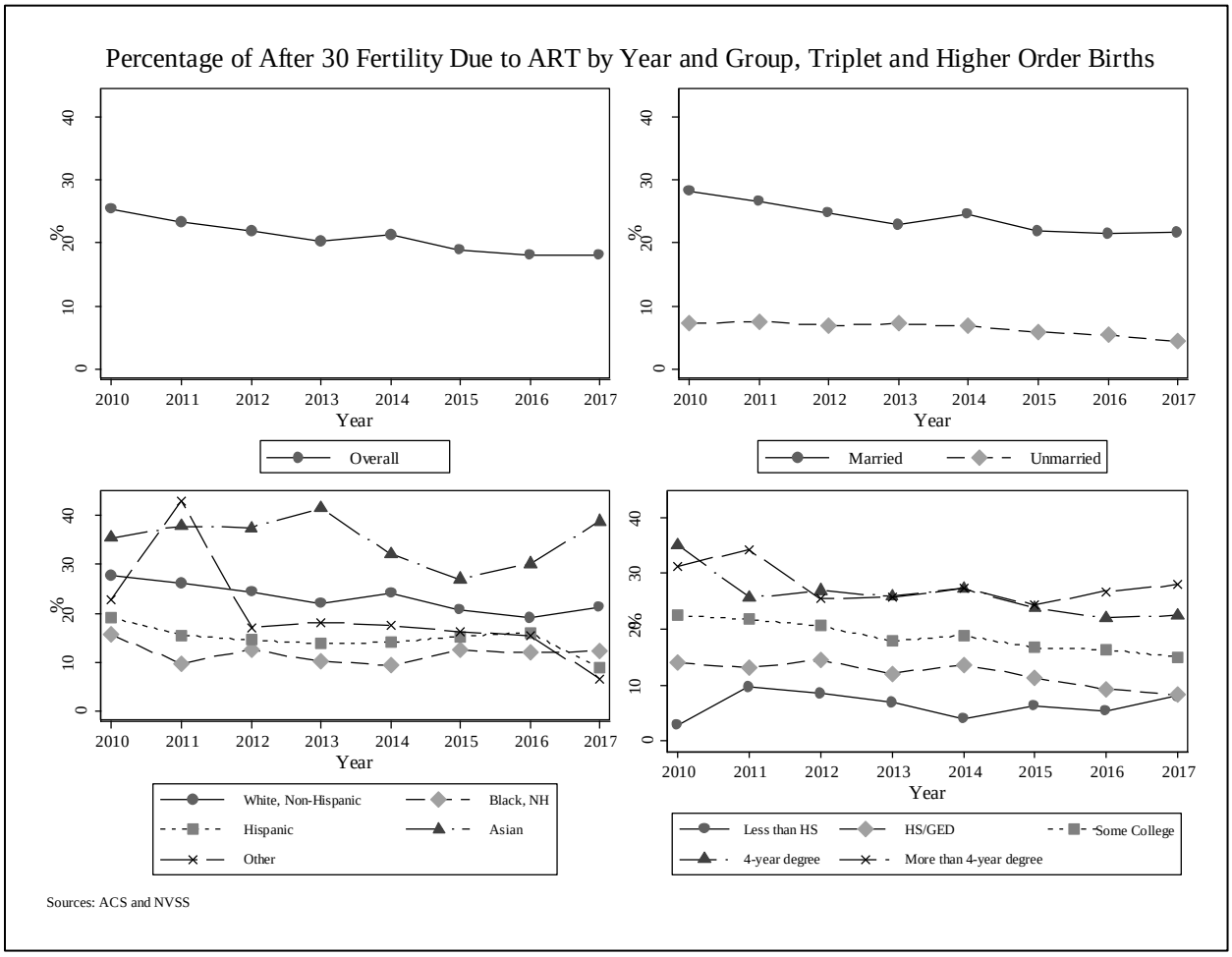
SUPPLEMENTAL FIGURE 1: COMPARISON OF THE AGE SPECIFIC FERTILITY RATES OF THE NVSS ART AND NASS DATA



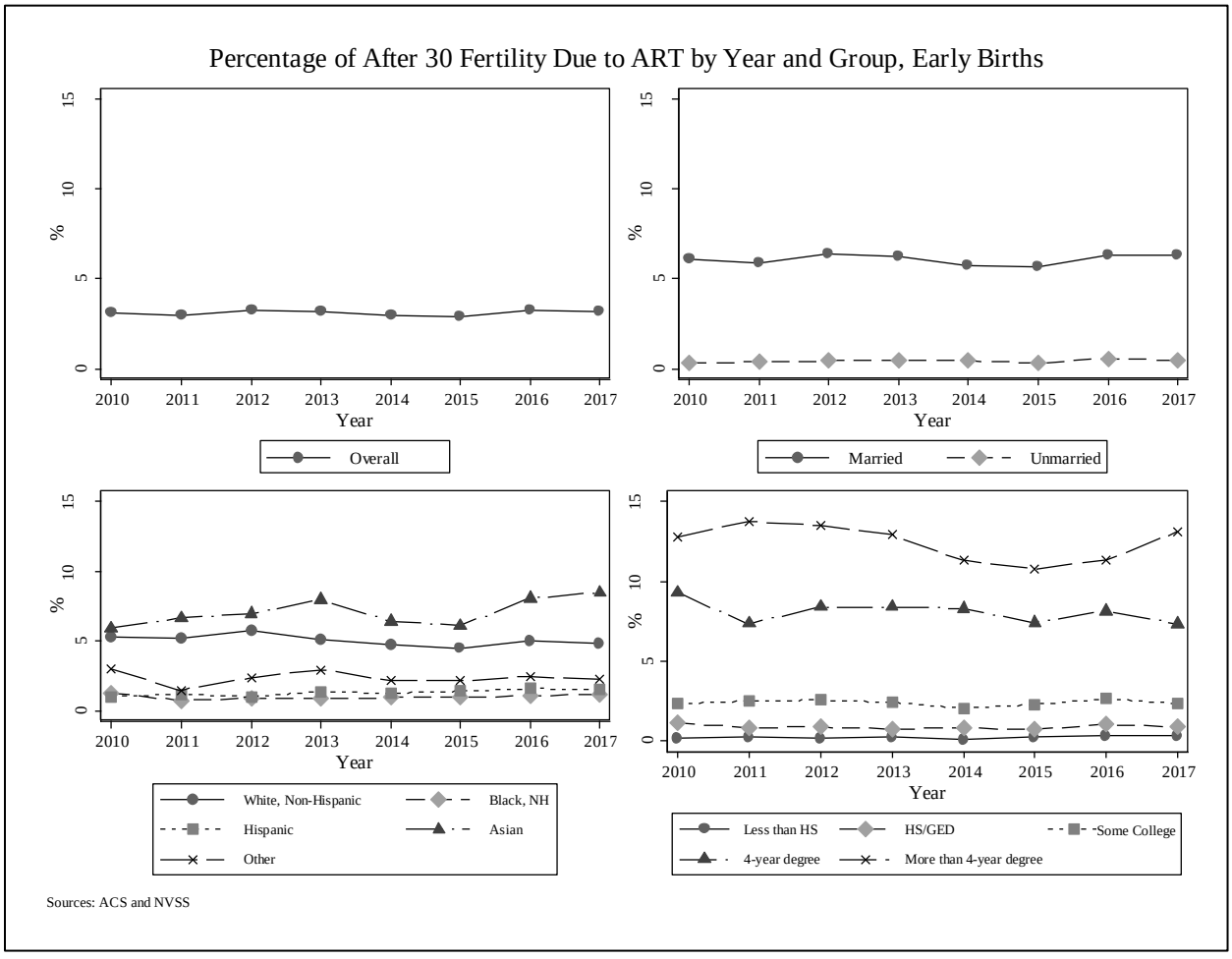
Notes:

NASS does not report the number of live births by age in the publicly available reports. However, the NASS reports on the CDC webpage report proportions of births, which were used to estimate the counts of ART births due in the NASS data. The birth counts were adjusted to exclude the proportion of births in states that do not report ART on birth certificates, and the denominators were matched to exclude non-reporting states. Data for 2010 were insufficiently detailed to use for estimating births by age, and data for 2017 has not yet been released. Births using donor eggs or embryos are distributed following non-donor age distributions for births with the exception of 2011, where data on donor eggs is insufficiently detailed to accurately calculate total number of live births. In Panel A, the denominator for the under 35-age group includes women 15-34. In Panel B, the denominator for the under 35-group includes women 30-34 only. In Panel B, the NVSS data includes ART births to women under 30 because we are unable to remove these births from the NASS data and this allows a better comparison between the rates.

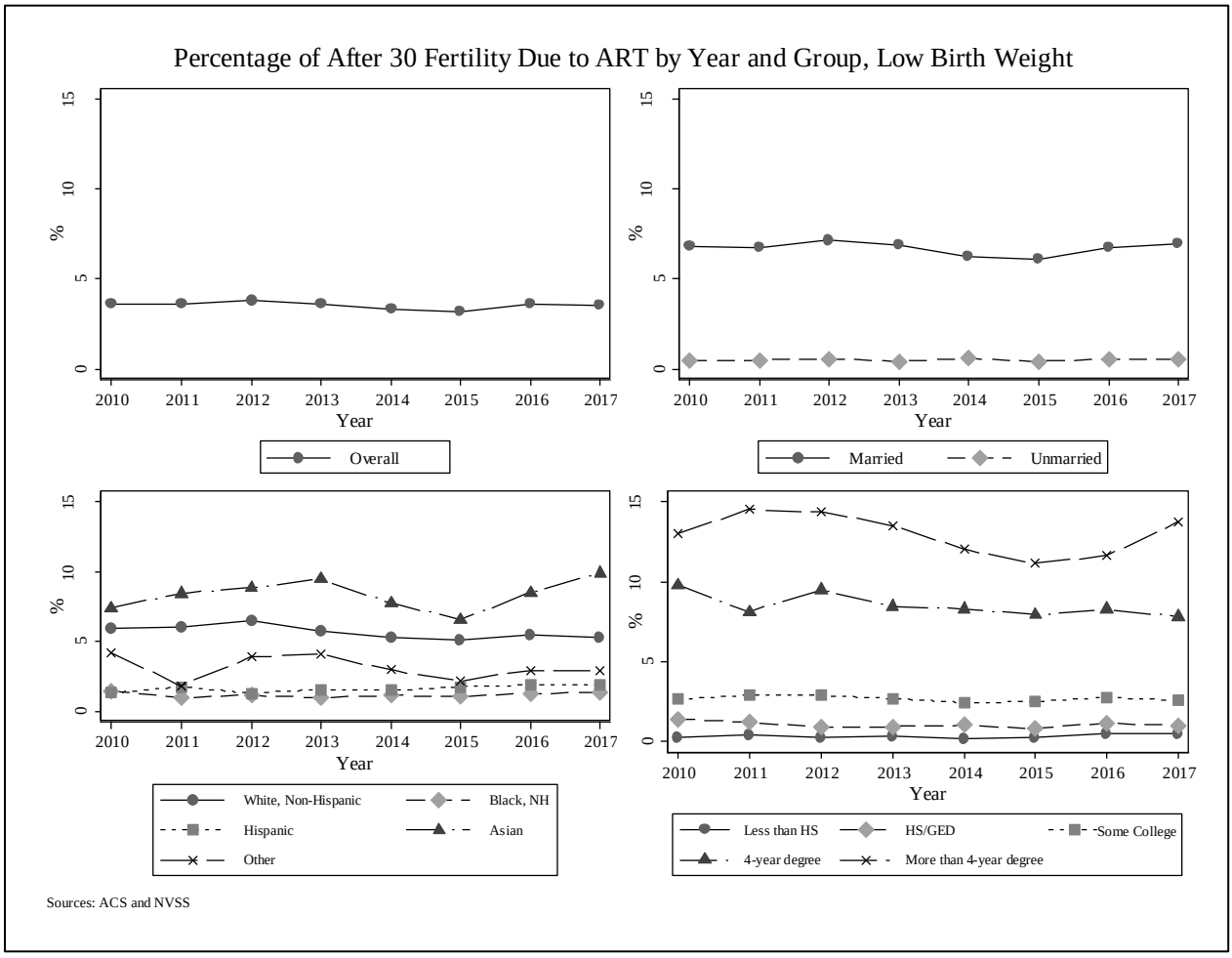
SUPPLEMENTAL FIGURE 3: TRUNCATED TOTAL FERTIITY RATES FOR WOMEN OVER 30 OVERALL AND BY RACE, MARITAL STATUS, AND EDUCATION INCLUDING ONLY TRIPLET AND HIGHER ORDER BIRTHS



SUPPLEMENTAL FIGURE 4: TRUNCATED TOTAL FERTIITY RATES FOR WOMEN OVER 30 OVERALL AND BY RACE, MARITAL STATUS, AND EDUCATION INCLUDING ONLY EARLY GESTATIONAL BIRTHS



SUPPLEMENTAL FIGURE 5: TRUNCATED TOTAL FERTIITY RATES FOR WOMEN OVER 30 OVERALL AND BY RACE, MARITAL STATUS, AND EDUCATION INCLUDING ONLY LOW BIRTH WEIGHT BIRTHS



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