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Descriptive Finding

The contribution of assisted reproductive technology to fertility rates and parity transition: An analysis of Australian data

Ester Lazzari

Edith Gray

Georgina M. Chambers

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The contribution of assisted reproductive technology to fertility rates and parity transition: An analysis of Australian data

Ester Lazzari¹

Edith Gray²

Georgina M. Chambers³

Abstract

BACKGROUND

Despite the widespread use of assisted reproductive technology (ART), few studies analyse its impact on the total fertility rate (TFR). Furthermore, very little is known about how ART affects fertility at older reproductive ages and contributes to family size.

OBJECTIVE

We aim to quantify the contribution of ART to total and age-specific fertility rates and in relation to the transition to first and subsequent births in Australia.

METHODS

Using data from a comprehensive clinical registry of ART treatments, age-specific ART and non-ART fertility rates were calculated and used to decompose the change in the TFR between 2010 and 2017 into ART and non-ART components.

RESULTS

ART represented an increasing and relevant contribution to the TFR, corresponding to an impact of the order of 4% to 5% per annum, or approximately to 1 in 20 births. Increasing fertility rates at age 33 and above exerted a positive effect on the overall TFR, and they were almost entirely attributable to the increasing use of ART. Women resorted to ART especially to have a first child.

CONTRIBUTION

This is the first study to provide a detailed examination of the contribution of ART to age-specific fertility rates and in relation to parity transition. While most studies focus on the impact of ART on the overall TFR, the importance of ART for the recovery of births at older reproductive ages could be underestimated.

¹ Australian National University, Australia. Email: ester.lazzari@anu.edu.au.

² Australian National University, Australia.

³ University of New South Wales, Australia.

1. Introduction

The shift to later parenthood represents one of the major demographic changes of the past few decades (Frejka and Sardon 2006; Frejka and Sobotka 2008). Demographic literature has shown that women delay childbearing due to a number of factors (Mills et al. 2011). These include completing education, establishing a job (Blossfeld and Huinink 1991; Kneale and Joshi 2008; Ní Bhrolcháin and Beaujouan 2012), and not being in a committed relationship (Cooke, Mills, and Lavender 2012; Testa 2007). The low period fertility levels registered in high income countries might be interpreted as a temporary consequence of lower fertility at younger ages, which will eventually be recuperated later in reproductive life, during a phase of fertility “recuperation” (Kohler, Billari, and Ortega 2002). However, from a biological perspective, the recovery of births cannot be taken for granted since the exposure is shifted to older ages when the probability of giving birth is lower because of the negative effect of age on fecundity (Leridon 2004; ESHRE Capri Workshop Group 2005). As a consequence of later patterns of childbearing, both the prevalence of age-related infertility and the risk of remaining involuntarily childless have increased. Thus, in demographic research, the topics of childbearing delay and childlessness have been increasingly concerned with assisted reproduction as it may be a potential tool to counteract the effect of declining fecundity with age (Leridon 2017) and, ultimately, reduce cases of involuntary childlessness (te Velde et al. 2012).

Assisted reproductive technology (ART) refers to a group of medical interventions aiming at assisting couples experiencing infertility to achieve a pregnancy. Latest estimates indicate that in most European countries an average of 2.6% of births are conceived through ART every year (The Annual Capri Workshop Group 2020), while in the United States ART accounted for slightly less than 2% of births in 2018 (Centers for Disease Control and Prevention 2018). Although ART has had an increasing contribution to the total birth rate, it cannot fully compensate for the drop in fecundity with age (Leridon 2004; Wyndham, Figueira, and Patrizio 2012) since the effectiveness of ART treatments also rapidly declines with female age. For example, for women commencing ART treatment when aged 30 to 34 years, the estimated chance of live birth is 65% to 74% after three complete treatments, while it is only 18% to 23% when aged 40 to 44 years (Chambers et al. 2017).

Quantifying the contribution of ART to current fertility levels is of interest to policymakers in low fertility countries characterised by a pattern of delayed childbearing. While most previous studies have focused on the impact of ART on overall fertility levels (Hoorens et al. 2007; Sobotka et al. 2008; Habbema et al. 2009; Leridon and Slama 2008), little is known about how ART affects fertility at older reproductive ages and contributes to family size, reflected by the transition to first and subsequent births. Moreover, despite Australia having a supportive policy context for using ART compared to international

standards (Chambers et al. 2009), resulting in one of the highest ART utilisation rates in the world (Adamson et al. 2018), the contribution of ART to the total fertility rate (TFR) remains unknown.

Using data from a comprehensive clinical registry of ART treatments, the aim of this study is to address these gaps in knowledge by (1) quantifying the impact that ART treatment has had on total and age-specific fertility rates in Australia, and (2) evaluating the role played by ART for women by parity (i.e., those who are childless and those who wish to achieve a larger family size). In Australia, the national health insurance scheme, Medicare, subsidises two-thirds of the cost for all ART treatments deemed clinically necessary, with no restrictions based on age, parity, or number of cycles already performed (Commonwealth Government 2018), which are limitations commonly in place in other countries. Socially infertile patients (same-sex couples and singles) cannot qualify for the government rebate, but they can access ART treatment. Such a supportive funding environment, particularly the lack of an age limit for access to infertility treatment, places Australia in a unique position to investigate the contribution of ART at advanced reproductive ages. The findings may serve as a point of reference for countries willing to increase their ART coverage and to relax age limitations in ART use.

2. Materials and methods

Births resulting from ART treatment were sourced in a de-identified format from the Australia and New Zealand Assisted Reproduction Database (ANZARD), a comprehensive women-based clinical registry comprising information on all ART cycles conducted in Australia, and the resulting pregnancies and birth outcomes (Newman, Paul, and Chambers 2021). All fertility clinics are required to report this information to ANZARD as part of their licencing requirements; therefore, full registration of ART births can be assumed. ART treatments, such as in vitro fertilisation, involve the fertilisation of an egg outside the body and the transfer of the embryo into a woman's uterus to achieve pregnancy (Zegers-Hochschild et al. 2017). More traditional infertility treatments, such as intrauterine insemination (IUI) and ovulation induction (OI), involve fertilisation inside the body and thus tend to be less complex in nature and are often used as a first-line treatment for infertility. Only births resulting from treatments involving ART are included in ANZARD.

Population birth data by single age are drawn from the Australian Bureau of Statistics (ABS) birth registrations collection, while population birth data by age group and parity are sourced from the National Perinatal Data Collection (NPDC), which is a women-based collection of data on pregnancy and childbirth for all births in Australia. The number of non-ART babies (babies conceived without ART) are obtained by

subtracting the number of ART-conceived babies from the number of total babies born for each year and age of mother. Since ART does not include IUI and OI, the group of non-ART births also include women that used these techniques to achieve pregnancy.

The TFR for a given year t can be derived from the sum of ART and non-ART age-specific fertility rates (f_x) as

$$TFR(t) = \sum_x f_x^a + \sum_x f_x^n = \sum_x \left(\frac{b_x^a}{W_x} \right) + \sum_x \left(\frac{b_x^n}{W_x} \right) \quad (1),$$

where b_x^a is the number of babies born to women of age x and conceived through ART, b_x^n is the number of babies born to women of age x and conceived without ART, and W_x is the total number of women in the population at age x .

From the age-specific fertility rates, the mean age at childbearing (MAC) is computed separately for women giving birth by means of ART (MAC_a) and women giving birth without ART (MAC_n), as in

$$MAC_a = \frac{\sum_x f_x^a * m}{\sum_x f_x^a} \quad \text{and} \quad MAC_n = \frac{\sum_x f_x^n * m}{\sum_x f_x^n} \quad (2),$$

where m is the midpoint for each single-age interval.

To isolate the contribution of ART at older reproductive ages, the change in the TFR between 2010 and 2017 is decomposed into age-specific components. The decomposition is based on changes in the age-specific fertility rates for the age groups 15 to 32 ($\Delta f_{(15-32)}$), 33 to 38 ($\Delta f_{(33-38)}$), and 39 to 49 ($\Delta f_{(39-49)}$) over the eight-year period of analysis. The difference in the TFR between 2010 and 2017 can then be obtained as

$$TFR(2017) - TFR(2010) = \Delta f_{(15-32)} + \Delta f_{(33-38)} + \Delta f_{(39-49)} \quad (3).$$

Age-specific fertility rates for the three age groups are further decomposed into their ART ($\Delta f_{(15-32)}^a$; $\Delta f_{(33-38)}^a$; $\Delta f_{(39-49)}^a$) and non-ART ($\Delta f_{(15-32)}^n$; $\Delta f_{(33-38)}^n$; $\Delta f_{(39-49)}^n$) components to disentangle the contribution of ART. An overall decomposition of the changes in the TFR between 2010 and 2017 for each single-age category is also presented.

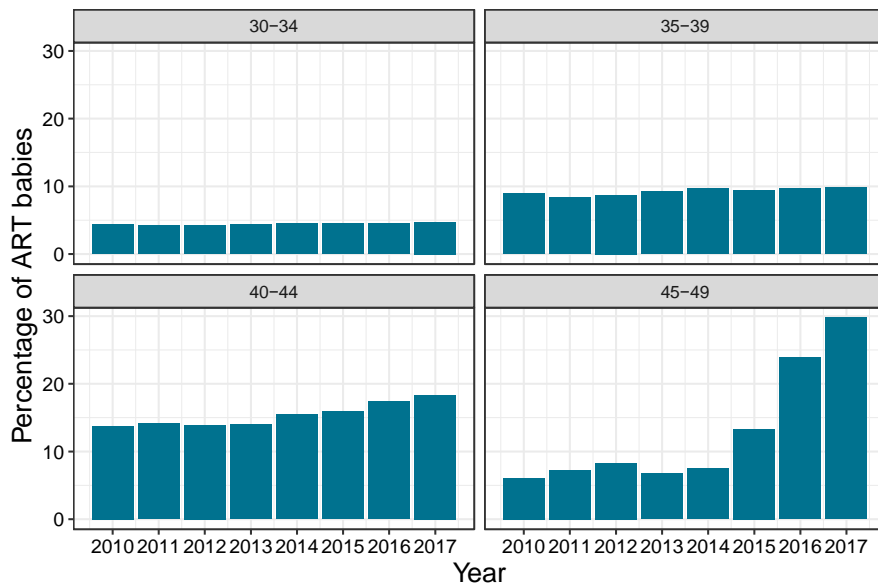
The higher incidence of multiple pregnancies (duplets and triplets) following ART compared to spontaneously achieved pregnancies is an aspect to generally take into account when estimating the contribution of ART to the TFR as it could lead to an overestimation of the effect of ART on fertility. This is an undesirable consequence of treatment since multiple births are associated with increased risks of maternal and neonatal complications (Gupta et al. 2020). However, compared to international standards, Australia has a very low ART multiple birth rate (Newman, Paul, and

Chambers 2021; Maheshwari, Griffiths, and Bhattacharya 2011). Hence, in this study, all multiple pregnancies due to ART are considered as intended.

3. Results

The proportion of ART babies out of total babies increased for women in all age groups over the eight-year period of analysis (Figure 1). The most substantial increase occurred among women aged 45 years and above, ranging from 6.1% in 2010 to 29.7% of total babies born in 2017. An important increase was also registered among women aged 40 to 44, with the share of ART babies increasing from 13.7% in 2010 to 18.3% in 2017. Among women aged 35 to 39 and 30 to 34, there was a similar, albeit more modest, rising trend corresponding to an average annual growth of 1.5% and 1.1%, respectively. Statistics for the proportion of ART babies born to women aged 30 and below are not shown as they accounted for only 1% of total babies on average.

Figure 1: Percentage of ART babies out of total babies born in 2010–2017 by age group of mother, Australia

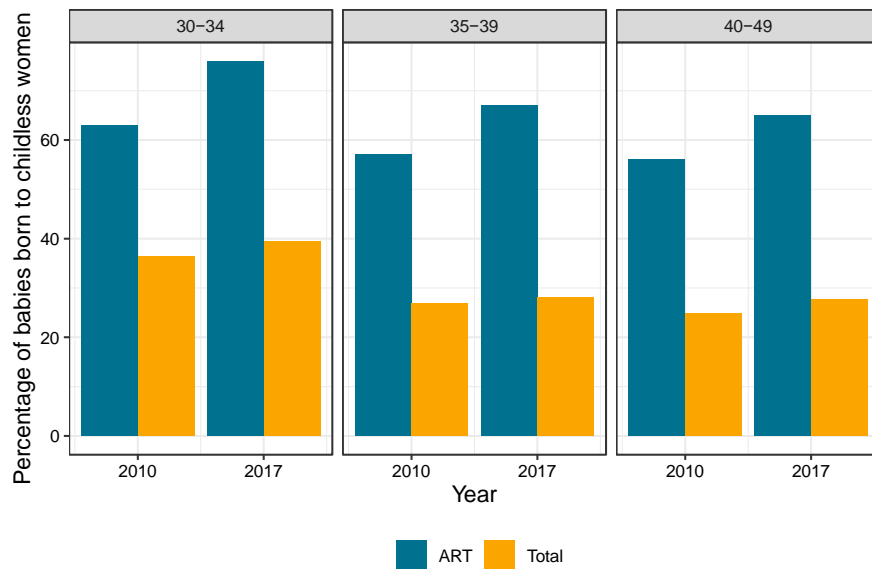


Source: Authors' calculations using ANZARD and ABS data.

Despite the substantial increase in the share of ART babies to women aged 40 and above, the majority of assisted childbearing happened before that age. In 2017, 34% of ART babies occurred among women aged 30 to 34 and 39% among women aged 35 to 39. At the same time, there has been an increase in the proportion of ART babies among women aged 40 and above, moving from 13% in 2010 to 17% in 2017, which has contributed to the increase in the mean age of mothers giving birth via ART over time.

The parity distribution of women who conceived using ART differed markedly from that of the general population. The proportion of babies born to childless women was higher among women giving birth using ART for all age categories (Figure 2). In 2017, 76% of women giving birth using ART between 30 and 34 years of age had no previous children, compared to only 39% in the general population. Similarly, among women aged 35 to 39 and 40 and above, the proportion of first-time mothers in the ART group was 64% and 62%, respectively, while it was only 28% and 27% at the population level. Between 2010 and 2017, the percentage of babies born to childless women has continued to increase in both ART and non-ART groups, although at a faster pace among the group of women giving birth using ART.

Figure 2: Percentage of babies born to childless women out of total babies born in 2010–2017 by age group of mother and method of conception, Australia



Source: Authors' calculations using ANZARD and NPDC data.

In 2017, 4.9% of babies born in Australia were the result of conception via ART. This represents a 20% increase over the corresponding rate in 2010 (4.1%). Between 2010 and 2017, the MAC has increased for women conceiving both spontaneously and by means of ART, although more so among women using infertility treatment (Table 1). In 2010, the MAC of women conceiving spontaneously was 30.3, compared to 35.2 for women using ART. By 2017, the MAC has increased to 30.8 years and 35.8 years for non-ART and ART births, respectively. ART births contributed to increase the TFR by between 0.08 and 0.09 annually, corresponding to an impact of the order of 4% to 5%. Due to the introduction of a cut in public funding for ART by the Australian government in 2010, patients were incentivised to bring forward their treatment cycles to 2009 (Chambers et al. 2012). This explains the relatively high ART contribution to the TFR in 2010 followed by a slight decrease in the following year.

Table 1: Mean age at childbearing and total fertility rate by method of conception, Australia, 2010–2017

	2010	2011	2012	2013	2014	2015	2016	2017
<i>MAC</i>	30.50	30.54	30.59	30.68	30.79	30.86	31.05	31.10
<i>MAC_n</i>	30.30	30.35	30.39	30.48	30.57	30.64	30.82	30.84
<i>MAC_a</i>	35.21	35.24	35.30	35.28	35.36	35.48	35.70	35.83
<i>TFR</i>	1.95	1.92	1.93	1.88	1.79	1.79	1.79	1.74
<i>TFR_n</i>	1.87	1.84	1.85	1.80	1.71	1.71	1.70	1.65
<i>TFR_a</i>	0.080	0.076	0.078	0.080	0.082	0.082	0.087	0.088
<i>TFR_a</i> (%)	4.1	3.9	4.0	4.3	4.6	4.6	4.9	5.0

Source: Authors' calculations using ANZARD and ABS data.

Notes: *MAC* (observed mean age at childbearing), *MAC_n* (estimated non-ART mean age at childbearing), *MAC_a* (estimated assisted mean age at childbearing), *TFR* (observed total fertility rate), *TFR_n* (estimated non-ART total fertility rate), *TFR_a* (estimated assisted total fertility rate). Results are obtained by using equations (1) and (2).

Table 2 reports the results of the decomposition analysis. Declines in age-specific fertility rates at age 32 and below accounted for most of the decline in the overall TFR (95%), while decreases in fertility rates at older reproductive ages had only a marginal effect. The decline in fertility among women aged 15 to 32 was mainly attributable to declines in non-ART age-specific fertility rates (−0.199), while the decrease in ART age-specific fertility rates had only a small contribution (−0.001). Among women age 33 to 38, the decline in non-ART age-specific fertility rates (−0.022) was partly offset by the increase in ART age-specific fertility rates (0.003). After age 38, the change in fertility rates was mostly driven by the increase in ART fertility rates (0.007), while non-ART fertility rates had only a modest contribution (0.001).

Table 2: Decomposition of the contribution of age-specific ART and non-ART fertility rates to changes in the total fertility rate, Australia, 2010–2017

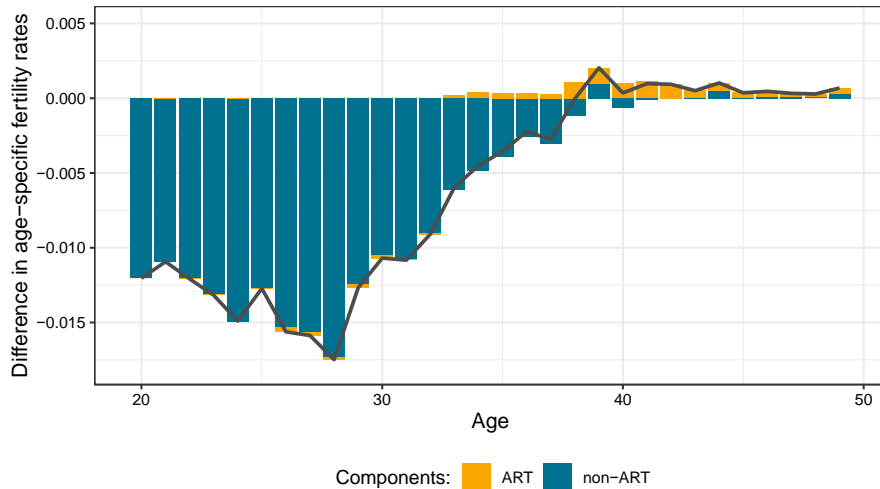
	$\Delta f_{(15-32)}$	$\Delta f_{(33-38)}$	$\Delta f_{(39-49)}$	ΔTFR
ART	-0.001	0.003	0.007	0.008
non-ART	-0.199	-0.022	0.001	-0.219
Total	-0.200	-0.019	0.008	-0.211

Source: Authors' calculations using ANZARD and ABS data.

Notes: $\Delta f_{(15-32)}$ (change in the age-specific fertility rates for the age group 15–32 between 2010 and 2017), $\Delta f_{(33-38)}$ (change in the age-specific fertility rates for the age group 33–38 between 2010 and 2017), $\Delta f_{(39-49)}$ (change in the age-specific fertility rates for the age group 39–49 between 2010 and 2017), ΔTFR (observed change in the TFR between 2010 and 2017). Results obtained using equation (3).

Figure 3 summarises the overall role that changes in age-specific ART and non-ART fertility rates played in determining the observed decline in the overall TFR between 2010 and 2017. The solid line indicates the total observed change in the fertility rate for each single year of age, while the stacked bars show the amount of change caused by a variation in ART (in yellow) and non-ART (in blue) fertility rates. Up to age 32 there has been a slight decrease in the contribution of ART to age-specific fertility rates, after which ART has consistently contributed to their increase. Such contribution became almost the only positive component of change from age 40 onwards, indicating that increasing age-specific fertility rates at older reproductive ages were largely driven by the increasing use of ART.

Figure 3: Changes in age-specific ART, non-ART, and total fertility rates between 2010 and 2017, Australia



Source: Authors' calculations using ANZARD and ABS data.

4. Conclusion

Our examination showed that, during the study period, ART represented an increasing and relevant contribution to the Australian TFR. The only exception to this overall rising trend was the year 2011, mainly as a result of the introduction of a cap in public funding for infertility treatment in the previous year (Chambers et al. 2012). ART has contributed to an average annual increase of the TFR of 0.08 from 2010 to 2017, corresponding to an impact of the order of 4% to 5% per annum, or approximately to 1 in 20 births. ART has largely contributed to raise the fertility rate at advanced reproductive ages, with the mean age at childbearing of women giving birth following ART being on average 5.0 years higher than that of women giving birth spontaneously. We estimated that in 2017 almost 1 in 5 babies born to women aged 40 to 44 and almost 1 in 3 babies born to women aged 45 and above were conceived using ART. The decomposition of the changes in fertility rates into ART and non-ART contributions revealed that an increasing number of ART births occurred among women aged above 32, which offset almost half of the ongoing decline in non-ART fertility rates. From age 40 onwards, increases in age-specific fertility rates were almost entirely driven by the increasing use of ART. Compared to the

general population, for all age groups women giving birth using ART were more often of first parity. This indicates that ART mainly contributed to reduce childlessness by helping women to have their first child, rather than increasing family size, even at old reproductive ages (40 and above).

It should be noticed that the age-related increase in the proportion of babies conceived using ART is accompanied by the increase in the proportion of babies born as a result of donor eggs, which, among patients aged 40 and above, can substantially increase success rates (Yeh et al. 2014). While most couples prefer to conceive a biologically related child, at advanced reproductive ages this goal is less likely to be achieved due to reduced number and quality of eggs. In Australia, as in most countries, the practice of using donor eggs is particularly common among women aged 45 and above, representing approximately 80% of total ART treatments (Newman, Paul, and Chambers 2021). The use of donor eggs coupled with the increasing number of ART treatments undertaken by women of advanced reproductive age have contributed to the rising proportion of ART births at these ages.

Some caution should be taken in interpreting these results. First, the availability of ART might have supported provision of treatment to couples that would have eventually conceived without it (Cahill et al. 2005; de La Rochebrochard et al. 2009; Troude et al. 2012). This is a common limitation among analysis estimating the contribution of ART to the TFR (Hoorens et al. 2007). In the present era of modern birth control methods, it is impossible to assess the age-specific distribution of natural conceptions, and insights into the age-related decline in the biological capacity to reproduce can be gained only from the study of natural populations. Eijkemans et al. (2014) estimate that at age 41, 50% of women have reached the end of their reproductive life, increasing to 90% at age 45. Hence, it is likely that the large majority of births conceived through ART at age 40 and above would not have happened without the treatment. More fundamentally, this confirms that the substantial contribution of ART at old reproductive ages (and especially for very late conceptions) shown in this study largely reflects the present reality. In contrast, our analysis may more importantly overestimate the contribution of ART at younger reproductive ages, when the reproductive potential is still substantial (93% of women at age 30 and 80% of women at age 35 are still able to conceive spontaneously). Second, in Australia, public attitudes towards ART have become increasingly more positive with community approval increasing from 77% in 1981 to 91% in 2011 (Kovacs et al. 2012). However, the acceptance level of ART largely varies across countries (Szalma and Djundeva 2019), and results may not be completely generalisable to other settings with different sociocultural attitudes to ART. Third, caution should be paid in relation to the potential influence of ART on the timing of births as the availability of infertility treatment may induce couples with poor knowledge regarding the decline in

ART success rates with age to further delay childbearing, increasing their risk of underachieving reproductive plans.

While this study necessarily focuses on female fertility rates due to the data available, infertility remains a couple-level outcome, and future research should shed more light on the contribution of both partners, as well as that of non-traditional patients such as single women and same-sex couples, to changes in fertility rates as a consequence of ART utilisation. Furthermore, despite male reproductive potential declining later and at a slower rate than for women (Sartorius and Nieschlag 2010), there is also a trend to men delaying family formation (Lazzari 2021), which contributes to overall fertility decline.

Our findings in general indicate that the growing utilisation of ART has become relevant when assessing recent fertility trends. It emerges that without births that result from ART, the Australian TFR would be substantially lower and that ART has a larger contribution in reducing childlessness rather than increasing family size. Additionally, this study clearly shows that recent increases in fertility rates at advanced reproductive ages are largely driven by the increasing use of ART, which may fuel further discussion on the potential role of ART in supporting fertility recuperation in a context of delayed childbearing.

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