Approaching the Limit: Long-Term Trends in Late and Very Late Fertility

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AN UNDERSTANDING of the long-term trends in the age limits of childbearing is important for evaluating contemporary below-replacement fertility and its consequences. Never before in history have European women borne their first children as late, on average, as at the beginning of the twenty-first century (Kohler et al. 2006; Prioux 2005). The entry into parenthood has also been increasingly delayed in many other developed countries, including the United States, where fertility postponement is particularly pronounced among non-Hispanic whites (Lesthaeghe and Neidert 2006; Martin et al. 2005). In light of these trends, Kohler, Billari, and Ortega (2002) have argued that contemporary fertility trends in developed countries are characterized by increasing, persistent, and arguably irreversible delays in childbearing across a wide range of socioeconomic conditions. This postponement of childbearing implies that a rising fraction of women attempt to become mothers at late ages and face concerns about age-related increases in infertility, increased uncertainty about the ability to achieve desired fertility, and a reduced ability to adjust to shocks to one's childbearing plans due to unanticipated union dissolution, delays in finding a suitable partner, miscarriages, or longer-than-expected waiting times to pregnancy.

There are social and biological limits to the delay of childbearing. The perception of normative age limits to fertility postponement was common in the past and continues in some contexts. Settersten and Hägestad (1996), for instance, in a survey of Chicago's Metropolitan Area, find that 78.5 percent

of respondents perceive a normative "age deadline" for childbearing. In the Northern Italian region of Friuli-Venezia Giulia, Billari, and Micheli (1999) find that 90 percent of the respondents perceive an age deadline for childbearing. Average age deadlines range from 40.4 years to 41.4 years, not unlike similar estimates obtained by Toulemon and Leridon (1999) for France. These age deadlines correspond closely to observed ages at last birth in France (Toulemon and Leridon 1999) and are close to estimates of the biological limit to childbearing that date back to Henry (1961). At the same time, books aiming for a popular readership such as *What Every Woman Should Know About Fertility and Her Biological Clock* (Birrittieri 2004) and brochures on "Preserving your fertility" (Resolve 2005) are proliferating, targeted at women who have delayed—or anticipate delaying—childbearing to relatively late ages. Amazon.com,[1] for instance, lists 1,207 books under the subject "infertility," 450 of which were published after the year 2000. The demand for such information indicates that current age deadlines for fertility are being challenged and biological limits are being pushed.

This process, however, is not without obstacles. In a much-noted book on *Creating a Life: Professional Women and the Quest for Children*, Hewlett (2002) describes the difficulties educated women face in having children at advanced ages, including job market concerns, problems finding a mate, subfecundity and infertility, and unrealized fertility desires. To address the challenges of delayed childbearing, such websites as www.extendfertility.com[2] promise "Fertility—Freedom—Finally" through an egg freezing service that "offers [women] the opportunity to effectively slow down their biological clocks," allowing them to take better advantage of an "astounding number of opportunities" such as obtaining advanced degrees, pursuing successful careers, and leading rich and demanding lives. A recent report prepared by RAND Europe advocates the incorporation of assisted reproductive technologies in the policy mix to increase fertility in Europe (Grant et al. 2006).

This article has three goals. First, we compare late childbearing in the United States and several European countries. We then discuss the physiological aspects of late fertility and review recent analyses of the extent to which assisted reproductive technologies affect the probabilities of conceiving and having successful pregnancies at advanced childbearing ages. Finally, we present analyses of late and very late fertility in Sweden, a country for which the relevant data are of high quality, cover a long time period, and permit calculation of conventional age-specific fertility rates, as well as occurrence-exposure rates that eliminate the influences of shifts in the parity distribution.

Comparative analysis of late childbearing

We define *late fertility* as childbearing at ages 40 years and above, and *very late fertility* as childbearing at ages 45 and above. We refer to ages 40 years and above as *advanced* childbearing ages, and to ages 45 years and above as *very*

advanced childbearing ages. For selected countries, Table 1 shows that, in the United States and western Europe, after declines during the 1970s and early 1980s along with the overall decline in fertility, late and very late childbearing have been increasing in recent years in terms of: total number of births; age-specific fertility rates at advanced and very advanced childbearing ages (ages 40 and above); and the fractions of all births and of the TFR that occur above age 40 years (for similar analyses, see Prioux 2005). Some of these changes have been substantial. In the United States, for instance, age-specific fertility rates at ages above 40 have more than doubled since 1980, while remaining at levels below those observed in several of the European countries in Table 1. On average in the United States, as of 2003, .046 births or 2.3 percent of the TFR occurred to women after age 40 (based on the sum of age-specific fertility rates). Moreover, the number of births in the United States to women aged 40 or older has increased more than fourfold since 1980, with 2.6 percent of all births in 2003 occurring to women aged 40 and over, and the number of births to women above age 50 has increased more than twofold since 1997 to 323 births in 2003 (Martin et al. 2005).

The fraction of fertility and of all births occurring to women above age 40 is larger in some European countries than it is in the United States. Sweden, for example, exhibits higher age-specific fertility rates at ages 40–44, with 9.6 annual births per thousand women aged 40–44 years; and the fraction of the TFR that occurs above age 40 is close to 3 percent—corresponding to an average of about .05 births after age 40 for each woman. The fraction of the TFR occurring after age 40 exceeds 3 percent in Italy and Spain, with these higher fractions in both countries due to lower fertility rates at younger ages rather than to higher fertility rates above age 40. Italy exhibits the highest fraction of births—3.9 percent—that occur to women aged 40 years and over.

Despite the recent increases in late and very late fertility in the countries in Table 1, however, the age-specific fertility rates at ages above 40 years in 2002/03 are far lower than the rates observed earlier in the twentieth century or prior to the demographic transition. In Sweden around 1860, for instance, age-specific fertility rates were around 127 births per thousand women aged 40–44 and 20 per thousand women aged 45–49, implying that on average around 0.7 births—or about 16 percent of the TFR—occurred to women after age 40 (Statistics Sweden 1999). More recently, the peak in the age-specific fertility rate at advanced ages in the United States occurred during 1956–57, with 16.3 births per thousand women aged 40–44 and 1.1 per thousand women aged 45–49 (NCHS 1997)—rates similar to those observed around 1970 in Italy and the Netherlands. During the peak of the baby boom in the United States, therefore, about 2.3 percent of the TFR occurred above age 40, or about .09 births per woman after age 40 in the 1957 synthetic cohort.

Across all countries in Table 1, the recent increase in the number of births to women aged 40 and older is substantially larger than the increase in age-specific fertility rates. The increase in the number of births to older

TABLE 1 Fertility at advanced and very advanced childbearing ages, United States and selected European countries, 1970–2002/03

Country/year	TFR	Number of births			Percent of all births occurring to women aged 40+	Age-specific fertility rate (per 1,000)		Sum of ASFRs above age 40	Percent of TFR above age 40	Percent aged 40–49 among women 15–49
		Total	Age 40–44	Age 45+		Age 40–44	Age 45+			
United States										
1970	2.48	3,731,386	49,952	2,146	1.4	8.1	0.1	40.8	1.6	25.4
1980	1.84	3,612,258	23,090	1,200	0.7	3.9	0.2	20.5	1.1	19.8
1990	2.08	4,158,212	48,607	1,638	1.2	5.5	0.2	28.5	1.4	24.4
2000	2.06	4,058,814	90,013	4,604	2.3	8.0	0.5	42.5	2.1	30.1
2003	2.04	4,089,950	101,005	5,845	2.6	8.7	0.5	46.0	2.3	31.1
Sweden										
1970	1.92	110,131	1,446	103	1.4	6.2	0.4	33.1	1.7	27.3
1980	1.68	97,046	987	31	1.0	4.2	0.2	21.7	1.3	23.6
1990	2.13	123,923	2,260	70	1.9	7.1	0.2	36.7	1.7	30.0
2000	1.54	90,432	2,203	101	2.5	7.7	0.3	40.3	2.6	29.1
2003	1.71	99,151	2,770	117	2.9	9.6	0.4	50.0	2.9	29.0
Denmark										
1970	1.99	70,791	774	46	1.2	5.4	0.3	28.4	1.4	25.9
1980	1.55	57,288	367	17	0.7	2.5	0.1	12.8	0.8	23.2
1990	1.67	63,431	747	29	1.2	3.9	0.2	20.2	1.2	28.9
2000	1.77	67,080	918	15	1.4	6.6	0.2	34.0	1.9	29.1
2003	1.76	64,679	1,460	56	2.3	7.5	0.3	39.1	2.2	30.0

France										
1970	2.47	847,565	18,795	1,311	2.4	11.4	0.8	60.8	2.5	27.8
1980	1.95	800,223	6,600	486	0.9	4.5	0.3	24.0	1.2	23.8
1990	1.78	762,292	12,481	500	1.7	5.8	0.3	30.6	1.7	24.9
2000	1.88	774,680	18,723	676	2.5	8.7	0.3	45.1	2.4	29.6
2002	1.88	761,539	19,889	811	2.7	9.1	0.4	47.4	2.5	29.8
Netherlands										
1970	2.57	238,882	5,321	441	2.4	14.0	1.2	75.9	3.0	24.7
1980	1.60	181,242	1,381	120	0.8	3.4	0.4	18.9	1.2	21.7
1990	1.62	197,629	2,171	226	1.2	3.8	0.5	21.4	1.3	25.8
2000	1.72	206,598	4,013	122	2.0	6.5	0.2	33.5	1.9	29.5
2002	1.73	202,083	4,353	147	2.2	6.8	0.3	35.4	2.0	30.3
Italy										
1970	2.43	900,971	29,946	2,243	3.6	15.8	1.2	85.2	3.5	28.4
1980	1.64	640,356	12,217	867	2.0	6.3	0.5	33.9	2.1	27.4
1990	1.33	569,246	10,679	415	1.9	5.4	0.3	28.0	2.1	26.2
2000	1.24	543,114	15,511	915	3.0	7.5	0.4	39.7	3.2	27.9
2003	1.29	524,742	19,585	892	3.9	9.2	0.5	48.3	3.8	29.8
Spain										
1970	2.88	n/a	n/a	n/a	n/a	26.1	3.5	148.0	5.1	27.1
1980	2.22	570,547	15,134	1,675	2.9	14.8	1.4	80.9	3.6	25.2
1990	1.36	401,272	7,094	487	1.9	5.9	0.4	31.4	2.3	23.7
2000	1.24	397,530	9,733	430	2.6	6.6	0.3	34.6	2.8	26.0
2002	1.27	418,725	11,751	560	2.9	7.6	0.4	40.0	3.1	27.0

SOURCES: United States: Martin et al. (2005) and US Census Bureau («www.census.gov», accessed 15 February 2007). For European countries: Eurostat («http://epp.eurostat.cec.eu.int», accessed 15 February 2007), ISTAT («http://demo.istat.it», accessed 15 February 2007) and Council of Europe (2004).

women thus results in part from an increase in the fraction of women of childbearing ages who are above 40. For instance, the fraction of women aged 40 years and older among women 15–49 years old has increased more than 50 percent since 1980 in the United States, and 23–40 percent in Sweden, Denmark, and the Netherlands; somewhat smaller increases have occurred in Italy and Spain during the 1990s. A substantial part of the increase in the number of births to women above age 40 is therefore due to compositional age-structure changes among women in childbearing ages. In addition, even controlling for these age-structure effects, the recent increase in age-specific fertility rates above age 40 is in part compositional and cannot be fully attributed to rising probabilities of conception or of successful pregnancy at advanced childbearing ages.[3] In particular, the age-specific fertility rates above age 40 in Table 1 are affected by a shift in the parity distribution of women at advanced childbearing ages. Most important in this context is the increase at ages 40 and above of childless women or women at parity one who delayed fertility and intend to have a first child or an additional child at advanced ages. For instance, an increase in the fraction of women who are still childless at age 40 can result in an increase in age-specific fertility rates above age 40—even if the probability of having a first child for women who are childless at age 40 is constant. In many countries such an increase in the proportion of women who are childless has occurred in recent years (see Table 2 for examples). In the United States, the proportion of childless or primiparous women at ages 40–44 increased by 74–80 percent during 1980–2000. To the extent that this trend is due to postponed fertility rather than increases in desired childless-

TABLE 2 Parity distribution of women at advanced childbearing ages, United States, Sweden, and Netherlands, 1970–2000

		Fraction of women at		
Country/age	**Year**	**Parity 0**	**Parity 1**	**Parity 2**
United States	1970	0.11	0.11	0.23
(women aged 40–44)	1980	0.09	0.11	0.25
	1990	0.14	0.17	0.35
	2000	0.16	0.19	0.34
Sweden	1970	0.15	0.20	0.34
(women aged 40)	1980	0.12	0.16	0.42
	1990	0.12	0.16	0.45
	1999	0.15	0.14	0.41
Netherlands	1980	0.12	0.10	0.42
(women aged 40)	1990	0.15	0.15	0.47
	1998	0.18	0.15	0.42

SOURCES: NCHS (1999) for United States; Kohler and Ortega (2002) for Sweden and the Netherlands

ness or single-child families, it is likely to have contributed to an increase in age-specific fertility rates above age 40.

In the broader sense, this shift in the parity distribution reflects the changing birth-order composition of late and very late fertility (see also Prioux 2005; Toulemon 2005). In natural fertility populations, as well as during periods of high fertility, childbearing at advanced and very advanced ages was primarily due to high-parity births occurring to relatively fecund couples. In contemporary low-fertility contexts, late and very late childbearing occurs increasingly at low parities, primarily first or second children. In Sweden in 2005, for instance, more than 50 percent of all births to women aged 40–44 years were first or second children, up from around 37 percent in the late 1960s. Similarly, in the United States about 50 percent of births to women aged 40–44 were first and second children in 2002.[4] This reversal of the parity composition of women who engage in childbearing at late and very late ages contributes to the scientific and popular concerns about the consequences of delayed childbearing since failures to achieve fertility desires at low parities—and particularly a failure to have at least one child—have significantly larger implications for individual well-being than do the widespread over- or undershooting of desired fertility at higher parities (Kohler et al. 2005; Quesnel-Vallée and Morgan 2003).

In summary, the evidence reported above shows that the widely observed increases in the number of births and age-specific fertility rates above age 40 result from compositional factors—age distribution and parity composition—in addition to the behavioral, biological, and technological changes that affect the probability of giving birth conditional on a woman's age and parity. The distinction between compositional factors and factors related to the probability of giving birth conditional on age and parity is essential for interpreting trends in late childbearing and the implications for well-being of unrealized fertility desires. So far, this aspect has been surprisingly absent in many discussions of the increased number of births at advanced ages (exceptions include Prioux 2005; Toulemon 2005). Moreover, studies of late and very late fertility in many countries are hampered by the fact that high ages at birth may be reported with error, and the fact that official statistics often report births at very advanced ages in an open-ended age category, usually 45 years and older. The US Census Bureau, for example, adjusted its practice only in 1997 by shifting the open-ended interval to 50+ years (Martin et al. 2005).

Physiological factors in late fertility

Menopause is the uppermost limit for the reproductive life span of women. While there have been cases of post-menopausal fertility with assisted reproductive technologies (ART), including recently a 62-year-old California

woman who gave birth to her twelfth child after in vitro fertilization (IVF) treatment (MSNBC, 21 February 2006), the onset of permanent sterility usually precedes menopause by some years (te Velde et al. 1998). Age at menopause averages about 50–51 years in Western countries and shows a remarkable variation among women, from age 40 to age 60 years. The variation partially depends on a woman's contraceptive use and parity (Kaufert et al. 1987; Stanford et al. 1987; van Zonneveld et al. 2001), but a large fraction of the variation—possibly as much as 85 percent— may be genetic (de Bruin et al. 2001). Moreover, there seems to be no evidence for an increase in the age at menopause in recent years that would parallel increases in longevity and would be consistent with a "rescaling" of the life course in response to prolonged life expectancies (Lee and Goldstein 2003; Leridon 2004).

A woman's chance to start a pregnancy that ends in a live birth declines and ends several years before menopause. This finding is supported by studies of populations not using contraception. Bongaarts (1983) reports that the median age of women at last birth is fairly stable around 40–41 years in natural fertility populations across different historical settings, signaling the approaching end of reproduction several years prior to menopause. Leridon (2004) estimates that in noncontracepting populations the mean ages for three markers of women's transition into post-reproductive life are 41.2 years for the delivery of the last birth, 44.7 years for the onset of sterility, and 50.5 years for menopause.

Fecundability—that is, the probability of conceiving within one month of unprotected sexual intercourse—has been shown to decline with age for both men and women (e.g., Auger and Jouannet 2005; Dunson et al. 2002; Gougeon 2005; Larsen and Vaupel 1993; Leridon 2004; Menken 1985; Skakkebæk et al. 2006). Biological aging has a strong impact on sterility especially above age 35 (e.g., Leridon 2005; Menken et al. 1986). Table 3 reports some frequently cited estimates of sterility by age. An additional sign of decreasing reproductive ability associated with delayed childbearing is the rising demand for infertility treatment by means of assisted reproductive technologies, including intracytoplasmatic sperm injection (ICSI), in vitro fertilization, gamete intrafallopian transfer (GIFT), and zygote intrafallopian transfer (ZIFT).[5] The number of ART cycles performed in the United States, which does not include insemination according to the CDC (Centers for Disease Control and Prevention) definition, has almost doubled from 64,810 (0.9 per thousand women aged 15–49) in 1996 to 122,872 (1.7 per thousand women aged 15–49) in 2003 (CDC 2005). The number of live birth deliveries resulting from ART has increased from 14,507 in 1996 to 35,785 (+147 percent) in 2003, and the number of infants born as a result of ART rose from 20,480 in 1996 to 48,756 (+138 percent) in 2003. In 2003, therefore, about 1.2 percent of children born in the United States were conceived using ART,

TABLE 3 Estimates of percent of couples definitely sterile (unable to have a live birth) by woman's age

Age	Vincent (1950)	Henry (1953) (England)	Henry (1953) (Norway)	Leridon (1977)	Trussell and Wilson (1985)	Menken and Larsen (1986)
20	4	3.5	3.5	3		4
25	6	6	5	6	6	7
30	10	11	8	10	11	12
35	17	19	13	17	16	22
40	37	33	24	29	24	46
45	75	58	50	50	58	

NOTES: The estimates for Menken and Larsen (1986) are averaged across the seven studied populations, with interpolation to obtain estimates at exact ages. All estimates are obtained from natural fertility populations or pre-transition populations, with the exception of Menken and Larsen (1986), which is based on twentieth-century populations.
SOURCE: Adapted from Leridon (2005).

as compared to 0.5 percent in 1996. ART use, however, differs substantially across countries. In Denmark, where ART treatments are generally covered by public health insurance, more than 4.2 percent of children during 2002–04 were born after assisted reproduction. In 2002, the contribution of ART to overall fertility was achieved using 11,311 cycles, or about 9 cycles per thousand women aged 15–49 years (Andersen and Erb 2006). In addition to these ART cycles, 9,526 insemination cycles were performed during 2002, resulting in a total of 17 ART and insemination cycles per thousand Danish women aged 15–49 years. This represents the highest ART use in Europe. Counting also foreign adoptions and children conceived through insemination, more than 7 percent of Danish children born in 2002 were not "naturally conceived" (Andersen and Erb 2006).

Several reasons have been advanced to explain the decline in fecundability with a woman's age (e.g., see Gougeon 2005). The variability of the length of menstrual cycles increases with age; this makes it more difficult for a couple to achieve conception, and it may be a sign of predisposition to fetal problems (Billari and Rosina 2001; Spira et al. 1993). The difficulty of predicting this pattern could explain some of the high female sterility and infecundity at older ages (Rahman and Menken 1993). In addition, sexual activity generally declines both with age and with the length of a given union (Brewis and Meyer 2005; Weinstein et al. 1993). Until recently, however, it has not been possible to distinguish the effect of this changing level of sexual activity from the effect of age on fecundity. Colombo and Masarotto (2000) have overcome this limitation through the combination of appropriate menstrual and intercourse diary data that allows the inference of daily fecundability (see also Rizzi et al. 2005). Using such data, Dunson et al. (2002) have also shown that women's fecundability begins to decline in the late 20s, with substantial decreases by the late 30s.

A study of natural fertility populations showed that declining fecundity with maternal age is primarily a result of aging at the level of the ovaries (O'Connor et al. 1998). In the peri-menopausal years, which are of key interest when looking at the possibilities of postponing childbearing, declining fecundity is a function of both declining fecundability and increasing risk of fetal loss (Wilcox et al. 1988), much of which is due to chromosomal abnormalities. In addition, Andersen et al. (2000) found in a longitudinal population-based register study in Denmark that maternal age at conception is a strong and independent risk factor for fetal death, irrespective of reproductive history, and they concluded that the chances of successful pregnancies in women aged 40 and over are poor. Nevertheless, there is also some evidence that the obstacles to late fertility are diminishing even in the absence of fertility treatments. In a Canadian medical database embracing the period 1961–93, for instance, fetal death rates substantially decreased over time, although they remained significantly higher for women aged 40 and over (Fretts et al. 1995). Leridon's (2005) estimates of infertility by age also indicate that more women than previously thought may be able to conceive at ages between 30 and 45 years, as many as 83 percent at age 40, but that many women at advanced childbearing ages will not be able to have a live birth because of miscarriage probabilities reaching 20 percent at age 37, 30 percent at age 44, and 40 percent at age 48. With ART using the woman's own embryos, the percent of live births per cycle also declines steeply with age, starting in the mid-30s at about 40 percent and falling below 5 percent for women in the early 40s. In contrast, the high success rate with ART using egg donation, which is around 40–50 percent without a marked age decline until the mid-40s, indicates that poor egg quality is the primary barrier to pregnancy in older women (CDC 2005). In addition to reduced fecundity, women aged 40 and over also face substantially higher risks of adverse health outcomes during pregnancy compared to younger women (Dolk et al. 2005; Gourbin 2005; Jolly et al. 2000; Ziadeh and Yahaya 2001); and for women aged 45 and over, Dildy et al. (1996) found a higher incidence of pre-gestational and gestational complications.

While the decline of fecundability with age as a function of the age of the male partner is less widely documented, there is evidence of a significant decline by the late 30s of the male (e.g., de la Rochebrochard and Thonneau 2005), potentially reinforced by a secular trend toward reduced sperm quality (Slama et al. 2004; Swan 2000). This finding is consistent with the high demand for ICSI treatment among couples seeking ART—about 30 percent of all in vitro cycles in Denmark and about 56 percent in the United States are ICSI (Andersen and Erb 2006; CDC 2005)—indicative of the significant number of couples with male infertility, caused in most cases by testicular failure and poor semen quality. Jørgensen et al. (2006) have also estimated that as many as 30 percent of young Danish men have semen quality in the

subfertile range, and more than 10 percent in the infertile range—consistent with similar estimates for the United States (Acacio et al. 2000). Children of older men who are more likely to be affected by poor semen quality have an increased risk of schizophrenia and new mutation autosomal dominant disorders (Thacker 2004). There is also mounting evidence that changing lifestyles and environmental exposure to chemical substances (e.g., to endocrine disrupters) are behind the trends in occurrence of male reproductive health problems, including testicular cancer, undescended testis, and poor semen quality (Andersen and Erb 2006).

In conclusion, our review of the literature on physiological factors affecting late fertility reveals substantial uncertainty about the feasibility of widespread and reliable childbearing above age 35 years for women, especially for first births. An example is the following summary statement (directed to women) by the American Society for Reproductive Medicine (2003): "Your fertility naturally declines as you get older. When this decline begins, however, and the rate at which it progresses vary widely in women. Generally, fertility begins to drop in your late 20s or early 30s and falls more rapidly after the age of 35." In vitro fertilization, intrauterine insemination, and oocyte donation may partially overcome age-related declines in fecundity. In one of the few available studies, Leridon (2004) evaluates the probability of childless women becoming mothers as a function of the age at the onset of the attempt to conceive. Leridon's simulation model shows that out of 100 women starting to become pregnant at age 30, 91 women will have a child without ART, 3 will have a child using ART, and 6 will remain childless. If the starting age is 40, 57 women will have a child without ART, 7 women will do so with ART, and 36 women will remain childless. Hence, if the attempt to become pregnant begins at age 40, ART will increase the probability of a successful pregnancy by a mere 7 percentage points, or, put another way, ART reduces the number of women who remain involuntarily childless from 43 to 36 out of 100 whose attempt to become pregnant starts at age 40. Leridon (2004) thus gives a two-fold recommendation: "The message for a woman aged <35 years trying to conceive is: be patient.… The message for women aged >35 years is: be impatient. The chances of a rapid spontaneous conception are still significant, but in case of failure, ART will not fully compensate for the years (and the chances of conceiving) lost." Consistent with these findings, Bewley et al.'s (2005) review concludes that "[w]omen want to 'have it all,' but biology is unchanged; deferring defies nature and risks heartbreak. If women want room for manoeuvre [with respect to fertility] they are unwise to wait till their 30s."

Despite skeptical and cautious perspectives in the medical literature, Beets et al. (1994) argue that the information available to women may not be sufficient to make them aware of the uncertainties associated with plans for childbearing after age 35. The insufficiency of information about the feasibility

of childbearing at advanced ages was the theme of a *Newsweek* cover story, "The truth about fertility: Don't believe the hype—even fertility specialists say younger is better" (27 August 2001).[6] Moreover, in Bewley et al.'s (2005) view, the availability of in vitro fertilization may "lull" women into waiting for a suitable partner, concentrating on their careers, and achieving security and a comfortable living standard, not recognizing that IVF is expensive and prone to high failure rates. In IVF with non-donor eggs, by far the most common procedure, the failure rate per cycle to result in a live birth is more than 60 percent for women younger than age 35 and increases to more than 85 percent for women in their early 40s (CDC 2005).

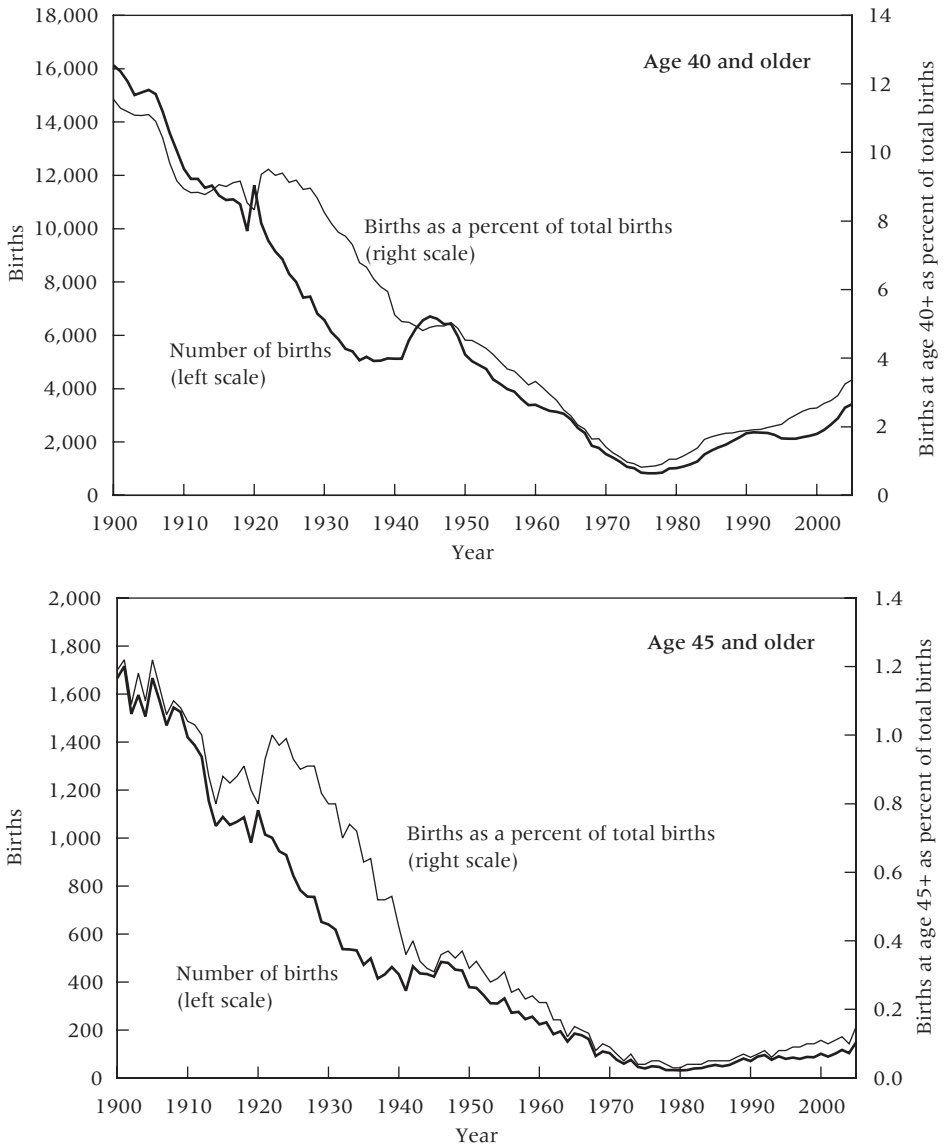
Information campaigns and technological progress in reproductive science may improve women's ability to predict the change in fecundity with age. For instance, a recent study reports that a technique that uses a mathematical model and transvaginal sonography has been shown to predict ovarian reserve, and thus the reproductive age that marks the distance of a woman from menopause. The study concludes that "The ability to make a direct assessment of ovarian reserve would be of enormous benefit to women who are being considered for assisted reproductive technologies, … and for women who are considering delaying starting a family for personal or professional reasons" (Wallace and Kelsey 2004).

Approaching the limit: Trends in late and very late fertility in Sweden

We use high-quality data from Sweden to assess recent trends in late and very late fertility. The data for our calculations are from the Swedish population-register system, which covers the whole population of the country and all vital events. We use two types of data. First, our analysis of long-term trends in late and very late fertility and the latest ages of giving birth relies on accurate registration of births by age of the mother starting in the late nineteenth century. A limitation of the birth register is that, until 1954, the data are on deliveries rather than births. Concerning long-term trends, however, this is a minor limitation as is demonstrated by the fact that no clear break in the time series is discernible around 1954. Second, for our analysis of first births above age 40, we use occurrence-exposure rates based on the number of first births and on the number of childless women, which are available for cohorts born from 1925 onward and for periods since 1970. The occurrence-exposure rates are derived from longitudinal information on the dates of each recorded birth of every woman in Sweden (see also Andersson 1999; Andersson and Guiping 2001).

Figure 1(a) graphs the number of births to mothers aged 40 and over during 1900–2005. The two lines represent the absolute number of births (scale on the left vertical axis) and the percentage of births to mothers aged

FIGURE 1 Late and very late fertility in Sweden: Number of births and births as a percent of total births, 1900–2005



NOTE: Data until 1954 pertain to deliveries, and from 1955 onward to live births.

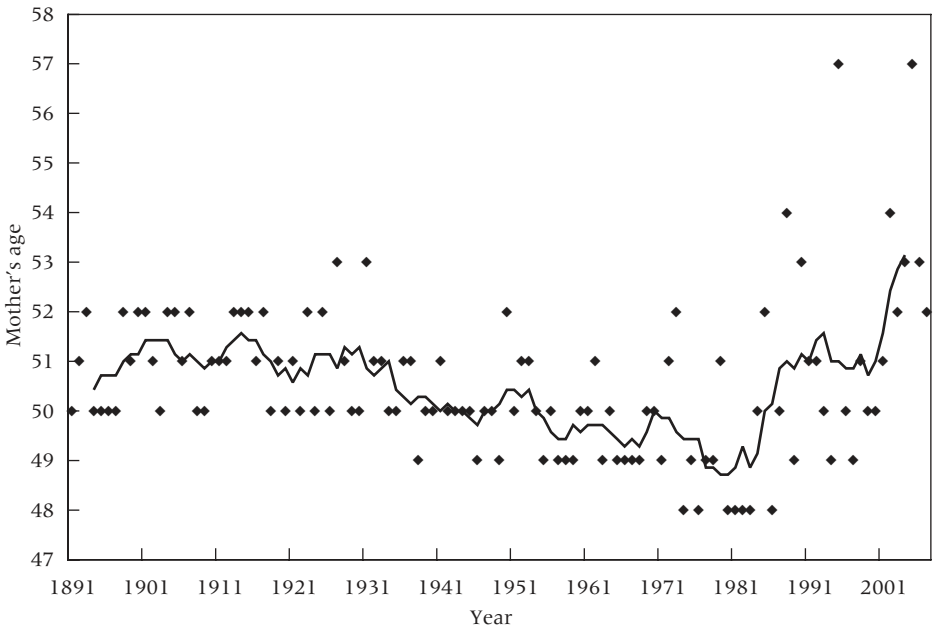
40+ years among all births (scale on the right vertical axis). Births at advanced ages (40 years and above) declined from the beginning of the twentieth century until the end of the 1970s, in both absolute and relative terms. This trend mirrors the pattern seen in Table 1 for Sweden and other developed

countries. At the end of the 1970s, however, the sharp decrease in the absolute number of births and in the percentage of births to mothers aged 40 and over stops, followed by a relatively slow upward trend through the end of the time series in 2005. The highest number of births to mothers aged 40 and over, which occurs at the beginning of the time series in 1900, is 16,125 births, or 11.6 percent of all births occurring during the year 1900. The minimum is reached in 1977, with 823 births, or 0.9 percent of total births occurring in the calendar year 1977. In 2005, the figure is up to 3,420 births, or 3.4 percent of total births.

A similar pattern can be observed for very late births, those to mothers aged 45 and over (Figure 1b). The long-term downward trend starts from a maximum of 1,716 births (1.2 percent of total births) in 1901, reaches the minimum of 31 births (0.03 percent of total births) in 1980, and begins a slow upward trend, reaching 149 births (0.15 percent of total births) in 2005. The share of births to women aged 45 and above among all births to women aged 40 and over also declined during 1900–80, and stabilized—or even increased slightly—in recent years. At the beginning of the twentieth century, births to mothers aged 45 and over were around 10 percent of all births to mothers aged 40 and over; this figure declined to about 3–4 percent at the end of the observation period.

While childbearing at ages 40+ and 45+ currently remains far below the levels observed earlier in the twentieth century and prior to the demographic transition, extreme cases of mother's advanced age at birth have occurred increasingly in recent years. Figure 2 shows the highest ages at birth in each year during the twentieth century in Sweden. While the population-level study of trends in extreme ages has received considerable attention in research on mortality (e.g., Wilmoth et al. 2000; Wilmoth and Lundström 1996), this has not been the case with fertility, perhaps for reasons of data quality. The dots in Figure 2 represent the highest age at birth in any given calendar year, and the line depicts a five-year moving average that better represents trends. The figure reveals that the extreme age at birth in Sweden has been stable around the age of 51 from the end of the nineteenth century to the period preceding World War II. Subsequently this extreme age declined, reaching a trough in the late 1970s. This decline also corresponds to the decline in the absolute and relative number of births to women aged 40+ or 45+ years. Beginning in the 1980s, this trend reversed, and the oscillation around age 51—which was characteristic of the first part of the twentieth century—was restored. There is some indication that the extreme age at birth has been increasing since the 1990s, particularly during the most recent years. For instance, the oldest Swedish woman giving birth during the twentieth century was recorded in 1993 at age 57, with another event of the same kind occurring in 2003. The oldest woman giving birth was 53 years or older in seven years during the 20-year period from 1986 to 2005. In contrast, an age at birth of 53 years or older was attained only twice in the 95 years of our time series prior to 1986.

FIGURE 2 Extreme ages at birth in Sweden, 1891–2005



NOTE: Dots represent the highest age at birth in any given calendar year, and the line depicts a five-year moving average. Until 1954 the extreme age at birth may sometimes be slightly overestimated, as our data refer to deliveries, including still births, rather than to live births.

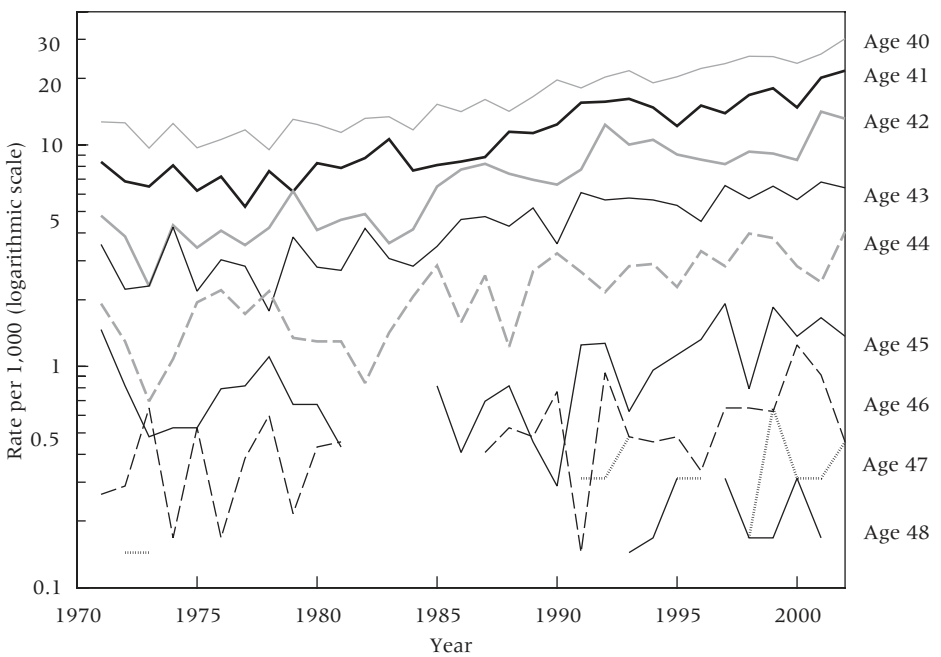
This trend toward new records in extreme ages at giving birth occurs in a context of a historically relatively small number of births to women aged 40+ or 45+ years. If "chance occurrences" of extreme ages at birth were the primary mechanism underlying the patterns in Figure 2, we would expect extremes to be concentrated in periods with the highest number of births above age 40, that is, early in the twentieth century rather than at the end.

Despite media claims that fertility postponement is pushing the limit of late childbearing, the fraction of births above age 45 among all births to women aged 40+ years has declined substantially from its peak early in the twentieth century, and it has not increased markedly since the 1980s. This constant contribution of births after age 45 to fertility at age 40 and above reflects the fact that the last two decades of the twentieth century witnessed an increase in childbearing at advanced ages (40+ years) and at very advanced ages (45+ years) in approximately equal proportion. At the same time, the absolute number of births to women aged 40+ or 45+, as well as the contribution of these births to overall fertility, is currently far below the levels observed in the first 60 years of the twentieth century. The absolute and relative contribution of childbearing at advanced and very advanced ages therefore remains low in contemporary Sweden compared to historical levels, even as a marked postponement of fertility since the 1970s has resulted in a cur-

rent mean age at first birth of almost 29 years. In addition, the examination of extreme age at birth during the twentieth century indicates a breakpoint around 1980 when the trend toward younger extreme ages at birth, which prevailed since the 1930s, reversed. In the 1980s and 1990s average extreme age at birth moved above age 51. Moreover, extreme ages at or above age 53 have become increasingly common. Undoubtedly, this trend is connected with the recent progress in reproductive technologies that has accelerated and proliferated since the 1980s (Socialstyrelsen 1998).

For the period 1971–2002, our analysis of late fertility in Sweden can additionally utilize occurrence-exposure fertility rates for first children, that is, rates that relate first births to the number of childless women.[7] These rates, which give the number of first births per thousand person-years lived by childless women, have the advantage of being unaffected by changes in the number of women at different parities at advanced ages. This is important since the population parity distribution varies with differential fertility behavior of cohorts. The first-birth occurrence-exposure rates for women aged 40–48 during 1971–2002 in Sweden are shown in Figure 3. The rates are plotted on a logarithmic scale to accommodate the substantial variation in level, ranging from below 1 first birth per thousand person-years lived by childless women at ages 46–48 to more than 25 first births per thousand person-years lived by childless women at age 40. Above age 45 the rates also

FIGURE 3 First birth rates (occurrence-exposure rates, per 1,000 woman-years childless) at ages 40–48 in Sweden, 1971–2002



reflect substantial year-to-year variation. In several years there are no first births at these advanced childbearing ages, hence the lines in Figure 3 are discontinuous for these years.

Figure 3 reveals a slight plateau in the first-birth rates at ages 40 and older during the 1970s, followed by a clear upward trend. Because our analysis is based on occurrence-exposure rates, this trend reflects an increased propensity of childless women at advanced childbearing ages to give birth. There are, however, important differences across ages. At ages 40–41 years, first-birth rates have more than doubled during 1971–2000; at ages 43–44, fertility rates doubled. Above age 45, however, the data are noisy at very low levels (mostly below 1 birth per thousand person-years lived by childless women), and there is no discernible trend toward an increase in these rates. Despite the substantial delay of childbearing during the observation period, childless women above age 45 did not experience an increased propensity to have children, and first-birth rates at age 45 and over have remained at very low levels.

Despite increasing fertility rates for women in their early 40s, however, the probability of a childless woman experiencing a first birth at advanced ages remains relatively small. In 2002, the probability that a 40-year-old childless woman will ever have a child is 7.48 percent, compared to 3.26 percent in 1970. That is, based on the 2002 rates, one in 13 childless women at age 40 will eventually enter parenthood, as compared to one in 30 in 1970. Much of this increase in the probability of entering parenthood after age 40—more than 80 percent—is due to the increase in fertility rates at ages 40–41. For a 45-year-old childless woman the probability of eventually having a child is far lower than at age 40, at 0.23 percent based on the 2002 rates (or less than one in 400) as compared to 0.17 percent based on the 1970 fertility rates. The lack of a major change in first-birth probabilities at very advanced ages, despite the substantial overall postponement of fertility, has two sources: (1) some women who are childless at ages above 45 have chosen to remain permanently childless; and (2) for those who have not, the ability to have a child at very advanced ages remains very small, despite recent progress in reproductive technologies, because of the low probabilities of conception and successful pregnancy at these ages. While our data cannot disentangle these two factors, it is apparent from our analysis that the postponement of fertility in the last three decades has not resulted in an increase in the fertility rates of childless women at very advanced reproductive ages.

Summary and discussion

Understanding the age patterns of fecundity and the age limits to successful pregnancies is essential for answering such questions as "How late can you wait?" (Menken 1985). The information provides a guideline for individuals' and couples' life course decisionmaking about the timing of fertility and

related behaviors. At the macro level, analysis of trends in delayed fertility are crucial in assessing whether declines in the pace of fertility postponement and associated reductions in tempo distortions are likely to lead to increases in period fertility levels in low- and lowest-low-fertility countries with late patterns of childbearing (Bongaarts 2002; Bongaarts and Feeney 1998). Knowledge about the long-term trends in late fertility, the propensity to have children at very advanced ages, and the potential effect of new assisted reproductive technologies on the ability to push the age limit of childbearing to increasingly later stages of the life course is insufficient.

In this article we focused on what we defined as late fertility (i.e., fertility at age 40 or above) and very late fertility (i.e., fertility at age 45 or above). While increases in late and very late fertility have been widespread among developed countries, our review of physiological factors related to late fertility indicates biological constraints on childbearing at advanced ages—even in the presence of assisted reproductive technologies. There is also substantial heterogeneity across developed countries in the contribution of late childbearing to overall fertility and in the use of assisted reproductive technologies.

Our empirical analysis of Swedish data shows that since the 1980s the numbers of births to women aged 40+ years and 45+ years have been rising. However, fertility at ages 45+ still constitutes only a minuscule fraction of overall births in 2005, and the contribution of late and very late fertility is currently far below the levels observed in the twentieth century until about 1960. Recent increases in the propensity to become a first-time mother around age 40+ have been substantial, while at ages 45+ this trend has been modest. Nevertheless, the upper age limit of having children is changing. We studied exceptional cases of late fertility by focusing on annual extreme ages at birth. Our analysis indicates that the tendency toward younger extreme ages at birth reversed around 1980. Before the 1980s, the decline in the extreme age at birth was linked to the historical decrease in family size. Since the 1980s, the upper age limit of fertility has been pushed toward new extremes, very likely as a likely result of the advances in reproductive technology. We speculate that the upper limit will be extended as reproductive technology further advances and its use becomes more widespread.

Notes

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1 Accessed 4 October 2006.

2 Accessed 4 October 2006.

3 For instance, see Kohler and Ortega (2004) for a general discussion of tempo and compositional influences on period fertility measures.

4 Own calculations based on Martin et al. (2005) and Eurostat («http://epp.eurostat.cec.eu.int», accessed 15 February 2007).

5 We follow the CDC definition for assisted reproductive technologies (ART) that includes all fertility treatments in which both

eggs and sperm are handled (CDC 2005). In general, ART procedures involve surgically removing eggs from a woman's ovaries, combining them with sperm in the laboratory, and returning them to the woman's body or donating them to another woman. They do not include treatments in which only sperm are handled (i.e., intrauterine—or artificial—insemination) or procedures in which a woman takes drugs only to stimulate egg production without the intention of having eggs retrieved.

6 The cover story also refers to a new generation of celebrities who seem to be "trend-setters" by having their first babies in their 20s. The examples mentioned in the article include Belgium's Princess Mathilde, socialite Jade Jagger, French model Laetitia Casta, and actress Kate Winslet.

7 These rates are also called "rates of the first kind" or "childbearing intensities"; see Kohler and Ortega (2004) for further discussion.

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