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Women's use of long-acting reversible contraception for birth timing and birth stopping

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Authors :

Mieke C.W. Eeckhaut
University of Delaware

Michael S. Rendall
Polina Zvavitch
University of Maryland

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Mieke C. W. Eeckhaut
Department of Sociology and Criminal Justice
University of Delaware
325 Smith Hall, 18 Amstel Ave., Newark, DE 19716

Michael S. Rendall
Department of Sociology
University of Maryland, College Park
3139 Parren J. Mitchell Art-Sociology Bldg., College Park, MD 20742

Polina Zvavitch
Department of Sociology
University of Maryland, College Park
2112 Parren J. Mitchell Art-Sociology Bldg., College Park, MD 20742

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ABSTRACT

The use of long-acting reversible contraceptive (LARC) methods—intra-uterine devices (IUDs) and implants—has recently expanded rapidly in the U.S., and now approaches the contraceptive pill in current prevalence. Research so far on LARCs has analyzed their use to reduce unintended pregnancies, but not their use to enable intended pregnancies. Knowledge of both is necessary to understand LARC's potential impacts on the reproductive life courses of U.S. women. We combine data from two nationally-representative surveys to estimate women's likelihood and timing of subsequent reproductive events, including intended births, up to nine years after discontinuing LARC. We estimate that two thirds will give birth, and one quarter will either have another LARC inserted (14.5%) or transition to sterilization (10.1%). Four in five of the births will be intended when the birth occurs within three years of discontinuing LARC with no intervening switch to a non-LARC method. We infer that women's motives for using LARCs are varied, but include to postpone a birth, to postpone a decision about whether to have a(nother) birth, and to transition definitively to the completion of childbearing.

Keywords: fertility, reproductive health, long-acting reversible contraception, intended childbearing

INTRODUCTION

The twenty-first century has seen the re-introduction and rapid growth in the use of long-acting reversible contraceptive (LARC) methods—intra-uterine devices (IUDs) and implants—in the United States. LARC use among U.S. women has increased from close to 1% of contraceptive use in 1995 to 6% in 2008 to 16% in 2015-2017 (Daniels and Abma 2018; Hubacher et al. 2011; Kavanaugh and Jerman 2018; Kavanaugh et al. 2011). It is now the third most used contraceptive method after sterilization (29%) and the pill (19%), and above that for the 13% of women whose primary method of protection against unintended pregnancy is the male condom. Foster et al.'s (2015) survey of over 100 contraceptive researchers found median and modal projections of U.S. women's LARC use in the absence of common access barriers in the range of 25–29% of contraceptive use. Research into LARC's impacts until now has largely been from a public health perspective that has emphasized LARCs' potential to reduce unintended pregnancy (Wu et al. 2018), following from IUD and implants' much lower contraceptive failure rates than all other reversible methods (Sundaram et al. 2017; Winner et al. 2012). This highly-focused scope of research into LARC's impacts may be contrasted with studies of the impacts of the historical introduction and diffusion of the pill in the U.S., which have investigated much more broadly the life-course and intergenerational impacts of that new method. These include, for example, women's labor market outcomes and economic wellbeing (Bailey 2013; Browne and LaLumia 2014) and child development (Bailey et al. 2018). In the present study, we begin to broaden investigation into the life-course impacts of the rapid diffusion of LARC in the U.S. over the last two decades by analyzing descriptively women's reproductive behavior and outcomes following LARC use and subsequent discontinuation.

We address questions both on the use of LARC to shift the timing of births to when they are "intended" and on the use of LARC to increase the likelihood that a woman will defer use of a permanent contraceptive method (sterilization) until she is sure that she has realized her childbearing goals. The latter question addresses the current U.S. context in which as many as one in four women who are sterilized subsequently report that they would like to have their sterilization reversed (Eeckhaut et al. 2018). In summary, we address the use of LARC to increase intended fertility over the reproductive life course. We quantify U.S. women's use of LARC as a precursor to an intended birth and as a precursor to either next LARC use or to sterilization. Our evidence is from women who have stopped using a LARC device and then have between one and nine years of exposure to reproductive events following LARC removal. Only recently have LARC devices been used to any substantial extent among the current generation of women of reproductive age, therefore relatively few women have years of post-LARC exposure to observe, and even fewer have had even moderately long periods of exposure. We address this data challenge in two ways. First, we combine data from two nationally representative data sources, the 2006 to 2017 years of the National Survey of Family Growth (NSFG) and the 2002 to 2015 waves of the National Longitudinal Survey of Youth 1997 (NLSY97). Second, we use a simulation that estimates up to nine years of exposure to reproductive events following LARC removal.

To anticipate our findings, we estimate that within nine years of discontinuing LARC, two thirds of women will have a birth and a quarter will either start a new LARC or begin sterilization as their method of contraception. A higher-than-average proportion of births following LARC discontinuation are intended (70%). Almost 80% of post-LARC births are intended when there is no intervening switch to a non-LARC contraceptive method. We infer

substantial use of LARC to optimize birth timing and substantial use of LARC as part of a woman's decision-making about definitively stopping childbearing.

LITERATURE REVIEW

Compared with other low-fertility countries, until very recently (Hubacher and Kavanaugh 2018) the U.S. has had one of the lowest rates of LARC use (Buhling et al. 2014; Eeckhaut et al. 2014). Recent years of rapid growth in the U.S.'s rate of LARC use, however, mean that it is now the second most used reversible method only three percentage-points less than the pill (16% versus 19%, Daniels and Abma 2018). The historical background of LARCs in the U.S.—first-generation IUDs such as the Lippes Loop—goes back to around 1960 (Thiery 1997). However, their take-up was shortly followed by steep declines in usage when serious safety concerns regarding the Dalkon Shield IUD in the early 1970s resulted in a prolonged period of litigation (Sonfield 2007). IUD use was revived in the United States after the levonorgestrel-releasing IUD was approved for medical use in 2000 (Kavanaugh et al. 2011). Although IUDs remain the dominant LARC in the U.S., as they do in most other developed countries (Eeckhaut et al. 2014; U.N. 2013), implant use has also increased rapidly in recent years, doubling from 1.3 percent of current contraceptive users in 2012 to 2.6 percent in 2014 (Kavanaugh and Jerman 2018). The first implant—Norplant—was approved in 1990, but there were early gaps in availability of the method. Norplant was withdrawn from market in 2002, and the second implant method, Implanon, was not approved until 2006, and then replaced by its newer version, Nexplanon, in 2011 (Strasser et al. 2016). The high up-front cost of LARCs has been slow to be covered by health insurance. LARC devices and their insertion cost were, until the introduction of the Affordable Care Act in 2010, omitted from many health insurance plans (Bearak et al. 2016;

Sonfield 2007). Reforms to Medicaid policy on immediate postpartum (IPP) LARC insertion have provided coverage at a critical time point (Rodriguez et al. 2014). Implementation, however, has occurred on a state-by-state basis and remains far short of being national in scope (Moniz et al. 2015).

Arguments for, and research on, LARC access and use in the U.S. has centered on its potential to reduce unintended fertility (Karpilow and Thomas 2017; Lindo and Packham 2017; Parks and Peipert 2016; Peipert et al. 2012; Ricketts et al. 2014; Secura et al. 2014; Trussell et al. 2013; Wu et al. 2018). The U.S. has a substantially higher rate of unintended pregnancy than that in other high-income countries. Sedgh et al. (2014) showed in a cross-national comparison of unintended pregnancy around 2012 that North America's (the U.S. and Canada's) 51% unintended fraction was as much as 50% higher than in other high-income countries: for example, 38% and 34% of pregnancies respectively in Northern and Western Europe, and 37% of pregnancies in East Asia and Oceania. Unintended pregnancies are associated with adverse birth and maternal health outcomes (Kost and Lindberg 2015; Lindberg et al. 2015). Therefore, increasing access to and use of LARC in the U.S. has been promoted as a public health goal (ACOG 2009, 2015; Wu et al. 2018). The use of highly-effective and reversible contraception, however, should enable women to better achieve a broader set of reproductive goals than that of reducing the risk of unintended pregnancy (Dehlendorf et al. 2018). A major criterion against which a new contraceptive method should be evaluated is whether it increases women's ability to have births of their desired number and timing over the reproductive life-course, that is, to have intended births. A further reason for attending to the impact of LARC use on intended fertility that should be of major salience to demographers is that, unless reductions in unintended fertility achieved through use of LARC are counter-balanced by positive impacts on intended fertility,

overall U.S. fertility will decrease markedly with increased LARC use. The U.S. total fertility rate (TFR), at 1.73 in 2018 (Martin et al. 2019), stands well below replacement (though see also Wu and Mark 2019). With unintended fertility accounting for approximately 35% of all U.S. births (Hayford and Guzzo 2016), a simple subtraction of all unintended births would leave the TFR at 1.12, squarely within the range of 'lowest-low' fertility.

We argue that efforts to increase use of LARC methods in the U.S. need to be grounded in a fuller understanding of their impact on women's reproductive life-courses. We note here that LARC devices are marketed as being a fully-effective contraceptive method for either three (implant and Skyla hormonal IUDs), five (Mirena, Liletta, and Kyleena hormonal IUDs), or ten years (Paragard copper IUD) (ACOG 2015; U.S. FDA 2018). Following a reproductive life-course perspective, use of LARC may increase intended fertility in two ways: (1) a birth that would have occurred earlier than desired (and thus be unintended) may instead occur later, as an intended birth; and (2) a birth that would not have occurred at all because the woman opts to rely on sterilization, may instead occur and be intended. That is, some women who would have eliminated their risk of unintended pregnancy by using a permanent method (contraceptive sterilization) might, following a period of LARC use in place of sterilization, experience a change in fertility goals and go on to have (further) intended children.

Intended children, almost by definition, come only after an interruption in contraceptive use. In the only study we know of that has analyzed birth intendedness following LARC use, Eeckhaut and Rendall (2019) found that when the last contraceptive method used was a LARC, the intended fraction of births was almost 20 percentage-points higher than when the last method used was either a moderately-effective method such as the pill, or a less-effective method such as condoms. That study did not, however, investigate the fraction of women that go on to have a

birth following LARC discontinuation. Kramer et al. (2018) found that fewer than half of current LARC users intend future births. We know of no study that has estimated realized fertility following LARC discontinuation.

We also know of no direct evidence on increasing intended births through reducing sterilization. Suggestive evidence is found in the substantial increases in LARC use between the late-2000s and mid-2010s that coincided with substantial decreases in sterilization (Kavanaugh and Jerman 2018). Moreover, Eeckhaut et al. (2014) found in a nine-country study of couples' contraceptive use in the mid-late 2000s that those countries that had the lowest prevalence of LARC use (Australia and the U.S.) had by far the highest prevalence of contraceptive sterilization.

METHODS

Data for this study were drawn from the NSFG's 2006-2010, 2011-2013, 2013-15, and 2015-2017 cycles (U.S. Department of Health and Human Services 2018) and the NLSY97's 2002 to 2015 waves (Bureau of Labor Statistics nd). Additional details on the two sources are given in Appendix A. In both surveys, we analyzed samples of women who reported having used and then discontinued use of a LARC.

Neither the NSFG nor NLSY97 if used alone would have allowed us to realize our study's aims. Only in the NSFG is birth intendedness asked. Only in the NLSY97, however, are there sufficient longitudinal data to analyze exposure to births, together with any permanent or non-permanent contraceptive method use, for more than two or three years following LARC discontinuation. Moreover, given the low prevalence of LARC use in the U.S. until very recently, in both surveys there are relatively few observed LARC discontinuations.

Combining data from the two surveys eases the constraints of analysis with small sample sizes, but requires that we simplify the sequences of contraceptive method use and discontinuation to those occurring in annual periods. We coded events in the NSFG by the calendar year in which they occurred and in the NLSY97 by the approximately 12-month period between annual survey waves. For the NSFG, year 0 indicates the calendar year that includes the month of last reported LARC use before the month of first reported non-use of LARC. For the NLSY97, year 0 indicates the approximately 12-month period before the wave of last reported LARC use. For the NSFG, most women can be followed for only one (year 1) to two (year 2) years after the year of LARC discontinuation (year 0), due to the limited time period covered by the contraceptive calendar (i.e., a maximum of three to four years). For the NLSY97, women can be followed for up to eight years (year 8) after the year of LARC discontinuation (year 0). We constructed an approximation of longer-duration period since LARC discontinuation in the NSFG using the question on whether the woman has "ever used" LARC. We are able to code her as having a LARC-discontinuation duration of greater than three to four years from this "ever use" question, and use this for estimating intendedness of births at longer durations since LARC discontinuation.

Our main outcomes of interest are whether or not the woman experienced a live birth and the intendedness status of that live birth. We also use contraceptive information in the years following LARC discontinuation in both the NSFG and NLSY97 to code a new LARC insertion and to code (female or male) sterilization. We are able to identify directly the intendedness of a birth after LARC discontinuation from the NSFG only. The intendedness of the live birth after LARC discontinuation was determined based on the NSFG question regarding whether "Right before you became pregnant …" the woman intended to have a(nother) baby. Following previous

work (Mosher et al. 2012), an unintended pregnancy was one reported as "too soon, mistimed," or "unwanted." An intended pregnancy was one reported as having occurred at the right time or later than desired. Finally, responses of "didn't care, indifferent" ($N = 1$) or "don't know, not sure" ($N = 1$) were also classified as intended.

We are also interested in whether the woman switched to a non-LARC contraceptive method following LARC discontinuation. We code this in both the NSFG and NLSY97 using information on contraceptive method use in the year before a birth. Specifically, we code whether the woman used a non-LARC contraceptive method versus no contraceptive method in the year preceding the year of a birth that followed LARC discontinuation. Because the NSFG allows such a short period of post-LARC-discontinuation exposure to a birth (i.e., a maximum of two years), and because we rely on the "ever use" question for periods of LARC discontinuation of more than three years, we are not able to code a more complete measure of contraceptive switching following LARC discontinuation.

STATISTICAL ANALYSIS

We estimate two multivariate logistic regression models: (1) a binary logit model of intendedness of births among women giving birth following LARC discontinuation, using data from the NSFG alone; and (2) using data from both the NSFG and NLSY97, a multinomial logit model of the annual competing hazard following LARC discontinuation of birth, new LARC insertion, and sterilization. To estimate that annual competing hazard, observations of LARC discontinuers in the NSFG and NLSY97 were pooled. Tests for suitability of the two data sources for pooled estimation were conducted using *F*-tests in the case of the bivariate outcome

statistics and in the case of multivariate estimation using model fit assessments (Rendall et al. 2013). All estimates were adjusted for the complex sample design of the NSFG and NLSY97.

For the birth-intendedness model, we include a predictor that combined information on duration since LARC discontinuation (used LARC 0-1; 2; 3+ calendar years before the calendar year of live birth) and whether the woman used non-LARC contraception in the year before the live birth (used no method; used a non-LARC method). We also take account of sociodemographic and reproductive characteristics of the woman, including: woman's age, education, union status, parity, and race/ethnicity. These we code at the time of the birth. In estimating models of the annual hazards of experiencing any of the three spell-ending outcomes (birth; new LARC insertion; and sterilization), we code woman's characteristics at the time of LARC discontinuation. In addition to the predictor variables used in the birth intendedness estimation, we include as predictors in the hazard regression the number of calendar (NSFG) or survey (NLSY97) years during which LARC use was reported before it was discontinued (1; 2; 3; 4+ years).

We combined estimates from simplified versions of models (1) and (2), with only time since LARC discontinuation and whether she switched to a non-LARC method before a birth as predictor variables, in a model that simulates nine years of post-LARC exposure to an intended or unintended birth, to a LARC re-insertion, or to sterilization. In results from this simulation, we consider both the risk of intended birth (i.e., the intended birth *rate*) and the risk that any subsequent birth is intended versus unintended (i.e., the intended birth *ratio*). A full description of this simulation method is given in Appendix B.

RESULTS

CHARACTERISTICS OF WOMEN WHO DISCONTINUE LARC

Although previous studies have described current LARC users (e.g., Kramer et al. 2018; Xu et al. 2011), no study to our knowledge has described women who have discontinued LARC use and who are still in their reproductive ages. In Table 1, we describe U.S. women who discontinued LARC use between 2002 and 2016 at all ages (NSFG) and at ages 34 and below (NSFG and NLSY97). The NLSY97 is a cohort panel survey, therefore the oldest women in the sample are 34 years old in 2015. The age and period distributions of women discontinuing LARC are better captured by the cross-sectionally-sampled NSFG than in the single cohort of the NLSY97. Our results describing the composition and characteristics of LARC discontinuers immediately below therefore focus on estimates from the NSFG, for the all-ages sample.

Table 1 about here

From the NSFG estimates, we see that three fifths of women were under 30 at discontinuation (30.2% between ages 15 and 24 and 30.1% between ages 25 and 29), followed in frequency by women ages 35+ (21.9%) and ages 30-34 (17.8%) at LARC discontinuation. The structure of cohort observation in the NLSY97 means that by the time LARCs were on the U.S. market again after the earlier IUD problems and the gap in implant availability following Norplant discontinuation, the NLSY97 cohort was mostly in their mid-20s. This, and our including NLSY97 discontinuations from 2002 and beyond to match the period observed in the NSFG, means that 25-29 year olds account for a large fraction of LARC discontinuers in the NLSY97 (59.6%), followed by women ages 15-24 (25.0%) and ages 30-34 (15.4%) at LARC discontinuation. The timing of the re-introduction of LARCs back onto the U.S. market also

contributes to the majority of LARC discontinuations having been in more recent years. Dividing LARC discontinuations into three five-year periods between 2002 and 2016, we see that more than half (55.1%) of discontinuations occurred in the most recent, 2012-2016 period, followed by 35.7% in 2007-2011 and only 9.3% in 2002-2006. The modal years of LARC discontinuation estimated from the NLSY97 were 2007-2011 (58.3%), although this is again best attributed to the structure of that cohort's observation.

The more recent sampling of women in the NSFG than in the NLSY97 means that, descriptively, the race/ethnic composition of the population of LARC discontinuing women is better represented by the NSFG estimates. We thus see that Hispanic women account for relatively large shares of LARC discontinuers (29.7%), consistent with relatively high prevalence found in estimates of current LARC users among U.S.-born and especially foreign-born Hispanics (Tapales et al. 2018). Non-Hispanic White women account for half (51.9%) of women discontinuing LARC, followed by Black (9.5%) and Other race/ethnicity women (8.9%), who include women of two or more race/ethnic groups. Women at all education levels are represented among LARC discontinuers, with high school graduates (28.2%) and "some college" (35.6%) being the largest two educational attainment groups. A relatively high fraction of LARC discontinuers were partnered at discontinuation. Approximately 70% of women were either married (49.5%) or cohabiting (19.8%) at the time of LARC discontinuation. Only 16.2% of women were nulliparous at the time of their discontinuing LARC use. More than half (54.4%) had already given birth to at least two children, and 29.3% had given birth to one child at the time of LARC discontinuation. The most common duration of women's LARC use before discontinuation is 4+ years (40.9%), followed by durations of 1 (22.9%) or 2 (20.3%) years.

Short durations may reflect method dissatisfaction or unintended expulsion of IUDs (Goldthwaite et al. 2017; Grunloh et al. 2013), or planning for a timely next birth.

INTENDED VERSUS UNINTENDED BIRTH AFTER LARC DISCONTINUATION

We next examine, in bivariate and multivariate analyses of the NSFG data, the likelihood that a birth following LARC discontinuation will be intended. We also present separate estimates for women whose LARC discontinuation was observed less than three years before the year of live birth (i.e., during the period covered by the contraceptive calendar). Overall estimates are of just over two-in-three live births following LARC discontinuation (67.7%) that were intended (first column of Table 2). Among those births occurring no more than three years after LARC discontinuation, 75.8% were intended. The risk of intended versus unintended live birth is highest, at 78.6% and 79.3%, respectively, for women who did not use another contraceptive method in the year before the birth and who either discontinued LARC 0 to 1 calendar years prior to the birth, or 2 calendar years prior to the birth.[1] The risk of intended live birth is also comparatively high, at 72.0%, for women who did not use another contraceptive method in the year before the birth and who discontinued LARC 3 or more years ago. We find much lower risks of intended live birth (higher risk of unintended birth) for women who used a non-LARC contraceptive method in the year before the birth, at 62.5% for those who discontinued LARC 2

[1] By design, all women in the category "0-1 years" since LARC discontinuation were coded as not having used any non-LARC contraception (i.e., value "no method") in the year before the live birth.

calendar years prior to the birth and 49.0% for those who discontinued LARC 3 or more years ago.

Table 2 about here

Bivariate associations with sociodemographic and reproductive characteristics show that the estimated risk of intended versus unintended birth is highest for those women whose discontinuation was in the last three years and who were married (89.0% intended), and whose birth was their first (91.4%) or second (88.8%). In contrast, only 54.4% and 40.7% of births were intended respectively among cohabiting and single women whose LARC discontinuation was in the last three years, and only 65.9% of third and higher-order births were intended after LARC discontinuation in the last three years. We find no statistically significant association of age or race/ethnicity with the estimated risk of intended versus unintended live birth following LARC discontinuation. Although no statistically-significant associations with education are revealed by an overall chi-square test, in results not shown we found that the BA+ group has a higher fraction intended than for all other women that is statistically significant at the .05 level for both the under-three-years (94.1% intended) and full samples (82.4% intended). Finally, the proportion intended in the full sample is lower for births in 2005-2008 (54.9%) versus births in 2009-2012 (67.3%) and in 2013-2017 (73.4%).

Table 3 about here

The multivariate models of birth intendedness (Table 3) largely confirm the above-described bivariate associations between the intended birth ratio and our key covariates. We again present estimates separately for women whose LARC discontinuation was observed less than three years before the year of live birth, versus from the full sample that also includes women who had ever discontinued LARC before the live birth. First, women who used a non-LARC contraceptive method in the year before live birth and who discontinued LARC three or more calendar years prior to live birth have a 75% lower odds (OR = 0.25) of the birth being intended, compared to the reference category of women who did not use another contraceptive method in the year before live birth and who discontinued LARC zero to one calendar years prior to the birth. In line with the bivariate results, we also find a 60% lower odds (OR = 0.40) of an intended birth for women who used a non-LARC contraceptive method in the year before the birth and who discontinued LARC two calendar years prior to the birth—a difference that falls just short of conventional levels of statistical significance (p = .082). We also estimated a model that included separate variables for time since LARC discontinuation and for use of non-LARC contraception in the year before the birth. In that model, we estimated an overall higher likelihood (OR = 2.75, p = .030) of intended live birth for women who did not use another contraceptive method in the year before live birth (results not shown).

The odds of an intended birth is 51% lower for births to women who were cohabiting (OR = 0.49), and 72% lower for births to women who were single (OR = 0.28), compared to births to women who were married. Intendedness odds for birth orders two and three and higher are jointly significantly different from intendedness odds for birth order one (first births). Compared to first births, a 63% lower odds of intended birth is seen for third and higher order births (OR = 0.37). Both the partnership status and birth-order contrasts are greater in the sample restricted to

those women who discontinued LARC in the three years before the birth than in the full sample of durations since LARC discontinuation. Differences by period of birth confirm the patterns as found in the bivariate analysis, with higher odds of the live birth following LARC discontinuation being intended when the woman had a birth in 2009-2017, compared to if the birth occurred in 2005-2008.

LIVE BIRTHS, NEW LARC INSERTIONS, AND STERILIZATIONS AFTER LARC DISCONTINUATION

We next present bivariate and multivariate estimates of the competing discrete-time annual hazard of experiencing one of the three events that end a spell of exposure following LARC discontinuation. These three events are a live birth, a new LARC, and (female and male) sterilization. Bivariate results are presented in Table 4, where we focus on time since LARC discontinuation and comparability of estimates between the NSFG and NLSY. Only years zero, one, and two following LARC discontinuation are observed in the NSFG, as for this analysis we are only able to use those discontinuations observed in the NSFG contraceptive calendar, which goes back only three years before the year of the survey. Year 0, moreover, has too few new reproductive events to include in our multinomial regression. However, sample sizes of women-years of exposure to one of three events in each of years 1 and 2 are much larger than those from the NLSY. This means that instead of having 348 women-years of observation of exposure to the three spell-ending events in year 1, and 198 women-years in year 2, when relying on the NLSY97 only, we have 820 women-years of observation of exposure to the three spell-ending events in year 1, and 324 women-years in year 2, when using the pooled NSFG and NLSY97 data. In year 3, we have 116 women-years of observation of exposure to the three spell-ending

events (using the NLSY97 alone). We pool 118 years of annual exposure to estimate annual event hazards for a combined-duration group of four to eight years since LARC discontinuation, again from the NLSY97 alone.

Table 4 about here

We first discuss results for women ages 20 to 34, using the NLSY97, NSFG, and NLSY97+NSFG pooled. We indicate results of tests for statistically-significant differences between the hazards as estimated from the two different data sources for those similar age ranges. The estimates from the NLSY97 show that the birth hazard is high in the first three years following the year of LARC discontinuation, at 23.7%, 29.8%, and 25.4% of all women still at risk in each of years 1, 2, and 3. Thereafter (years 4 to 8), the annual hazard of birth falls to 13.0% of all women still at risk. The hazard of new LARC use is highest in the two years following the year of last LARC discontinuation, at 5.8% and 8.3% of all women still at risk in each of years 1 and 2, followed by 0.0% and 3.3% annual risks respectively in years 3 and years 4 to 8. The hazard of sterilization following LARC discontinuation is highest in the year after LARC discontinuation, at 5.1%, followed by 3.1% or lower annual risks thereafter. The annual hazards of the three events can also be estimated from the NSFG for the first two years after the year of LARC discontinuation. Apart from a statistically-significant difference between the NSFG and NLSY97 at Year 1, in which 33.0% of post-LARC women give birth, compared to the NLSY's 23.7%, the estimates are seen to be broadly similar. In the pooled NSFG and NLSY97 hazards, we estimate 28.5% and 28.8% respectively as the annual birth hazards in Years 1 and 2. The hazard of new LARC use is at similar levels between the NSFG and NLSY97

in the two years following the year of last LARC discontinuation, at 8.6% and 4.3% of all women still at risk in each of years 1 and 2 estimated from the NSFG, and 5.8% and 8.3% estimated from the NLSY. The risk of sterilization in Year 1, the year after LARC discontinuation, is 7.6% estimated from the NSFG and 5.1% estimated from the NLSY. The higher, 13.9% risk of sterilization estimated from the NSFG in the year following the year of LARC discontinuation for the unrestricted NSFG sample takes advantage of the ages of women including those 35 and older.

Table 5 about here

Multivariate estimates of the associations of women's characteristics measured at the time of LARC discontinuation, and of period and number of years since the year of LARC discontinuation on the likelihood of a live birth, new LARC use, and sterilization after LARC discontinuation based on the pooled NSFG (all women ages 15-44) and NLSY97 are shown in Table 5. Compared to the reference age group 15-24, the likelihood of live birth was lower for women who were aged 30-34 (RRR = 0.46) at LARC discontinuation (with age 35+ in the same direction but not statistically significant). Being Black is associated with a lower likelihood of birth (RRR = 0.61), and Other race/ethnicity a higher likelihood (RRR = 3.54), compared to being non-Hispanic White. Being at parity one at LARC discontinuation is associated with a higher probability of birth than either being nulliparous (RRR = 0.37) or parity two or above (RRR = 0.58). Being married at the time of discontinuing LARC use is also associated with a higher probability of birth compared to either cohabiting (RRR = 0.65) or being single (RRR = 0.46). That being married, having only one birth, and being under age 30 is associated with the

highest birth hazards among women who have discontinued LARC use is consistent with reproductive life-course expectations of who is most at risk of giving birth. Very short (one year) duration of the use of LARC before discontinuing is associated with an elevated risk of birth (RRR = 1.83), as are longer (four or more years) duration of LARC use *before* discontinuing (RRR = 1.55, $p < .10$). Finally, having been four or more years *since* LARC discontinuation is associated with a lower annual birth hazard compared to two years since discontinuation (RRR = 0.34).

The other two spell-ending events whose associations with women's characteristics and duration and period we are interested in are restarting LARC and sterilization. Restarting LARC is mostly dependent on how long they had used their previous LARC device and how much time had passed between discontinuing use of it. Women were much more likely to restart LARC use if they reported that they had used the previous LARC device for only one year (RRR = 2.69), and were much less likely to restart LARC use after three or more years had passed since it was removed (RRR = 0.00 at 3 years and RRR = 0.32 at 4 or more years). Women of Other race/ethnicity (RRR = 5.95) were much more likely to restart LARC use compared to White women. None of the other socio-demographic characteristics were statistically-significantly related to restarting LARC.

Regarding the factors associated with sterilization, these included being over age 35 (RRR = 7.30, compared to being age 15-24 at LARC discontinuation), and having had two or more live births (RRR = 2.64, relative to parity 1). These findings are also consistent with general reproductive life-course expectations of who is most at risk of sterilization (Chandra 1998; Eeckhaut and Sweeney 2016). Compared to a high school graduate, a woman with some college years had a lower annual likelihood of sterilization (RRR = 0.41), but no other education

contrasts, nor race/ethnic or partnership-status variables, were statistically-significantly associated with sterilization. Women are at higher risk of sterilization if they used a LARC for more time before discontinuing: compared to two years of LARC use before removal, an elevated risk of sterilization is seen after three years (RRR = 3.28) and after four or more years (RRR = 3.10) of LARC use before removal. In these cases, we infer that LARC might have been used by the woman to defer a decision to stop childbearing.

INTENDED VERSUS UNINTENDED BIRTH AFTER LARC DISCONTINUATION: SIMULATION RESULTS

Our simulation results are summarized first in Table 6. By nine years after LARC discontinuation, 90.6% of women are projected to have experienced either a birth (66.0%) or another spell-ending event (14.5% a new LARC insertion and 10.1% female or male sterilization). This 66% of women experiencing a birth by nine years following LARC discontinuation is comprised of 46.7% experiencing an intended and 19.2% experiencing an unintended birth, for an intended fertility ratio following LARC discontinuation of 70.8%. In summary, we estimate that just under half of LARC discontinuations will be followed by an intended birth, one in five by an unintended birth, and one in four either by a new LARC or by contraceptive sterilization. Only one in ten LARC discontinuations result in none of these events within nine years.

Table 6 and Figures 1a and 1b about here

The distribution of intended births and unintended births by years since LARC discontinuation is shown graphically in Figure 1a, and the joint distribution of births by intendedness and time since LARC discontinuation is shown in Figure 1b. These distributions illustrate that the fraction of births that are intended is lower at longer durations after LARC discontinuation. In Table 6, we divide the occurrence of each of the three reproductive events into three cumulative periods, 0-2 years, 0-5 years, and 0-8 years. By two years after discontinuation (year 2), two thirds of all post-LARC discontinuation births will have occurred (44.7% out of a total of 66.0% women having a post-LARC birth within nine years). Intended births account for 34.0% of these post-LARC births occurring within two years of discontinuation, and unintended births for 10.7%, for an intended fertility ratio of 76.1%. By five years after discontinuation, most LARC-discontinuing women who will experience a birth (60.3%) have done so, with 43.4% an intended birth and 17.0% an unintended birth for an intended ratio of 71.8%. Only 17.5% of women discontinuing LARC had not experienced a birth, LARC restart, or sterilization after five years. Almost all LARC restarts and transitions to sterilization occur within years 0-5, but another 6% of women give birth in years 6-8.

Switching to a non-LARC contraceptive method between the LARC discontinuation and the birth is the second factor reducing the fraction of births that are intended. The intended fertility ratio among women giving birth without switching to a non-LARC method is 77.4% (see again Table 6). Among women giving birth within three years post LARC discontinuation without switching to a non-LARC method after LARC discontinuation, the intended fertility ratio is 78.8%. The intended fertility ratio is low, at 54.4%, among women who switched to a non-LARC method irrespective of when in the 0-8 years after LARC discontinuation they had a birth.

DISCUSSION

A major rationale in the U.S. for efforts to increase accessibility and use of LARCs has been to reduce unintended pregnancy (ACOG 2009, 2015; Parks and Peipert 2016; Trussell et al. 2013; Wu et al. 2018). LARCs are highly-effective contraceptive methods (Winner et al. 2012), with their under 1% typical-use annual failure rate making them as effective as sterilization, in contrast to typical-use annual failure rates of 9% for the pill and 18% for condoms (Trussell 2011; see also Sundaram et al. 2017). Finer and Zolna (2016) explicitly associate a six percentage-point reduction in the U.S. unintended pregnancy rate between 2008 and 2011 with a contemporaneous increase in LARC use. A somewhat separate question, one that we addressed in the present study, is whether use of LARC leads to subsequent intended births. In addition, we investigated the extent to which women, after LARC discontinuation, go on to have a new LARC insertion or sterilization. Accordingly, we aimed to broaden investigation of LARC beyond the current public health focus on LARCs' potential to reduce unintended pregnancy.

We found that approximately two-thirds (66.0%) of women who discontinue LARC use have a live birth within nine years of discontinuation. This is relatively high given that almost half of LARC-discontinuing women already had two or more children. However, LARC discontinuers also had characteristics facilitative of going on to a next birth, including the two thirds of women who were either married or cohabiting at the time of LARC discontinuation. From our simulations, we estimated a cumulative intended fertility rate of 47%. That is, almost half of LARC discontinuers go on to have an intended birth inside a spell of up to nine years after discontinuing LARC use. This is broadly consistent with Kramer et al.'s (2018) findings from analysis of intentions of current LARC users in 2011-

2015, in which just under half of non-Hispanic White (45%) and Hispanic (38%), and just over half (57%) of Black women expressed an intention to consider a future birth.

The estimated magnitude of intended births within our maximum nine-year exposure period following LARC use is produced by a combination of a relatively high overall cumulative fertility rate among LARC discontinuers and their relatively high intended fertility ratio. Concerning the latter, we estimate that of those women who discontinue LARC and have a birth within nine years, 71% of those births will be intended. This is somewhat higher than the intended proportion of U.S. births overall (62% and 65% in 2005-2009 and 2010-2013, respectively; Hayford and Guzzo 2016). Among women who had a birth a short time after discontinuing LARC (no more than two years after the year of discontinuation) and without having switched to a non-LARC contraceptive method, as many as 79% of their births were intended. This high intendedness ratio suggests that many women were using LARC with the intention to successfully transition to an intended birth.

We also investigated the sociodemographic factors associated with a greater chance of giving birth and the factors associated with a greater likelihood that a birth following LARC use will be intended. Characteristics associated with a higher likelihood of a birth being intended included being married and having had just one, or at most two, births. These characteristics have similarly been found to be predictive of birth intendedness more generally (Mosher et al. 2012). Moreover, they are sociodemographic characteristics that we found to be associated also with a higher likelihood of giving birth following LARC discontinuation. As noted above, both birth hazards and intendedness ratios are at their peak around two years since discontinuation of LARC use. Together, then, the women most likely to have any birth post-LARC-discontinuation are also the women most likely to have a birth

that is intended. This in turn suggests that further increases in LARC use will likely contribute to the public health priority and Healthy People 2020 objective of increasing the proportion of pregnancies that are intended (see FP-1; U.S. Department of Health and Human Services nd).

We also considered two other reproductive behaviors following LARC use and subsequent discontinuation. The majority of women who do not have a birth within nine years after discontinuing LARC either have another LARC reinserted (14.5%), or begin use of (female or male) sterilization (10.1%). Women at highest risk for new LARC use were those who had their LARC devices inserted for no more than one year before discontinuing use. Many of these women likely experienced either IUD expulsion or opted to have their LARC removed because of dissatisfaction (e.g., side effects). By subsequently having a new LARC—possibly of a different type—inserted, they opted to continue highly effective, but reversible, pregnancy protection. This we infer to be either to further postpone a (next) birth or to further postpone a decision about whether or not to have a (next) birth.

Factors predicting a higher likelihood of sterilization are related more to the stage of a woman's reproductive life course. Women most at risk of subsequent sterilization are aged 35+, at parity two or higher, and who had their LARC device inserted for three or more years before its removal. They were also women who may have reached the end of their LARC lifecycle (which is three to ten years, depending on LARC type) and, rather than renew their LARC use, decided to switch to sterilization—possibly because their decision to permanently end childbearing had crystallized.

In summary, although necessarily speculative with respect to women's contraceptive motives, the profiles we estimated of women most at risk of birth, of new LARC use, and of

sterilization were consistent respectively with: (1) using LARC to successfully transition to an intended birth; (2) using LARC to further postpone a birth when the initial LARC device use was discontinued after a brief time, and when the woman may not yet have been ready to have a next birth or to make a decision on ceasing further childbearing; and (3) to transition to a permanent method of preventing further childbearing after the woman has decided that she has achieved her reproductive goals. Taken together, our results suggest that women not only use LARC to reduce the likelihood of an unintended birth, but also to better time their first or next birth, or as part of a trajectory towards definitively completing childbearing.

These varied reproductive behaviors and outcomes following LARC discontinuation make clear that the composition of women who will start and then subsequently discontinue use of LARC while still of reproductive ages will affect LARC-using women's future fertility, and their future intended fertility in particular. This composition may change as LARC use in the U.S. continues to increase (Foster et al. 2015). For example, nulliparous women in 2008 had lower IUD use than parous women (Kavanaugh and Jerman 2018:Table 2), but this is likely to be in part because of provider bias against IUD provision to nulliparous women that is likely to decline in the future (Luchowski et al. 2014). Nulliparous women experienced the largest relative increase in IUD use between 2008 and 2014 (Kavanaugh and Jerman 2018:Table 2), but as recently as 2014 constituted only 6% of all contraceptive users among nulliparous women, versus 18 and 10% of all contraceptive users among women of parity 1-2 and parity 3 and higher, respectively. The more recent increase in implants use has similarly been concentrated among nulliparous women (Kavanaugh and Jerman 2018). If future increases in LARC use continue among nulliparous women, this will imply greater use of LARC to optimize timing of births, thereby potentially both decreasing

unintended fertility and increasing intended fertility. In contrast, if future increases in LARC use were to be concentrated among higher parity women—for example, by LARC acting as a substitute to, or a precursor to use of permanent sterilization for women who plan no future births—this would likely mean that effects on intended fertility will be limited primarily to that resulting from women changing their childbearing plans. However, the effects of LARC on intended fertility could still be sizeable given the high current incidence of sterilization regret (Eeckhaut et al. 2018; Grimes and Mishell 2008). Future research investigating how the composition of LARC users is changing therefore may yield substantial insights about LARC's likely impacts on both unintended and intended fertility.

Results of our analyses advance understanding of how continued increases in LARC use may shape U.S. (intended) fertility by helping women to intentionally time the arrival of their first or next birth, or prevent a next birth. These findings build on previous research showing LARCs' ability to reduce contraceptive failure and unintended fertility (e.g., Winner et al. 2012), and are essential to improving our understanding of the potential broader impact of increasing LARC use on U.S. women's fertility and reproductive life courses.

Considerable efforts have been undertaken in recent years to increase access to LARCs, including efforts to improve LARC supply, provider training, reimbursement, practice guidelines, and product labeling (Biggs et al. 2014; CMS 2016; Pace et al. 2016; Society of Family Planning Guideline 20092 2010). Such efforts may advance women's reproductive autonomy by reducing common barriers to LARC use. Additionally, it is known that women balance a variety of preferred features when selecting a contraceptive method (Lessard et al. 2012), and ensuring that women can use their preferred method has been found to be associated with lower method discontinuation rates (Hubacher et al. 2017; Simmons et al.

2019). Further research that informs about the different purposes for which LARC is used by women to shape their reproductive life courses will also be helpful in informing the above-mentioned efforts by providers and policymakers towards ways that align well with women's contraceptive and reproductive decision-making.

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Table 1: Percent distribution of characteristics of women at LARC discontinuation, United States 2002 to 2016

	NSFG[a]	***NSFG[a] (women ages <35 at LARC discontinuation)***	***NLSY97[b]***
N	718	607	367
Age at LARC discontinuation		p_{diff} = .000	
15-24	30.2	38.7	25.0
25-29	30.1	38.6	59.6
30-34	17.8	22.8	15.4
35+	21.9	*NA*	*NA*
Calendar year of LARC discontinuation		p_{diff} = .000	
2002-2006	9.3	9.0	12.8
2007-2011	35.7	36.8	58.3
2012-2016	55.1	54.3	28.9
Race/ethnicity		p_{diff} = .000	
White	51.9	50.6	69.1
Hispanic	29.7	28.1	19.7
Black	9.5	11.2	10.2
Other	8.9	10.2	1.1
Education at LARC discontinuation		p_{diff} = .046	
<High School	13.8	13.6	20.3
High School	28.2	29.7	28.4
Some College	35.6	38.2	29.2
BA+	22.4	18.5	22.2
Union status at LARC discontinuation		p_{diff} = .188	
Married	49.5	44.3	39.9
Cohabiting	19.8	22.2	28.7
Single	30.6	33.6	31.4
Parity at LARC discontinuation		p_{diff} = .842	
0	16.2	18.3	19.5
1	29.3	33.4	34.7
2+	54.4	48.3	45.8
Duration of LARC use before discontinuation		p_{diff} = .002	
1 year	22.9	22.7	33.4
2 years	20.3	21.7	26.1
3 years	15.9	16.8	15.0
4+ years	40.9	38.8	25.5

Notes: All percentages are weighted. $p_{diff.}$ indicates results of *F*-test of null hypothesis that there is a difference between the NSFG (women ages <35 at LARC discontinuation) and NLSY97 estimates.

Sources: [a] National Survey of Family Growth, 2006-2010, 2011-2013, 2013-2015, and 2015-2017. LARC discontinuation occurred no more than three calendar years before the calendar year of the woman's survey interview.
[b] National Longitudinal Survey of Youth 1997 Cohort.

Table 2: Percent of live births following LARC discontinuation that are intended versus unintended: Women who experienced a live birth in the calendar year of or before survey interview, 2005-2017

	Ever discontinued LARC (*N* = 313)	Discontinued LARC <3 years before the year of birth (*N* = 168)
ALL	67.7	75.8
Time since LARC discontinuation, used non-LARC contraception in the year before the live birth	**	
0-1 years, no method	78.6	78.6
2 years, no method	79.3	79.3
2 years, non-LARC method	62.5	62.5
3 or more years, no method	72.0	NA
3 or more years, non-LARC method	49.0	NA
Age at live birth		
15-24	56.7	68.4
25-29	70.1	75.5
30-34	76.8	87.3
35+	67.7	76.8
Education at live birth		
<High School	64.1	74.1
High School	63.3	63.6
Some College	67.3	77.7
BA+	82.4	94.1
Race/ethnicity		
White	70.3	77.8
Hispanic	68.7	73.9
Black	53.7	65.8
Other	65.8	82.1
Birth order of live birth		**
1	75.8	91.4
2	74.8	88.8
3+	62.4	65.9
Union status at live birth	***	***
Married	77.4	89.0
Cohabiting	56.9	54.4
Single	47.3	40.7
Year of birth	*	
2005-2008	54.9	59.8
2009-2012	67.3	73.6
2013-2017	73.4	80.7

Notes: * $p < .05$, ** $p < .01$, *** $p < .001$. Symbols opposite of variable names indicate results of Chi-squared tests of no difference. All percentages in this table are weighted.

Source: 2006-2010, 2011-2013, 2013-2015 and 2015-2017 NSFG.

Table 3: Likelihood of intended versus unintended (ref. cat.) live birth following LARC discontinuation: Women who experienced a live birth in the calendar year of or before survey interview, 2005-2017 (Odds Ratios)

	ORs	
	Ever discontinued LARC (*N* = 313)	Discontinued LARC <3 years before the year of birth (*N* = 168)
Time since LARC discontinuation, used non-LARC contraception in the year before the live birth	*	
0-1 years, no method	1.00	1.00
2 years, no method	0.81	0.74
2 years, non-LARC method	0.40+	0.33+
3 or more years, no method	0.75	NA
3 or more years, non-LARC method	0.25**	NA
Age at live birth		
15-24	1.00	1.00
25-29	1.85	1.67
30-34	4.15*	2.35
35+	1.70	1.62
Education at live birth		
<High School	1.19	2.14
High School	1.00	1.00
Some College	1.14	1.38
BA+	0.97	3.13
Race/ethnicity		
White	1.00	1.00
Hispanic	1.08	1.29
Black	1.06	1.59
Other	0.90	1.36
Birth order of live birth	*	*
1	1.00	1.00
2	0.95	0.75
3+	0.37	0.21
Union status at live birth	*	***
Married	1.00	1.00
Cohabiting	0.49+	0.17**
Single	0.28*	0.09***
Year of birth		+
2005-2008	0.47+	0.19*
2009-2012	0.85	0.61
2013-2017	1.00	1.00

Notes: + $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$. Symbols opposite of variable names indicate results of Wald test of null hypothesis that the full set of odds ratios are jointly equal to one.

Source: 2006-2010, 2011-2013, 2013-2015 and 2015-2017 NSFG.

Table 4: Annual hazard of experiencing a live birth, new LARC use, or sterilization among women who discontinued LARC use, 2002-2016

Year of follow-up	*N* at risk[a]	No event	Live birth	New LARC use	Sterilization	$p_{diff.}$[d]
			NLSY97			
Year 0	367	98.9	1.1	0.0	0.0	NA
Year 1	348	65.4	23.7	5.8	5.1	NA
Year 2	198	58.8	29.8	8.3	3.1	NA
Year 3	116	72.2	25.4	0.0	2.5	NA
Years 4 to 8	118	81.2	13.0	3.3	2.5	NA
			NSFG (women ages 20-34)			
Year 0	550	97.6	2.4	0.0[b]	0.0[b]	NA
Year 1	366	50.9	33.0	8.6	7.6[b]	NA
Year 2	96	64.9	26.3	4.3	4.5	NA
			Pooled NSFG (women ages 20-34[c]) and NLSY97			
Year 0	917	98.1	1.9	0.0[b]	0.0[b]	.276
Year 1	714	57.9	28.5	7.2	6.4[b]	.021
Year 2	294	60.6	28.8	7.1	3.5	.691
Year 3	116	72.2	25.4	0.0	2.5	NA
Years 4 to 8	118	81.2	13.0	3.3	2.5	NA
			NSFG			
Year 0	718	98.1	1.9	0.0[b]	0.0[b]	NA
Year 1	472	50.6	27.6	8.0	13.9[b]	NA
Year 2	126	63.7	29.4	4.0	3.0	NA
			Pooled NSFG and NLSY97			
Year 0	1,085	98.3	1.7	0.0[b]	0.0[b]	.433
Year 1	820	56.8	26.0	7.0	10.2[b]	.002
Year 2	324	60.6	30.0	6.7	3.1	.694
Year 3	116	72.2	25.4	0.0	2.5	NA
Years 4 to 8	118	81.2	13.0	3.3	2.5	NA

Notes: All percentages in this table are weighted.

[a] Women who experienced an event (i.e., live birth, new LARC use, or sterilization) in a previous follow-up period were excluded from the risk set but, for the NSLY97 women only, could reenter the risk set (i.e., be included in *N* at risk in year 0) after experiencing another LARC discontinuation.

[b] To increase comparability with the yearly reporting of contraceptive use in the NLSY97, in the NSFG, women who reported reliance on sterilization in the calendar year of LARC discontinuation were considered as starting sterilization in year 1 (rather than year 0). Women reporting starting a new LARC in the year of LARC discontinuation (i.e., in year 0) were omitted from the analysis, as we would not be able to detect these short LARC discontinuations based on the yearly reporting of contraceptive use in the NLSY97.

[c] To increase comparability with the ages of women in the NLSY97, we only included NSFG women ages 20-34 at LARC discontinuation for this pooled NSFG and NLSY97 data.
[d] $p_{diff.}$ indicates results of *F*-test of null hypothesis that there is a difference between the NSFG and NLSY97 estimates for that year.

Sources: 2006-2010, 2011-2013, 2013-2015 and 2015-2017 NSFG and NLSY97 2002-2015.

Table 5: Likelihood of live birth, new LARC use, and sterilization after LARC discontinuation (relative risk ratios): Women who discontinued LARC use in the pooled NSFG and NLSY97 data (N = 1,378).

	Live birth	New LARC use	Sterilization
Age at LARC discontinuation		***	
15-24	1.00	1.00	1.00
25-29	1.03	0.52+	0.91
30-34	0.46*	0.60	1.78
35+	0.72	1.21	7.30**
Education at LARC discontinuation			
<High School	1.20	0.85	0.45
High School	1.00	1.00	1.00
Some College	0.99	0.85	0.41*
BA+	1.41	0.77	0.53
Race/ethnicity		**	
White	1.00	1.00	1.00
Hispanic	1.05	1.00	0.74
Black	0.61*	1.65	0.42
Other	3.54**	5.95**	2.82
Parity at LARC discontinuation		***	
0	0.37***	0.70	0.73
1	1.00	1.00	1.00
2+	0.58**	0.67	2.64*
Union status at LARC discontinuation		**	
Married	1.00	1.00	1.00
Cohabiting	0.65+	0.75	0.55
Single	0.46***	1.18	0.52
Duration of LARC use before discontinuation		***	
1 year	1.83**	2.69**	2.10
2 years	1.00	1.00	1.00
3 years	1.30	1.23	3.28*
4+ years	1.55+	0.55	3.10*
Time since LARC discontinuation		***	
1 years	0.82	1.18	2.30
2 years	1.00	1.00	1.00
3 years	0.78	0.00***	0.91
4 or more years	0.34**	0.32+	0.93
Year of LARC discontinuation			
2002-2006	0.69	1.37	0.61
2007-2011	0.91	1.90+	1.14
2012-2026	1.00	1.00	1.00

Notes: + $p < .05$, * $p < .05$, ** $p < .01$, *** $p < .001$. Symbols opposite of variable names indicate results of Wald test of null hypothesis that the full set of variable coefficients are jointly equal to one.

Source: 2006-2010, 2011-2013, 2013-2015 and 2015-2017 NSFG and NLSY97.

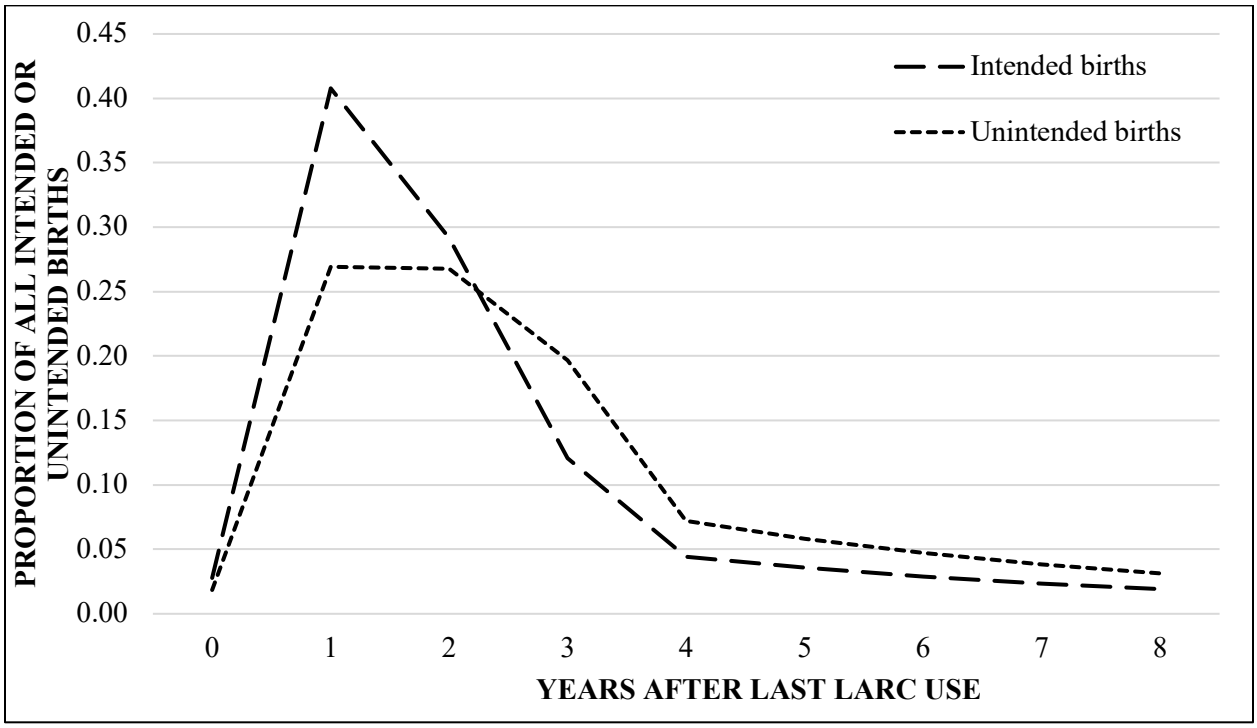
Table 6: Summary statistics of births and birth intendedness by time since LARC discontinuation and whether switched to a non-LARC method after LARC discontinuation

	Years after LARC discontinuation			Contraceptive method in year before birth	
	0-8	0-5	0-2	None	Non-LARC method
Distribution of LARC discontinuation spell-ending events					
Birth	66.0	60.3	44.7	47.2	18.8
intended birth	46.7	43.4	34.0	36.5	10.2
unintended birth	19.2	17.0	10.7	10.7	8.6
LARC restart	14.5	13.1	11.5		
Sterilization	10.1	9.0	6.9		
No event	9.4	17.5	36.9		
Percentage intended among births following LARC discontinuation	70.8	71.8	76.1		
Percentage intended among births following no method	77.4	77.7	78.8		
Percentage intended among births following non-LARC method	54.4	55.4	62.5		

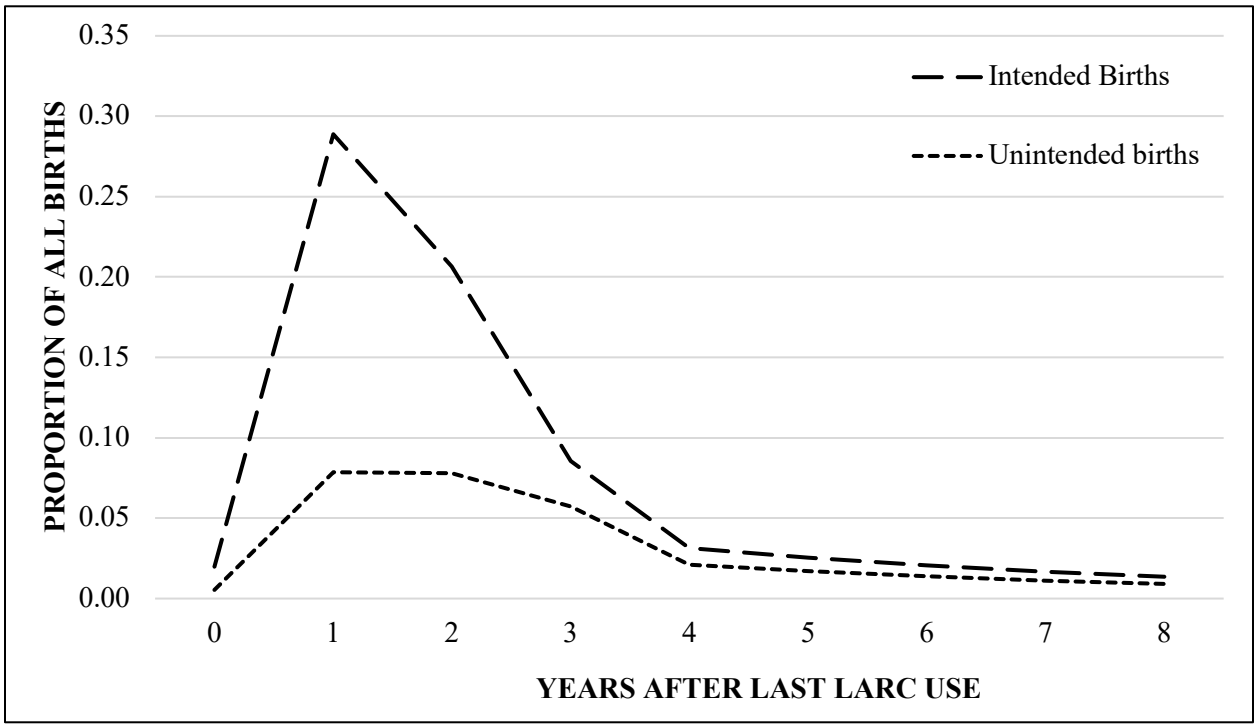
Source: authors' simulations using NSFG 2006-2010, 2011-2013, 2011-2015, and 2015-2017 and NLSY97 2002-2015 data.

Fig. 1 Distributions of intended and unintended births by years after LARC discontinuation

a. Proportion of intended and unintended births, by years after LARC discontinuation



b. Intended and unintended proportions of all births, by years after LARC discontinuation



APPENDIX A: Data and Coding

Data for this study were drawn from the 2006-2010, 2011-2013, 2013-2015, and 2015-2017 rounds of the *National Survey of Family Growth* (NSFG), and from the 1997 cohort of the *National Longitudinal Survey of Youth* (NLSY97) observed through 2015.

The NSFG is a series of cross-sectional surveys of fertility and contraceptive behavior, designed and administered by the *National Center for Health Statistic*s (NCHS), that has been conducted since 1973. The NSFG data are representative of the U.S. non-institutionalized population ages 15-44 when properly weighted,[2] and include oversamples of teens, blacks, and Hispanics. For the 2006-2010, 2011-2013, 2013-2015 and 2015-2017 surveys, a total of 12,279, 5,601, 5,699, and 5,554 women were interviewed, respectively, resulting in response rates of 78%, 73%, 71%, and 67% (U.S. Department of Health and Human Services 2018).

The NLSY97 is a nationally representative probability sample of 8,984 youths aged 12 to 16 years on December 31, 1996, including 4,385 females (Bureau of Labor Statistics nd). The data are representative of people living in the United States during the initial survey round and born between January 1, 1980, and December 31, 1984, and include oversamples of blacks and Hispanics. Participants in the NLSY97 were followed annually through 2011 and biennially thereafter. We use data from the annual waves from 1997 through 2011 and from the biennial 2013 and 2015 waves. We use LARC discontinuations from 2002 onward to best match the timeline of LARC discontinuers in the NSFG. At baseline, there was a response rate of 90.7% and of the original wave 1 (1997) sample, 79% were interviewed in 2015 (Bureau of Labor Statistics nd).

[2] The 2015-2017 NSFG is representative of the U.S. non-institutionalized population ages 15-49, but we limited the sample to respondents aged 15-44 for the current study.

SAMPLES

Our analytic samples were limited to women who reported having used and then discontinued LARC. For the models with birth intendedness as the outcome, we relied on the NSFG only. More specifically, we relied on a sample of women who had a live birth in the year of or the year before survey interview after having discontinued LARC use. We focus on births, which may differ from pregnancies due to miscarriages and abortions, because the latter are poorly reported in surveys (Lindberg and Scott 2018). LARC discontinuation was based on two sources. For discontinuations in the up to three to four years before the survey, information comes from the contraceptive calendar. This calendar measures monthly contraceptive use (up to four methods each month) for a minimum of three, and a maximum of four years (depending on month of interview) prior to the survey interview. We considered women to have discontinued LARC use if they reported using an IUD or implant in a given month of the contraceptive calendar, but not in the following month. For discontinuations that occurred before the contraceptive calendar (i.e., more than three to four years before the survey), information comes from a question about whether the woman has ever used LARC.

For the models of the annual hazards of experiencing any of the three spell-ending outcomes (birth; new LARC insertion; and sterilization), observations of LARC discontinuers in the NSFG and NLSY97 were pooled. For the NSFG, we included only those women who reported having discontinued LARC during the contraceptive calendar period, which covers the three to four year period before the survey (cf., supra). LARC discontinuations identified from the ever LARC question were not included, as for these women, we do not know when they last used LARC, and what intervening events, including any birth, occurred after their last LARC use. For the

NLSY97, LARC discontinuation was based on the answer to the following question, asked in every survey year: "Still thinking about birth control you used within the past 12 months, which one of these methods did you or your partner use most often…?" The NLSY97 provides several options as a response, including IUDs and implants.[3] Women were considered as having discontinued LARC use if they reported using an IUD or implant in a given survey year, but not in the following survey year. We relied on annual data through 2011 and, following the switch to a biennial survey calendar after 2011, we applied rules to impute contraceptive method use in the "off" years 2012 and 2014. First, for all survey years, if a removal is reported on the same year as a birth, we assume that the removal precedes a birth. Similarly, if we see an insertion on the same year as a birth, we assume the insertion follows the birth. These assumptions are carried through to the post-2011 imputation. For example, if a woman is not using LARC in 2011, is using a LARC in 2013, and experienced a birth in 2013, then we assume that the 2013 LARC use started after experiencing the 2013 birth. Therefore, assuming non-use of LARC in 2012. Second, and along those same lines, if a woman is using LARC in 2011 and using LARC in 2013, but has a birth in 2013 then we assume that she was not using LARC in 2012 and thus experiencing a LARC removal. The rationale here is that the very high contraceptive effectiveness of LARC makes it highly unlikely that she was still using a LARC in 2012, and

[3] In 2001 to 2015, before being asked about most used birth control, respondents were first asked how many times they had used condoms. If the respondent stated using condoms 100% of the time, they were not asked further about other birth control method use. In 2001, the survey introduced a separate option for "Norplant," giving us the ability to determine implant LARC use. No other implants (e.g., Implanon) were asked about in any of the NLSYS97 survey years. Implant use before 2015, however, was quite low (it doubled between the 2013-2015 NSFG and 2015-2017 NSFG). Also, implant use tends to be heavily concentrated among childbearing starters and spacers, so the fact that the NLSY97 women are somewhat older in the later years probably lowered the extent of any potential underestimation of implant use in the NLSY97 versus NSFG. The IUD option was available in all survey years.

that any LARC use in 2013 would then be a new insertion. Likewise, we checked that if a woman is using LARC in 2013 and 2015, but has a birth in 2015 then we would assume that she was not using LARC in 2014 and thus experiencing a LARC removal. But, we did not see any such cases in the 2015 interval. Finally, if a respondent had a removal in 2011 or before (and is therefore not using LARC in 2011) *and* they are not using a LARC in 2013, then we assume they are still not using a LARC in 2012. Similarly, if a respondent is not using a LARC in 2011, 2013, and 2015, then we assume the respondent is also not using a LARC in 2014. Thus continuing our exposure period.

NEW LARC INSERTIONS AND STERILIZATION

Both the NSFG and NLSY97 allow for the coding of contraceptive method in the years observed after LARC discontinuation. We use contraceptive information in the years following LARC discontinuation to code a new LARC insertion and either female or male sterilization[4] as spell-ending events (for the NSFG, LARC discontinuations identified based on the contraceptive calendar data only). To increase comparability with the yearly reporting of contraceptive use in the NLSY97, in the NSFG, women who reported reliance on sterilization in the calendar year of LARC discontinuation were considered as starting sterilization in year 1 (rather than year 0). Women reporting starting a new LARC in the year of LARC discontinuation (i.e., in year 0) were omitted from the analysis, as we would not be able to detect these short LARC discontinuations based on the yearly reporting of contraceptive use in the NLSY97.

[4] In the NLSY97, "Vasectomy or Tubal Ligation" was not available as an option for a birth control method before 2007.

We are also interested in whether the woman switched to a non-LARC contraceptive method following LARC discontinuation. We code this in both the NSFG and NLSY97 using information on contraceptive method use in the year before a birth. Specifically, we code whether the woman used a non-LARC contraceptive method versus no contraceptive method in the year preceding the year of a birth that followed LARC discontinuation. If a respondent had a birth in the year of or the year after LARC discontinuation (i.e., "0-1 years"), they were coded as not having used any non-LARC contraception (i.e., value "no method") in the year before the live birth. In the NLSY97, if a respondent had a birth in 2013 or 2015, we considered the method used two years prior to the year of the birth, instead of one year, as we do not know the birth control method in the "off" years 2012 and 2014.

APPENDIX B: Simulation of Cumulative Probability of a Birth and Cumulative Probability of an Intended Birth, an Unintended Birth, of a LARC Restart, and of Sterilization Following LARC Discontinuation

We describe here the structure of, and estimated parameter values for, our simulation model. These quantities are all derived for exposure of up to nine years after discontinuing LARC use. The years are enumerated from year 0 to 8. Year 0 is the year in which the woman last used LARC, otherwise described as the year in which LARC was discontinued. Because this discontinuation may have been early in the year, we allow for a positive probability that she will give birth in year 0. Year 8 is the farthest year out from LARC discontinuation for which we have observed data on giving birth during the post-LARC spell. Competing with the birth event in these nine years are the event of restarting LARC use and the event of sterilization. We derive the annual and cumulative rates of giving birth, of restarting LARC, and of sterilization in these nine years after discontinuing LARC use. Not all women will have experienced one of these three events within nine years. Therefore, discontinuing LARC use may in the simulation model result in an intended birth, an unintended birth, restarting LARC, sterilization, or no event. For births, we distinguish whether they are intended or unintended, and we derive annual and cumulative intended and unintended fertility rates and intended-to-unintended ratios.

MODEL STRUCTURE

Our simulation of intended and unintended fertility after LARC discontinuation, taking into account the competing events of restarting LARC and sterilization, has two components:

(1) The probability of a birth *b* at each annual duration *x* since the year that LARC was discontinued, where this probability is among all women who discontinued LARC use. This

probability is generated from a triple-decrement life table in which restarting LARC *r*, and sterilization *s*, are competing decrements. Following life table notation, we denote by $d_b(x)$ the probability of birth *x* years after the year that LARC was discontinued among all women who discontinued LARC use. We denote respectively by $d_r(x)$ and by $d_s(x)$ the probabilities of LARC restart and sterilization *x* years after the year that LARC was discontinued among all women who discontinued LARC use. The cumulative fertility rate nine years following LARC discontinuation is given by $f = \sum_{x=0}^{x=8}[d_b(x)]$. Analogous expressions can be written for the cumulative rates of restarting LARC and of sterilization.

(2) The intended proportion of all births at duration *x* years since LARC discontinuation. Denoting by $\Pr(B_i(x)|B(x) = 1)$ the probability that a birth at duration *x* is intended, we model this probability as depending on both duration and the fraction of LARC-discontinuing women switching to another, non-LARC method of contraception before giving birth at duration *x*. We expect there to be a higher probability that a birth is intended if the woman uses no contraceptive method after LARC discontinuation than if she switches to another contraceptive method between LARC discontinuation and the birth. Denoting births that occur after no method by $c = 0$, and after a non-LARC method by $c = 1$, we first estimate $\Pr\big(B_i(x,c)\big)$, the birth intendedness probability at duration *x* conditional on whether she switched to another, non-LARC method before the birth. These probabilities are then weighted by the proportions of births at duration *x* that occur after no method and after a non-LARC method, $\Pr(c|x, B = 1)$. We thereby obtain the intendedness probability for all births at duration *x* years since LARC discontinuation:

$$\Pr(B_i(x)|B(x) = 1) = \sum_{c=0}^{1}\big[\Pr(c|x, B = 1)\ \mathrm{x}\ \Pr\big(B_i(x,c)\big)\big].$$

The probability that a woman discontinuing LARC will then go on to have an intended birth *x* years later is given by the product of the above two components:

$$d_{b,i}(x) = \Pr(B_i(x)|B(x) = 1) \text{ x } d_b(x)$$

The intended proportion of births occurring *x* years after LARC discontinuation is given by:

$$p_{b,i}(x) = d_{b,i}(x)/d_b(x)$$

The intended proportions of all births within nine years of LARC discontinuation, which we term the **intended birth ratio**, is given by:

$$p_{b,i} = \sum_{x=0}^{x=8}[d_{b,i}(x)] \ / \ \sum_{x=0}^{x=8}[d_b(x)] \qquad \text{(A1)}$$

The **cumulative intended fertility rate** among women who discontinue LARC, f_i, is given by the numerator of (A1):

$$f_i = \sum_{x=0}^{x=8}[d_{b,i}(x)] \qquad \text{(A2)}$$

The **cumulative unintended fertility rate** among women who discontinue LARC, f_u, is given by the cumulative fertility rate minus the intended fertility rate:

$$f_u = \sum_{x=0}^{x=8}[d_b(x)] - \sum_{x=0}^{x=8}[d_{b,i}(x)] \qquad \text{(A3)}$$

MODEL PARAMETER ESTIMATION

A TRIPLE-DECREMENT LIFE TABLE FOR HAVING A BIRTH, RESTARTING LARC, AND STERILIZATION

The probabilities each year of having a birth *b*, restarting LARC use *r*, and sterilization *s* among a synthetic cohort of women who discontinue LARC are generated in a triple-decrement life table in which duration *x* is the number of years since the year that LARC was discontinued. Events start in year $x = 0$ and continue through $x = 8$. In life table notation, we generate: $\{d_b(x), d_r(x), d_s(x)\}$. These are sufficient to estimate the cumulative probability of giving birth

after LARC use up to nine years after discontinuing LARC, f = Pr(B) = $\sum_{x=0}^{x=8}[d_b(x)]$, and also the cumulative probabilities of restarting LARC or sterilization up to nine years after discontinuing LARC, Pr(R) = $\sum_{x=0}^{x=8}[d_r(x)]$ and Pr(S) = $\sum_{x=0}^{x=8}[d_s(x)]$

[TABLE A1 ABOUT HERE]

ESTIMATION OF THE ANNUAL COMPETING HAZARD PARAMETERS OF THE TRIPLE-DECREMENT LIFE TABLE

The set of parameters needed to estimate the triple-decrement life table are the three annual hazards, $\{q_b(x), q_r(x), q_s(x)\}$. They can be estimated either from the NSFG or NLSY97 or from observations pooled across the NSFG and NLSY97. Pooled estimation is optimal because in the NLSY97 the period over which exposure to a birth following LARC discontinuation is longer (in the NSFG it is no more than three years), and the total estimation sample is then larger. The pooled estimates are presented in Panel A of Table A1. The hazard of birth is highest at durations 1, 2, and 3, at conditional probabilities of 0.246, 0.301, and 0.255 respectively (pooled estimation). The combined probability of either restarting LARC or sterilization at duration 1 is 0.119 and at duration 2 is 0.108, and is low thereafter. Because of the relatively low frequency of observations of women who have not experienced any of these three spell-ending events by duration 4, we assume a constant hazard of birth, LARC restart, and sterilization at each subsequent duration. The annual hazards are estimated respectively at 0.130, 0.033, and 0.025 for birth, LARC restart and sterilization at duration 4 years and over.

USE OF NO METHOD OR SWITCHING TO A NON-LARC CONTRACEPTIVE METHOD AFTER LARC DISCONTINUATION

As noted above, we expect a birth to be more likely to be intended after LARC discontinuation if the woman subsequently uses no other contraceptive method than if the woman switches to another contraceptive method after LARC discontinuation. Only in the NSFG is the intendedness of the birth observed. However, we are able to incorporate NLSY97 data into the estimation of the intendedness probability by breaking down this probability into two components: the probability of switching to another contraceptive method after LARC discontinuation, $\Pr(c|x, B = 1)$, which is estimated from both NSFG and NLSY97 women who have discontinued LARC; and the intendedness probability of births at duration *x* by whether the birth occurred after no method or after a non-LARC method, $\Pr\big(B_i(x, c)\big)$, which is estimated from the NSFG alone.

At durations 0 and 1, the $\Pr(c|x, B = 1)$ component is assigned to "no contraceptive method" (c = 0) for all women. This is necessary because of the annual question about contraceptive method in the NLSY97. At duration 0, we therefore do not know if a reported non-LARC contraceptive method was used before or after the birth. At duration 1, we do not know if any reported non-LARC contraceptive method was used in the previous year, because the previous year is that in which LARC use was last reported as the main contraceptive method. At duration 2, $\Pr(c|x = 2, B = 1)$ is estimated from a pooled NSFG and NLSY97 sample of births following LARC discontinuation. At duration 2, we are able to observe any non-LARC contraceptive method used one year before in both the NSFG and the NLSY97, although there are some differences in the operational definitions. In the NSFG, c = 1 is defined for any use of a non-LARC method in the year before the year of the birth at duration 2 years. In the NLSY, c =

1 is defined by the main contraceptive method used in the year before the birth at duration 2 years. Consequently, the estimated probability of a non-LARC method in the year before the birth is higher in the NSFG than in the NLSY97 (results not shown). We effectively average over the two in using a pooled-survey estimation. For the years 2012 and 2014 in the NLSY, when it had moved to biennial surveying, no contraceptive method is asked. The contraceptive method before the birth (none versus non-LARC) is then assigned to be the method used two years before the year of the birth. For durations 3 and above, we estimate $\Pr(c|x, B = 1)$ from an NLSY-only sample. For three or more years after LARC discontinuation, we need to use the NSFG question about whether she has ever used LARC. We do not know from this question when she last used LARC, nor what intervening events, including any birth, occurred between her last LARC use and the year of the recent birth (for which intendedness is reported). Therefore, we use the NSFG at three years and more only in estimating the intendedness probability given contraceptive method use (for which no NLSY97 data are available). For years 3 to 8, we assume a constant probability of no contraception and non-LARC contraceptive method. This constant probability assumption is made both because of our needing to use data from the NLSY97 alone at these durations and because of the small number of observations at each individual duration year above three years post-LARC-discontinuation.

We show in Panel B of Table A1 our estimates of the probability of no method and the probability of switching to another contraceptive method between discontinuing LARC and giving birth, $\Pr(c|x, B = 1)$. As noted above, in most cases this probability is approximated by the contraceptive method, if any, used in the year before the year of giving birth following LARC discontinuation. Also as noted above, only for years of birth at durations 2 and above do we allow for a positive probability of having switched to a non-LARC contraceptive method. At

duration 2, this probability of use of a non-LARC contraceptive method in the year after the year of last LARC use is estimated by pooling across the NLSY97 and NSFG samples. We find that 59.9% of births occurring two years after the year of last LARC use followed a year in which no contraception was used, with the other 40.1% of births occurring two years after the year of last LARC use followed a year in which a non-LARC contraceptive method was used. We find that 47.2% of births occurring three or more years after the year of last LARC use at durations 3 to 8 followed a year in which no contraception was used, and the other 52.8% of births followed a year in which a non-LARC contraceptive method was used.

BIRTH INTENDEDNESS BY DURATION SINCE LARC DISCONTINUATION AND WHETHER THE WOMAN SWITCHED TO ANOTHER CONTRACEPTIVE METHOD AFTER DISCONTINUATION

Finally, estimates of the probability that a birth is intended as a function of both duration (number of years x) since LARC discontinuation and whether in the year before the year of the birth the woman used another (non-LARC) form of contraception, $\Pr\big(B_i(x,c)\big)$, are presented in Panel C of Table A1. These are estimated from the NSFG alone. We find that births with the highest probability of being intended are those occurring within two years of discontinuing LARC and after using no contraception in the year before the year of the birth. Births in the year after the last year of LARC use have a 0.786 probability of being intended. Births two years after the last year of LARC and following no contraceptive method use in the previous year have a 0.793 probability of being intended. Births occurring three or more years after the last year of LARC discontinuation and without any contraception used in the year prior to the year of the birth have a 0.720 probability of being intended. Births occurring two years after LARC use and

following a year in which a non-LARC contraceptive method was used have a 0.625 probability of being intended. Births occurring three or more years after last LARC use and following a year in which a non-LARC contraceptive method was used have the lowest probability of being intended, at 0.490.

Appendix Table 1: Intended Fertility Simulation Model Parameters

A. Conditional probabilities (annual hazards) of having a Birth, LARC Restart, or Sterilization

	Spell-ending event		
Years since LARC discontinuation	Birth	LARC restart	Sterilization
0	.017	.000	.000
1	.246	.067	.052
2	.301	.078	.030
3	.255	.000	.024
4 to 8	.130	.033	.025
Sample n			1,801

B. Proportion Using No Contraceptive Method versus a non-LARC Contraceptive Method in the Year Before the Birth

Years since LARC discontinuation	No method (t-1)	non-LARC method (t-1)
0 or 1	1	0
2	.599	.401
3 to 8	.472	.528
Sample n		349

C. Proportion Intended for Births by Years Since LARC Discontinuation and Whether No Method or a non-LARC contraceptive Method was Used in the Year Before the Birth

Years since LARC discontinuation	No method (t-1)	non-LARC method (t-1)
0 or 1	.786	n.a.
2	.793	.625
3 to 8	.720	.490
Sample n	186	127

Sources: Panels A and B, National Longitudinal Survey of Youth 1997 Cohort, and National Survey of Family Growth, 2006-2010, 2011-2013, 2013-2015, and 2015-2017 (NSFG); Panel C, NSFG only.