Biomedical influences on second births

ABSTRACT

(200 words)

We examined how several biomedical and sociodemographic characteristics are associated with mothers' probability of having a second child and the timing of this birth. Data from the Norwegian Mother, Father and Child Cohort Study (MoBa) and linked registers were used. Mothers who had certain pregnancy-related health problems during the first pregnancy, or other mental or physical health problems before or shortly after the first birth, were less likely than others to have a second child – net of differences in relationship status, education and economic resources. The same was the case if the first child had colic or poor sleeping patterns. Fecundity problems before the first birth and delivery by caesarean section were also associated with a reduced probability of a second birth. Some other health problems in the pregnancy and factors related to the delivery, plus a preterm/low-birth-weight first child, were associated with a slower transition to parity two, but not with the probability of ever making that transition. The biomedical variables considered contributed in total far less to the variation in the second-birth probability than the sociodemographic variables. Nevertheless, these results suggest that it may be useful to pay more attention to biomedical influences on fertility in future studies.

(Main text 6856 words)

The paper also includes two appendices in the online supplementary material

INTRODUCTION

The social science literature, especially the demographic literature, includes numerous studies on sociodemographic, policy and ideational influences on fertility in high-income countries. Partnership, education, income, family policies, access to day care, expectations from the older generation, and attitudes to abortion or gender equality are a few examples. Demographers have, of course, also long recognized the importance of fecundity as a determinant of fertility (Wood 1994; Bongaarts 2015), and a substantial literature has focussed on behavioural factors through which sociodemographic and other characteristics operate on fecundity and thus, ultimately, achieved fertility (Menken and Kuhn1996; Lavely 2007). Recently, the use of assisted reproductive technology (ART) has attracted much interest (Chanfreau et al. 2025), and some demographers have analysed genetic influences on fertility (Mills and Tropf 2024) and the effects of general health (Dommermuth et al. 2011; Gray et al. 2013; Fiori et al. 2017; Barclay and Kolk 2020; Alderotti and Trappolini 2021; Syse et al. 2022). Effects of HIV/AIDS and other sexually transmitted infections on fertility, which partly involve fecundity, have also been studied (Terceira et al. 2003; Trinitapoli and Yeatman 2017; Szreter 2019). However, other specific diseases have, with a few exceptions, attracted little interest (Guzzo et al. 2025; Kravdal et al. 2025).

Outside demography, there is a larger literature on how fecundity and fertility are influenced by specific mental or physical diseases (Laursen and Munk-Hansen 2010, Power et al. 2013; Wiebe et al. 2014; Ban et al. 2015; Ferraro et al. 2017; Gade et al. 2014; Pieczynska 2018; Dumanski and Ahmed 2019; Liu et al. 2024), including eclampsia and other severe maternal morbidities in or shortly after previous pregnancy (Bane et al. 2021). The importance of smoking (Wesselink et al. 2019), alcohol (Anwar et al. 2021), and nutrition (Gaskins and Chavarro 2018) has also been addressed. Additionally, the medically oriented literature includes studies of the influence of earlier birth experiences, but see Grundy and Kravdal (2025) for an example of a more demographic perspective on this issue.

The importance of earlier parenting experiences including the health of older children (as opposed to their death) for subsequent fertility has been lower on the research agenda both within and outside social science. Only a few studies in high-income settings have considered whether the health of existing children is associated with subsequent childbearing (e.g., Fuse 2009; Wehby and Hockenberry 2017), and there is very little evidence about whether having a child with colic or who sleeps little – which may be very burdensome to the parents for some time – matters for later fertility. These issues have been addressed in only a few studies, which have some limitations (e.g., Newman 2008, Fallesen and Breen 2016; Varghese 2022; see details below).

In this study, we examined how both sociodemographic and health-related factors are associated with the transition to a second child among one-child mothers, using data from a large Norwegian survey linked to registers. The main goal was to add to the knowledge about how the following biomedical variables are associated with the probability of having a second

child: subfecundity (indicated by use of ART or time to the pregnancy leading to the first live birth, if that birth was planned); indicators of the mother's and father's mental and physical health before, in or after the pregnancy leading to the first live birth; whether the mother had certain specific pregnancy-related health problems; the birth experience (indicated especially by delivery mode); and indicators of the first child's health or behaviour in infancy. While most of these biomedical factors have received some, but not much, attention as possible fertility determinants in earlier investigations (largely outside the social sciences), others – such as nausea in pregnancy – have, to our knowledge, not been addresses at all. Also, earlier studies regarding effects of women's and men's health on fertility have often focussed on either childlessness, when that is relevant (Liu et al. 2024), or the total number of children born (Wiebe et al. 2014), rather than (like Barclay and Kolk [2020]) parity progressions among parents. Furthermore, previous investigations have usually dealt with only one or a few of the mentioned biomedical factors. The inclusion of a wide range of such factors in the same analysis - which allows comparison of their effects – should therefore make our study particularly valuable, and the controls for several potentially important sociodemographic variables should further enhance its value.

Our second goal was to examine the importance of biomedical variables as confounders or mediators in analyses of sociodemographic variations in fertility. Thirdly, we wanted to get some insight into the relative importance of biomedical and sociodemographic variables for fertility.

The study setting was Norway, where the second-birth rates are now lower than in the mid-1960s (although the reduction has been much smaller than that in the third-birth rates; Hart and Kravdal 2020). However, the second-birth rates are still high compared to many other high-income countries (Zeman et al. 2018). Among Norwegian women who had their first child around year 2000, about 82% had a second child. Our study sample included more than 37000 women in the Norwegian Mother, Father and Child Cohort Study (MoBa) who were interviewed when they were pregnant with their first live born child and 6 months after that birth. MoBa includes several sociodemographic and biomedical characteristics, and additional characteristics were added from registers that cover the entire Norwegian population.

Our main outcome was the probability of having a second live born child within approximately 10 years after the first live birth, examined by using linear probability models. However, some attention was also given to the corresponding 3-year probabilities, to gain insight into the differences in the *timing* of the second births.

BACKGROUND

The biomedical and sociodemographic factors considered in this study, which were measured around the time of first birth, are listed in bold in two boxes in Figure 1. They may influence a one-child mother's probability of having a second child through one or more of the (unobserved) factors shown in the larger box, or they may be lagged versions – or indicators of lagged versions – of those factors. These more proximate factors in the larger box are fecundity, sexual activity, whether the mother lives in a union, whether another child is

wanted, and the extent to which contraception is used adequately to avoid an unplanned birth (reflecting the framework proposed by Easterlin and Crimmins [1985]). Whether a child is wanted may in turn be considered as influenced by the woman's (and her partner's, if any) purchasing power, the perceived opportunity and direct costs of childbearing, and 'preferences' for spending time and money on children rather than other sources of satisfaction, as well as social expectations.

(Figure 1 about here)

These biomedical and sociodemographic variables are also linked to each other. Additionally, they are linked to the mother's age at first birth and the calendar year of first birth (included in the models and listed in another box in Figure 1), which may also be considered sociodemographic variables. Below, we will review some reasons why biomedical and sociodemographic factors may affect the probability of having a second child, with special attention to the biomedical factors.

Biomedical characteristics

The mother's mental or physical health before or after first pregnancy likely has implications for whether another child is wanted, partly because of its impact on income, but also because poor health may have an impact on the 'preferences', to use the terminology introduced above. For example, individuals with poor health may be think they may be too tired to enjoy the parental role or unable to provide the best care for an additional child (Shover 2005; Schmidt et al. 2016; Ferraro et al. 2017; Meaney 2018; Harpe et al. 2022). Health may also have an impact on sexual activity, fecundity (Penovich 2000; Meirow and Nugent 2001; Gill et al. 2009; Green et al 2009; Lourenco et al. 2010, Gade et al. 2014; Wiebe et al. 2014; Bhongade et al. 2015; Darai et al. 2017; Pieczynska 2018; Dumanski and Ahmed 2019), partnership stability (Maccabe et al. 2009; Wiik and Dommermuth 2014; Sandström et al. 2020), and even contraceptive use (Penovich 2000; Hall et al. 2015; Phillips et al. 2018). Also, in some cases there may be concerns about teratogenic effects of medication (Munk-Olsen et al. 2018; Leroy et al. 2015; Harpe et al 2022). The health of the father of the first child may also influence the probability of having a second birth, through similar mechanisms. Clearly, such paternal effects are particularly relevant if the parents live together after the first birth, which itself may be influenced by health.

If the mother had pregnancy-related health problems in the first pregnancy, she may fear the same problems in another pregnancy, which may make her less likely to want additional children (Bane et al., 2021; see also some evidence in a qualitative study by Newman 2008). Adverse birth experiences, indicated for example by an emergency caesarean section, may also weaken the interest in having another child, and may lead to reduced fecundity as well (Grundy and Kravdal 2025). Additionally, elective caesarean for a normal-presentation baby – which may partly be the result of maternal characteristics such as obesity, hypertension, or extreme fear of childbirth (Murphy et al. 2002; Kjerulff et al. 2020) - has

been shown to be associated with a low subsequent birth rate (Gurol-Urganci et al. 2014; Grundy and Kravdal 2025).

Finally, concerns about the first child's health, or having a particularly demanding child, may deter individuals or couples from having a second child. They may fear that it would be too burdensome to provide good care for another child in this situation, or that the next child might have similar problems. One study from Japan showed that firstborns who were often sick were less likely to have younger siblings (Fuse 2009). Other studies have shown lower subsequent fertility among parents of children with low birth weight or born preterm (Alenius et al. 2018; Wehby and Hockenberry 2017; Kristensen et al. 2003). However, in a recent American investigation, there was no evidence of reduced fertility among mothers whose child was disabled or had serious health problems (Wehby and Hockenberry 2017).

A child's lack of sleep may affect the parents' health and wellbeing negatively (Coles et al. 2022), with implications not least for their 'preferences' for further childbearing. Indeed, a recent investigation based on British data (Vargese 2022) showed that women whose first child had frequent night wakings were less likely than others to become pregnant again, although this association was seen only during the first three years. Additionally, there is evidence from qualitative research suggesting that sleep deprivation may reduce the chance of having additional children (Newman 2008). Infant colic may also be challenging for the family (Rautava et al. 1995; Botha et al. 2019), but little is known about the fertility effects. In an analysis where the implications for subsequent fertility could only be assessed rather indirectly because of data limitations, no effects appeared (Fallesen and Breen 2016).

We also included a measure of whether the first child was planned. An unintended or mistimed first birth may, on the one hand, indicate a weaker interest in becoming a parent (so soon), suggesting a lower probability of wanting another child (rather fast). On the other hand, it may also indicate inadequate contraceptive use before first birth, perhaps in combination with a negative attitude to abortion, which could signal a similar situation after first birth and thus a relatively high second-birth probability.

For women whose first child was intended, we included a fecundity measure based on time to first pregnancy and whether ART was used. Fecundity problems at this stage indicate, of course, a relatively low fecundity also after the first birth and thus a lower probability of having a second child.

Sociodemographic characteristics

Income and education are likely to be among the determinants of several of the biomedical factors we consider and may also be affected by them (Huits et al. 2010; Arechvo et al. 2023, Vigoreux et al. 2023; Pintor et al. 2024). Additionally, income and education may influence fertility in other ways, through most of the mentioned proximate determinants. In contemporary high-income populations, better-educated men tend to have relatively high fertility, and a similar association has recently been observed among women in many countries, while an opposite association was more common a few decades ago (Kravdal and Rindfuss 2008; Jalovaara et al. 2019). Studies have also shown reduced fertility when a man

has low income, while the relationship between women's income and their fertility is less clear (Hart 2015 [for first births]; Kornstad and Rønsen 2018; Trimarchi and van Bavel 2020). It would be reasonable to expect a low second-birth probability among women who perceive their economic situation as difficult (Hofman and Hohmeyer 2013).[1]

Similarly, some of the biomedical variables may be influenced by the mother's partnership situation, which is indicated in this study by whether she is in a union around the time of first birth and the quality of the relationship (Robles et al. 2014; Goldfarb and Trudel 2019; Kravdal et al. 2023). As mentioned, the partnership situation may also be influenced *by* the biomedical variables, and it may affect subsequent fertility. The importance of being in a partnership for later fertility is obvious, but the partnership quality may also matter. For example, if the couple do not have a good relationship, the burdens associated with childrearing may be seen as heavier than they would otherwise be, and the couple may also be more likely to separate (Rijken and Thomson 2011).

We also took into account whether the father already had a child or children with another partner. This may not be closely related with the biomedical variables but may be linked to the other sociodemographic variables and influence later fertility (Stewart 2002).

Selection

Obviously, many individual and societal characteristics may affect both the biomedical and sociodemographic factors we considered and the second-birth probability (not indicated in Figure 1). These selection factors include biomedical and sociodemographic factors we did *not* consider as well as other types of factors. Genes, personality, and grandparents' attitudes and resources are some examples.

DATA AND METHODS

Data sources

The analysis was based on the Norwegian Mother, Father and Child Cohort Study (MoBa), the Population Register, the Medical Birth Register, and various databases operated by Statistics Norway.

MoBa is a population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health and is regulated by the Norwegian Health Registry Act (Magnus et al. 2016). Pregnant women from all over Norway in 1999-2008 were invited to participate, and 41% of them accepted. The cohort includes approximately 95200 mothers (who have had 1145000 children) and 75200 fathers.

The Population Register includes all individuals who have ever lived in Norway since 1964. They are assigned a personal ID which is also used in other registers and databases, as well as in MoBa. From the Population Register, we extracted information about date of birth and (if any) death, year of immigration or emigration, and IDs of parents. Thus, we could find out whether women included with a first live birth in MoBa had a second live birth later, up to the end of 2018, which is the last date covered by the data we had access to.[2]

The Medical Birth Register includes information about all births in Norway after 1967. Information about education and income was extracted from the Education Database and data from the Tax Directorate, operated by Statistics Norway.

The study sample included women i) who were interviewed in the 15th week of the pregnancy leading up to their first live singleton birth, ii) who also took part in the interview 6 months after that birth, and iii) whose first live birth was recorded in the Medical Birth Register. Further restrictions based on residence in Norway are specified below.

Statistical models

We estimate linear probability models for the probability of having a second live birth by the end of the 9th full calendar year after the first live birth (i.e., 108-119 months after the live first birth), conditioned on being resident in Norway at that time.[3] 37459 mothers contributed to this analysis. There are two advantages with this type of model compared to a logistic model: the easily interpretable metric, and the comparability across models with different variables included. Clearly (and as with a logistic model), one cannot include time-varying covariates and make use of the information from the (very small number of) individuals emigrating or dying within the observation window.

In order to shed light not only on the differences in the 'quantum' of second births (very few have a second birth after more than 10 years), but also in the 'tempo', we additionally estimated models for the probability of having a second child within 35 months.

Variables

The main variables were grouped into *biomedical* and *sociodemographic*. In addition, almost all models included calendar year of first birth and mother's age at first birth. The biomedical variables were:

- Whether the pregnancy leading up to the first live birth was planned and indicators of fecundity problems before that pregnancy: Time to pregnancy and use of ART
- Indicators of the mother's mental and physical health: Depression or anxiety in pregnancy, postnatal depression, specific pre-pregnancy chronic physical diseases and BMI, general physical health 6 months after birth
- Indicators of the mental and physical health of the father of the first child: Depression or anxiety in pregnancy, specific pre-pregnancy chronic physical diseases
- Indicators of pregnancy-related health problems: Hypertension, gestational diabetes, (pre-)eclampsia, oedema, long-lasting nausea and vomiting, severe muscle or joint pain, on sick leave after week 30 of pregnancy
- Indicators of the birth experience: Caesarean section, whether birth worse than expected

- Indicators of the first child's health and behaviour: Low birth weight or born preterm, malformation, Apgar score, relatively serious health problems, colic, hours of sleep, indicator of demandingness

The sociodemographic variables were:

- Income of both parents
- Education of both parents
- The mother's perceptions of her or the couple's economic situation
- Marital or cohabitation status around the time of first birth
- Indicator of the partnership quality 6 months after birth
- Whether the father of the first child had older children with another woman

More precise labels of variables and brief descriptions of categories can be found in Table 1. Details about the construction of the variables, including the selection of specific health problems from the very rich information in MoBa, are reported in Appendix 1.

Some models included only the biomedical variables (in addition to year of first birth and mother's age at first birth), some included only sociodemographic variables (including year of first birth and mother's age at first birth), and some included both these sets of variables. The reason for controlling for the year of first birth in almost all models was that time-varying societal characteristics in principle may affect the biomedical and sociodemographic characteristics under study as well as the probability of a second birth. However, the inclusion of year of birth turned out to have essentially no impact on the estimates.

The mother's age at first birth is a determinant of some of the biomedical and (other) sociodemographic variables. For example, being older at birth increases the probability of certain conditions that make a caesarean section more likely (Rydahl et al. 2019). Additionally, a higher age at first birth has implications for later fertility for several other reasons: At a given duration since first birth the fecundity will be lower the higher the age at first birth (given the general reduction in fecundity by age), and a higher age may also increase the probability of a broad range of health problems, strengthen the economic platform and have various other consequences of importance for fertility. In fact, there may be effects of age at first birth on later fecundity – or at least a relationship - even net of the (quite crude) indicator of fecundity included in the analysis.[4] Similarly, there may effects on health and economic resources net of the corresponding indicators.[5] Given these likely mechanisms, a control for age at first birth brings us a step closer to a causal effect of a caesarean section, or of the more proximate health factors and circumstances that may necessitate such an intervention. Similar arguments may be made about some of the other biomedical and sociodemographic characteristics considered.

However, some characteristics we considered may also influence fertility partly *through* the age at first birth. For example, it is reasonable to assume that health in earlier years may have an impact on age at first birth (Kravdal et al. 2025). In this situation, where age at first birth is a mediator rather than selection factor, a hypothetical change in the characteristic will have an indirect effect on the second-birth probability through the age at

first birth in addition to the effect through other channels - which is more or less close to the net effect we have estimated, depending on how well we have accounted for joint determinants.[6] We did not carry out a formal mediation analysis, but consider effects through age at first birth in parts of the discussion below, and refer to results obtained without control for age at first birth.

RESULTS

87.0% of the 37459 women included in the analysis had a second child (not shown in tables). This is higher than the 82.0 % among all Norwegian women who had their first child in 1999-2009[7] and indicates that the MoBa respondents are relatively 'fertility prone'.

The biomedical variables

According to a model including all the biomedical variables, age at first birth and birth year, the 10-year second-birth probability was reduced by 0.078 (i.e., 7.8 percentage points) for those with an unplanned first birth (Table 1, Model 1). Also, as would be expected, women with low fecundity as indicated by use of ART for the first pregnancy or (less so) by having had unprotected intercourse for a year or more before the pregnancy, had relatively low subsequent fertility.

(Table 1 about here)

Depression and anxiety reported by the mothers in the 15th pregnancy week and postnatal depression were linked to a lower probability of having a second child. Furthermore, the general health 6 months after birth and pre-pregnancy BMI, musculoskeletal disease, hypertension/diabetes and sexually transmitted or gynaecological disease were negatively associated with the second-birth probability. Additionally, mothers were less likely to have a second child if the father of the first child suffered from depression, prolonged back/neck/shoulder pain, CVD/diabetes, or headache. Three conditions during pregnancy - oedema, long-lasting vomiting and severe muscle and joint pain - and having full sick leave after week 30 were also linked with low second-birth probability, while associations with (pre)eclampsia, gestational hypertension or gestational diabetes were not significant.

Women whose first child was delivered by means of emergency caesarean or elective caesarean for a normal-position baby had a reduced probability of having a second child, while this was not the case for those who had an elective caesarean for a breech position, or whose first birth was worse than expected. Finally, if the first child was born preterm and with low birth weight, had colic or slept relatively little, the second-birth probability was reduced. However, having a child with malformations, low Apgar score, a relatively serious health problem 6 months after birth, or whom the mother considered to be rather demanding, was unrelated to the progression to second birth.

Most of the significant relationships were stronger when we only controlled for a few other similar biomedical variables along with age at first birth and year, as judged by the point estimates (Appendix table A.2.1). According to these simpler models, the second-birth probability was also significantly reduced among mothers who had pre-pregnancy stomach disease or experienced preeclampsia or eclampsia during pregnancy, had an elective caesarean for a breech-position baby, or whose first birth experience was worse than expected.

Many of the associations between the biomedical variables and subsequent fertility became less clearly negative when the sociodemographic factors were controlled for (compare Models 1 and 3). The associations with sexually transmitted or gynaecological disease, overweight (but not obesity), severe muscle or joint pain during pregnancy, sick leave during pregnancy, father's depression, father's back/neck/shoulder pain, and having a child born preterm and with low birth weight were no longer significant with these controls included.

The sociodemographic variables

According to the models including age at first birth, year, and sociodemographic variables, the second-birth probability was slightly higher if the mother or father were in the highest income tertile (Model 2). The associations between higher education and fertility were more clearly positive. Those who reported having economic problems had significantly reduced probability of having a second child.

Being unpartnered (i.e., being neither married nor cohabiting) in pregnancy, at birth or 6 months afterwards - or being in a union where the relationship quality was low - was associated with lower second-birth probability.[8] Furthermore, the probability of having a second child within 10 years was reduced by about 9 percentage points if the father had one child with another woman before, and almost twice as much if he had two or more such children.

These associations did not change very much when the biomedical variables were added to the models (compare Models 2 and 3). For example, only a couple of the point estimates changed (weakened) by more than 0.02; most changed much less.

In supplementary discrete-time hazard model analysis, we included the same variables as in the main analysis plus time since first birth and a time-varying dummy variable for whether the mother and father still lived together. The estimates, which reflect a combination of differences in 'tempo' and 'quantum' of second births[9], are shown in Appendix table A2.2. The analytical set-up is described in a note to that table. Union disruption reduced the odds of having a second child within a three-month period by as much as 100*(1-0.39)=61% [10]. As one would expect, addition of this variable weakened the association between low relationship quality and the second-birth probability.[11] Other estimates were changed very little, and the pattern in them was very similar to that in the main analysis (based on linear probability models).

The relative importance of the biomedical and sociodemographic variables.

Some of the associations between biomedical factors and the second-birth probability were quite strong, in the sense that the probability was reduced by as much as 5-10 percentage points for some groups of women. Many of these groups were quite small, however. To compare the explanatory power of the biomedical and sociodemographic variables, we considered the R-square measures of the fit of various models. When only age at first birth and year were included in the model, the R-square[12] was 0.109 (Table 1). Addition of the biomedical variables increased the R-square to 0.149, i.e. by 0.040. Including the sociodemographic variables instead gave a higher R-square of 0.184, i.e. an increase of 0.075 compared to the model with only age at first birth and year. When both types of variables were included, the R-square was 0.198. In other words, net of the sociodemographic variables, the biomedical variables increased the R-square by 0.014. Conversely, the sociodemographic variables increased the R-square by 0.049 net of the biomedical variables. These two increases are 15.6% and 55.1%, respectively, of the total explanatory power of the biomedical and sociodemographic variables (0.198-0.109). The remaining increase in R-square (0.198-0.109-0.014-0.049=0.026), which may be interpreted as reflecting the effects of the biomedical and sociodemographic variables operating through each other, is 29.3% of the total explanatory power.

The fecundity variable reflects whether the first child was unplanned, which has received much attention in demographic research, and may be more reasonable to consider a sociodemographic factor than a biomedical one. In supplementary analysis, we split the fecundity variable into a dummy for unplanned and a new fecundity variable where those with unplanned births were in the reference category. If included alone, the latter would still reflect a combination of fecundity and unplanned childbearing, but if the unplanned dummy was included along with the sociodemographic variables, later addition of the new fecundity variable along with the other biomedical variables, would give us a better picture of the importance of biomedical factors. However, the R-square only increased from 0.184 to 0.186 (not shown) when the unplanned dummy was included along with the other sociodemographic variables – leaving a correspondingly smaller increase in R-square when adding the biomedical variables (0.012 rather than 0.014).[13]

The probability of having a second child within 3 years

Many of the biomedical factors that were significantly associated with a reduced probability of having a second child within 10 years were even more strongly associated with a reduced probability of making this transition within 3 years - as we defined quite arbitrarily by the absolute value of the point estimate being at least 0.010 larger (compare the two columns to the left in Appendix table A2.2 and see also Table 1, where symbols indicate the difference between the two models). This is the case for the first child being unplanned, the mother having been depressed in or after that pregnancy, having poor general physical health after the first birth, having suffered from long-lasting nausea in that pregnancy, the first child being delivered by means of an elective caesarean for a normal-presentation baby, and the first child having slept little.

Additionally, the following biomedical factors that were not significantly associated with the 10-year probability were significantly associated with the 3-year probability: having had severe muscle or joint pain in the first pregnancy, the first child being delivered by an elective caesarean for a breech presentation, the first delivery being worse than expected, and the first child being born with low weight or preterm.

Conversely, some biomedical factors that were negatively associated with the 10-year probability were unrelated to the probability of having a second child within 3 years: a long time to first pregnancy, having musculoskeletal disease, hypertension or diabetes, having had oedemas in the first pregnancy, and the father having CVD, diabetes or headache.

In total, the biomedical variables may be considered as explaining a larger proportion of the variation in the 3-year probability than in the 10-year probability: Adding these variables to a model including age at birth, year and the sociodemographic variables increased R-square from 0.068 to 0.084, while the corresponding increase when analysing the 10-year probability was from 0.184 to 0.198. The latter difference is clearly smaller relative to the total explanatory power (15.6% versus 25.8%).

Turning to the estimates for the sociodemographic variables, mother's low income, father's low education, not being married at first birth and low partnership quality were more negatively associated with the 3-year probability than the 10-year probability.

DISCUSSION AND CONCLUSIONS

In this study we investigated how a range of biomedical and sociodemographic variables were associated with the transition to a second child among first-time mothers in Norway - with attention both to the tempo of this transition and the probability of ever making it. Several of the biomedical factors were significantly associated with the progression to a second child net of each other and net of the sociodemographic characteristics, which are important control variables. Even more associations were significant when only a few of the biomedical variables were included, rather than all of them. They likely operate through each other in complex ways, examination of which is beyond the scope of this paper. By and large, the biomedical variables were more strongly linked to the probability of having a second child within the next three years than to the probability of ever having a second child.

Our indicators of *fecundity problems* before first birth (use of ART or long time to the pregnancy leading up to the first birth) were negatively associated with the likelihood of having a second child. This probably reflects the fact that, when we compare women who had their first child at the same age (which we control for), those with apparently lower fecundity before the first birth also have lower fecundity in the years after the first birth. However, the associations were only moderately strong (compared to others we estimated), and the groups were relatively small. Therefore, in a prediction based on simply 'moving women out of the subfecundity categories' (without regard to how this could be achieved in practice), while nothing else changes, the national 10-year second-birth probability would only be 0.3 percentage points higher (the ART estimate of 0.058 multiplied by 2.9% plus the 0.023 long-time-to-pregnancy estimate multiplied by 7.3%).

The fecundity indicators are not relevant for women whose first child was *unplanned* (which, as mentioned, should perhaps not be considered a biomedical factor). These women were found to have a relatively low probability of further childbearing, which may reflect a relative weak interest in having a child that outweighs their possibly less adequate contraceptive use.

Several of the indicators of the *mother's mental and physical health problems* were negatively associated with the probability of having a second child. While this is theoretically reasonable, and some studies have shown reduced fertility among women with certain diseases (see references above), almost no attention has been given specifically to second births, which might be expected to be more weakly influenced than first births. Some indicators of the physical *health of the father* of the first child were also related to the second-birth probability, while an association with mental health only appeared when the sociodemographic factors were not controlled for. It should be noted, however, that in many cases there is a union disruption after first birth (the probability of which may itself be influenced by health), and the characteristics of another man may then be more important for the subsequent fertility.

Most of the health indicators referred to health before pregnancy. This was also the case for some of those that were associated with high age at first birth (associations not shown in tables). In other words, they may be seen as being among the determinants of the first birth timing. This means that, if we for a moment interpret the estimates as reflecting causal effects, the total effect of hypothetically eliminating these health problems would be larger than indicated by the estimates: There would be an additional effect on the second-birth probability through the lower age at first birth. As an illustration of this, the estimated effect of obesity without control for age at first birth is -0.052 (table available on request), while it is -0.040 with this control.

Not surprisingly, some *pregnancy problems* were associated with a reduced probability of progressing to higher parity within 3 or 10 years. More specifically, this was the case for oedema, long-lasting nausea, and severe muscle and joint pain, although the associations were quite weak. Women with (pre-)eclampsia, gestational hypertension or gestational diabetes did not have a particularly low second-birth probability. Associations between pregnancy problems and subsequent fertility have been reported only in a few earlier studies (see references above).

Our analysis also confirms earlier studies showing an association between *caesarean section* and subsequent childbearing, including studies of the second birth in particular (Grundy and Kravdal 2025). Especially caesareans that are not planned because of breech presentation may signal fear of giving birth, underlying health problems (that we have not adequately captured), or a traumatic birth experience. It is also worth noting that, net of the delivery mode, those who reported that their first birth was worse than expected were less likely than others to have a second child rather quickly, but as likely as others to ever have a second child.

Finally, some of the indicators of the first *child's health and behaviour* were linked to the second-birth probability: if the child had colic or slept relatively few hours (according to

the mother's judgment), there was a smaller likelihood of having another child. However, the relationships were not strong compared with, for example, the reduced second-birth probability among the (smaller group of) women who had six or more weeks with postnatal depression, were obese, or had a planned caesarean section for a normal-position baby. Clear associations with colic have not been shown earlier, but it has been documented that colic or excessive crying in the first months of life has detrimental impact on the everyday life of the family, straining the parental relationship and reducing parents' self-confidence (Botha et al. 2019; Fallesen and Breen 2016), which might well reduce subsequent fertility. The association probably reflects a largely causal effect of colic, as this condition is thought to occur quite randomly.

We also found that, if the child had a difficult start, as indicated by being born preterm or with low birth weight, the time to the second birth was relatively long. However, the probability of ever having a second child was not strongly reduced in these cases. Having a child who was born with a malformation (very uncommon), who had a relatively serious health problem 6 months after birth, or who in total was consider as quite demanding was not associated with a low second-birth probability.

To summarize some of this, it seems that various negative experiences in pregnancy or quite shortly after birth may reduce the probability of having a second child. We found associations between progression to a second child and maternal postnatal depression, physiological symptoms in pregnancy such as nausea, and the first child's colic or poor sleep. In other words, relatively common conditions that may not affect the mother's or the child's health in the longer term may nevertheless have an impact on the family structure. There is no perfect cure for nausea, child night wakings and colic, but the findings suggest that, if parents received better psychosocial support at this stage, they might be likely to have more children.

The associations between sociodemographic characteristics around the time of first birth and the second-birth probability accorded well with what one might expect. However, a positive relationship between income and fertility is not obvious, and a low second-birth probability among those who perceive their economic situation to be difficult or who are in low-quality relationships has not often been documented.

How much do the biomedical characteristics matter in total?

The biomedical variables appeared – on the whole – to be less important fertility determinants than the sociodemographic ones: In the analysis of the 10-year probability, the R-square increased 3.5 times more when the sociodemographic variables were added to a model including age at birth, year, and biomedical variables (by 0.049, from 0.149 to 0.198) than when the biomedical variables were added to a model including age at birth, year and sociodemographic variables (by 0.014, from 0.184 to 0.198). The biomedical variables contributed somewhat more to the variation in the probability of having a second child within 3 years.

Also, while control for sociodemographic variables changed the estimated effects of the biomedical variables quite markedly, the opposite was to lesser extent the case. In other

words, the biomedical factors appeared neither to be important channels through which these socioeconomic characteristics affect fertility nor determinants that it is hugely important to take into account when trying to identify causal effects of the socioeconomic characteristics on fertility. As mentioned, the fecundity variable includes the planning status of the first child, which may be considered a sociodemographic component. If that was taken into account, the total contribution from the biomedical variable became even smaller, but not much.

However, it is important to keep in mind that the picture might have been different if the variables had been categorized differently, or if variables had been added to one or both main groups (e.g., breastfeeding, indicators of other diseases, or other measures of economic resources). Other results might also have appeared if third rather than second births had been analysed, with attention to health-related factors in or around the first or second pregnancy. People are generally less eager to have a third than a second child, and it is possible that health problems that are not very severe could have a larger impact.

Finally, it should be noted that, even in the models including all biomedical and sociodemographic variables, the estimated effect of age at first birth may reflect biomedical influences on the second-birth probability, for example fecundity [14]. However, it may also reflect sociodemographic influences, and we do not know whether these are larger or smaller.

Conclusion

To conclude, many of the biomedical variables we considered were significantly associated with the probability of having a second child. It is plausible that these associations to some extent reflect causal effects of the biomedical variables on fertility, and not only joint determinants that are not controlled for. Demographers may find it valuable in future fertility research to include this type of variables. While this may not shed very important light on the effects of the sociodemographic factors that demographers tend to be particularly interested in, a more complete picture of the fertility determinants may - to the extent that the biomedical factors change over time – help us understand earlier fertility trends and predict future fertility. Additionally, some of the associations between the biomedical factors and fertility are of interest because they may inform discussion about how increased supports to parents might influence their subsequent childbearing.

REFERENCES

Alderotti, G., & Trappolini, E. (2021). Health status and fertility intentions among migrants. *International Migration*, 60(4), 164-177.

Alenius, S., Kajantie, E., Sund, R., Näsänen-Gilmore, P., Vääräsmäki, M., Gissler, M., & Hovi, P. (2018). The missing siblings of infants born preterm. *Pediatrics*, 141(1).

Anwar, M. Y., Marcus, M., & Taylor, K. C. (2021). The association between alcohol intake and fecundability during menstrual cycle phases. *Human Reproduction*, *36*(9), 2538-2548.

Arechvo, A., Wright, A., Syngelaki, A., von Dadelszen, P., Magee, L. A., Akolekar, R., ... & Nicolaides, K. H. (2023). Incidence of pre-eclampsia: effect of deprivation. *Ultrasound in Obstetrics & Gynecology*, 61(1), 26-32.

Ban, L., Tata, L. J., Humes, D. J., Fiaschi, L., & Card, T. (2015). Decreased fertility rates in 9639 women diagnosed with inflammatory bowel disease: a United Kingdom population-based cohort study. *Alimentary Pharmacology & Therapeutics*, 42(7), 855-866.

Bane, S., Carmichael, S.L., Snowden, J.M., Liu, C., Lyndon, A., & Wall-Wieler, E. (2021). The impact of Severe Maternal Morbidity on probability of subsequent birth in a population-based study of women in California from 1997-2017. *Annals of Epidemiology*, 64, 8-14.

Barclay, K., & Kolk, M. (2020). The influence of health in early adulthood on male fertility. *Population and Development Review*, 46(4), 757-785.

Bhongade, M. B., Prasad, S., Jiloha, R. C., Ray, P. C., Mohapatra, S., & Koner, B. C. (2015). Effect of psychological stress on fertility hormones and seminal quality in male partners of infertile couples. *Andrologia* 47(3), 336-342.

Bongaarts, J. (2015). Modeling the fertility impact of the proximate determinants: Time for a tune-up. *Demographic Research*, *33*, 535-560.

Botha, E., Joronen, K., & Kaunonen, M. (2019). The consequences of having an excessively crying infant in the family: an integrative literature review. *Scandinavian Journal of Caring Sciences*, 33(4), 779-790.

Chanfreau, J., Goisis, A., & Kravdal, Ø. (2025) Conceptualising and measuring the contribution of assisted reproductive technologies to fertility rates". Forthcoming in *Population and Development Review*.

Coles, L., Thorpe, K., Smith, S., Hewitt, B., Ruppanner, L., Bayliss, O., ... & Staton, S. (2022). Children's sleep and fathers' health and wellbeing: A systematic review. *Sleep Medicine Reviews*, 61, 101570.

Daraï, E., Cohen, J., & Ballester, M. (2017). Colorectal endometriosis and fertility. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, 209, 86-94.

Dommermuth, L., Klobas, J., & Lappegård, T. (2011). Now or later? The theory of planned behavior and timing of fertility intentions. *Advances in Life Course Research*, 16(1), 42-53.

Dumanski, S. M., & Ahmed, S. B. (2019). Fertility and reproductive care in chronic kidney disease. *Journal of Nephrology*, 32(1), 39-50.

Easterlin, R., & Crimmins, E. (1985). *The fertility revolution: A supply-demand analysis*. Chicago: University of Chicago Press.

Fallesen, P., & Breen, R. (2016). Temporary life changes and the timing of divorce. *Demography*, 53(5), 1377-1398.

Ferraro, D., Simone, A. M., Adani, G., Vitetta, F., Mauri, C., Strumia, S., & Sola, P. (2017). Definitive childlessness in women with multiple sclerosis: a multicenter study. *Neurological Sciences*, 38, 1453-1459.

Fiori, F., Rinesi, F., & Graham, E. (2017). Choosing to remain childless? A comparative study of fertility intentions among women and men in Italy and Britain. *European Journal of Population*, *33*(3), 319-350.

Fuse, K. (2019). Gender and parenting difficulty of the first-born: implications for parity progression among Japanese couples. *Journal of Comparative Family Studies*, 50(2), 116-138.

Gade, E. J., Thomsen, S. F., Lindenberg, S., Kyvik, K. O., Lieberoth, S., & Backer, V. (2014). Asthma affects time to pregnancy and fertility: a register-based twin study. *European Respiratory Journal*, 43(4), 1077-1085.

Gaskins, A. J., & Chavarro, J. E. (2018). Diet and fertility: a review. *American Journal of Obstetrics and Gynecology*, 218(4), 379-389.

Gill, J. S., Zalunardo, N., Rose, C., & Tonelli, M. (2009). The pregnancy rate and live birth rate in kidney transplant recipients. *American Journal of Transplantation*, 9(7), 1541-1549.

Goldfarb, M. R., & Trudel, G. (2019). Marital quality and depression: A review. *Marriage & Family Review*, 55(8), 737-763.

Gray, E., Evans, A., & Reimondos, A. (2013). Childbearing desires of childless men and women: When are goals adjusted? *Advances in Life Course Research*, 18(2), 141-149.

Green, D. M., Kawashima, T., Stovall, M., Leisenring, W., Sklar, C. A., Mertens, A. C., ... & Robison, L. L. (2009). Fertility of female survivors of childhood cancer: a report from the childhood cancer survivor study. *Journal of Clinical Oncology*, 27(16), 2677-2685.

Grundy, E. & Kravdal, Ø. (2025). Mode of delivery of the first child and progression to a second birth in Norway. Forthcoming in *Population*.

Gurol-Urganci, I., Cromwell, D.A., Mahmood, T.A., van der Meulen, J.H., & Templeton, A. (2014). A population-based cohort study of the effect of Caesarean section on subsequent fertility. *Human Reproduction*, 29, 1320-1326.

Guzzo, K.B., Juteau, G., Manning, W.D, & Dush, C.K. (2025). Physical and mental health and fertility goals among U.S. couples. Paper presented at the Annual PAA Meeting, Washington DC, 2025.

Hall, K. S., Steinberg, J. R., Cwiak, C. A., Allen, R. H., & Marcus, S. M. (2015). Contraception and mental health: a commentary on the evidence and principles for practice. *American Journal of Obstetrics and Gynecology*, 212(6), 740-746.

Harpe, J., Bernstein, C., & Harriott, A. (2022). Migraine and infertility, merging concepts in women's reproductive health: A narrative review. *Headache: The Journal of Head and Face Pain*, 62, 1247-1255.

Hart, R. K. (2015). Earnings and first birth probability among Norwegian men and women 1995–2010. *Demographic Research*, *33*, 1067-1104.

Hart, R.K. & Kravdal, Ø. (2020). Fallende fruktbarhet i Norge. Report. Norwegian Institute of Public Health.

Hofmann, B., & Hohmeyer, K. (2013). Perceived economic uncertainty and fertility: Evidence from a labor market reform. *Journal of Marriage and Family*, 75(2), 503-521.

Huijts, T., Eikemo, T. A., & Skalická, V. (2010). Income-related health inequalities in the Nordic countries: examining the role of education, occupational class, and age. *Social Science & Medicine*, 71(11), 1964-1972.

Jalovaara, M., Neyer, G., Andersson, G., Dahlberg, J., Dommermuth, L., Fallesen, P., & Lappegård, T. (2019). Education, gender, and cohort fertility in the Nordic countries. *European Journal of Population*, 35, 563-586.

Kjerulff, K.H., Paul, I.M., Weisman, C.S. et al. (2020). Association Between Mode of First Delivery and Subsequent Fecundity and Fertility. *JAMA Network Open,* 3(4), e203076.

Kornstad, T., & Rønsen, M. (2018). Women's wages and fertility revisited evidence from Norway. *European Journal of Population*, 34, 491-518.

Kravdal, Ø., & Rindfuss, R. R. (2008). Changing relationships between education and fertility: A study of women and men born 1940 to 1964. *American Sociological Review*, 73(5), 854-873.

Kravdal, Ø., Wörn, J., & Reme, B. A. (2023). Mental health benefits of cohabitation and marriage: A longitudinal analysis of Norwegian register data. *Population Studies*, 77(1), 91-110.

Kravdal, Ø., M. Flatø, and F. A. Torvik (2025). Fertility among Norwegian women and men with mental disorders. Forthcoming in *European Journal of Population*.

Kristensen, P., Irgens, L.M., & Bjerkedal, T (2003). Impact of low birthweight on subsequent fertility. *Paediatric and Perinatal Epidemiology*, 17, 10-16.

Laursen, T. M., & Munk-Olsen, T. (2010). Reproductive patterns in psychotic patients. *Schizophrenia Research*, 121(1-3), 234-240.

Lavely, W. (2007). Sex, breastfeeding, and marital fertility in pretransition China. *Population and Development Review*, 33(2), 289-320.

Leroy, C., Rigot, J. M., Leroy, M., Decanter, C., Le Mapihan, K., Parent, A. S., ... & Vantyghem, M. C. (2015). Immunosuppressive drugs and fertility. *Orphanet Journal of Rare Diseases*, 10(1), 1-15.

Liu, A., E.T. Akimova, X. Ding, S. Jukarainen, P. Vartiainen, T. Kiiskinen, S. Koskelinen, A.S. Havulinna, M. Gissler, S. Lombardi, T. Fall, M.C. Mills, and A. Ganna. 2024. Evidence from Finland and Sweden on the relationship between early-life diseases and lifetime childlessness in men and women, *Nature Human Behaviour*, 8(2): 276-287.

Lourenco, M., Azevedo, L. P., & Gouveia, J. L. (2010). Depression and sexual desire: An exploratory study in psychiatric patients. *Journal of Sex & Marital Therapy*, 37(1), 32-44.

MacCabe, J. H., Koupil, I., & Leon, D. A. (2009). Lifetime reproductive output over two generations in patients with psychosis and their unaffected siblings: the Uppsala 1915–1929 Birth Cohort Multigenerational Study. *Psychological Medicine*, 39(10), 1667-1676.

Magnus, P., Birke, C., Vejrup, K., Haugan, A., Alsaker, E., Daltveit, A. K., ... & Stoltenberg, C. (2016). Cohort profile update: the Norwegian mother and child cohort study (MoBa). *International Journal of Epidemiology*, *45*(2), 382-388.

Meaney, M. J. (2018). Perinatal maternal depressive symptoms as an issue for population health. *American Journal of Psychiatry*, 175(11), 1084-1093.

Meirow, D., & Nugent, D. (2001). The effects of radiotherapy and chemotherapy on female reproduction. *Human Reproduction Update*, 7(6), 535-543.

Menken, J., & Kuhn, R. (1996). Demographic effects of breastfeeding: fertility, mortality, and population growth. *Food and Nutrition Bulletin*, 17(4), 1-14.

Mills, M.C, & Tropf, F.C. (2024). Genetics and reproductive behaviour: A review. In Burger, O., R. Lee, & R. Sear (eds.) *Human Evolutionary Demography*. Open book publishers. DOI: https://doi.org/10.11647/OBP.0251

Mood, C. (2010). Logistic regression: Why we cannot do what we think we can do, and what we can do about it. *European Sociological Review*, 26(1), 67-82.

Murphy, D,J,, Stirrat, G.M., Heron, J.; & ALSPAC Study Team. (2002). The relationship between caesarean section and subfertility in a population-based sample of 14 541 pregnancies. *Human Reproduction*, 17, 1914-1917.

Newman, L. (2008). How parenthood experiences influence desire for more children in Australia: A qualitative study. *Journal of Population Research*, 25(1), 1-27.

Penovich, P. E. (2000). The effects of epilepsy and its treatment on sexual and reproductive function. *Epilepsia*, 41, S53-S61.

Phillips, R., Pell, B., Grant, A., Bowen, D., Sanders, J., Taylor, A., ... & Williams, D. (2018). Identifying the unmet information and support needs of women with autoimmune rheumatic diseases during pregnancy planning, pregnancy and early parenting: mixed-methods study. *BMC Rheumatology*, 2(1), 1-18.

Pieczyńska, J. (2018). Do celiac disease and non-celiac gluten sensitivity have the same effects on reproductive disorders? *Nutrition*, 48, 18-23.

Pintor, M. P., Fumagalli, E., & Suhrcke, M. (2024). The impact of health on labour market outcomes: a rapid systematic review. *Health Policy*, 105057.

Power, R. A., Kyaga, S., Uher, R., MacCabe, J. H., Långström, N., Landen, M., ... & Svensson, A. C. (2013). Fecundity of patients with schizophrenia, autism, bipolar disorder, depression, anorexia nervosa, or substance abuse vs their unaffected siblings. *JAMA Psychiatry*, 70(1), 22-30.

Rautava, P., Lehtonen, L., Helenius, H., & Sillanpää, M. (1995). Infantile colic: child and family three years later. *Pediatrics*, 96(1), 43-47.

Rijken, A. J., & Thomson, E. (2011). Partners' relationship quality and childbearing. *Social Science Research*, 40(2), 485-497.

Robles, T. F., Slatcher, R. B., Trombello, J. M., & McGinn, M. M. (2014). Marital quality and health: a meta-analytic review. *Psychological Bulletin*, 140(1), 140.

Rydahl, E., Declercq, E., Juhl, M., & Maimburg, R. D. (2019). Cesarean section on a rise—Does advanced maternal age explain the increase? A population register-based study. *PloS one*, 14(1), e0210655.

Sandström, G., Namatovu, F., Ineland, J., Larsson, D., Ng, N., & Stattin, M. (2021). The persistence of high levels of living alone among adults with disabilities in Sweden, 1993–2011. *Population Research and Policy Review*, 40(2), 163-185.

Schmidt, R., Richter, D., Sender, A., & Geue, K. (2016). Motivations for having children after cancer–a systematic review of the literature. *European Journal of Cancer Care*, 25(1), 6-17.

Schover, L. R. (2005). Motivation for parenthood after cancer: a review. *JNCI Monographs*, 2005(34), 2-5.

Stewart, S. D. (2002). The effect of stepchildren on childbearing intentions and births. *Demography*, 39, 181-197.

Syse, A., Thomas, M., Dommermuth, L., & Hart, R. K. (2022). Does women's health matter for fertility? Evidence from Norwegian administrative data. *Population Studies*, 76(2), 191-212.

Szreter S. (2019) (ed). T*he Hidden Affliction : Sexually Transmitted Infections and Infertility in History*. University of Rochester Press, Rochester.

Terceira, N., Gregson, S., Zaba, B., & Mason, P. (2003). The contribution of HIV to fertility decline in rural Zimbabwe, 1985-2000. *Population Studies*, 57(2), 149-164.

Trimarchi, A., & Van Bavel, J. (2020). Partners' educational characteristics and fertility: Disentangling the effects of earning potential and unemployment risk on second births. *European Journal of Population*, *36*, 439-464.

Trinitapoli, J., & Yeatman, S. (2017). The flexibility of fertility preferences in a context of uncertainty. *Population and Development Review*, 44(1), 87.

Varghese, N.E. (2022*). Essays in wellbeing, health and human capital development*, PhD Thesis, Bocconi University.

Vigoureux, S., Lorthe, E., Blondel, B., Ringa, V., & Saurel-Cubizolles, M. J. (2023). Women's occupational status during pregnancy and preventive behaviour and health outcomes

between 1998 and 2016 in France. *Journal of Gynecology Obstetrics and Human Reproduction*, *52*(3), 102545.

Wehby, G.L., & Hockenberry, J.M. (2017). Impact of child health and disability on subsequent maternal fertility. *Review of Economics of the Household*, 15, 995–1016.

Wesselink, A. K., Hatch, E. E., Rothman, K. J., Mikkelsen, E. M., Aschengrau, A., & Wise, L. A. (2019). Prospective study of cigarette smoking and fecundability. *Human Reproduction*, 34(3), 558-567.

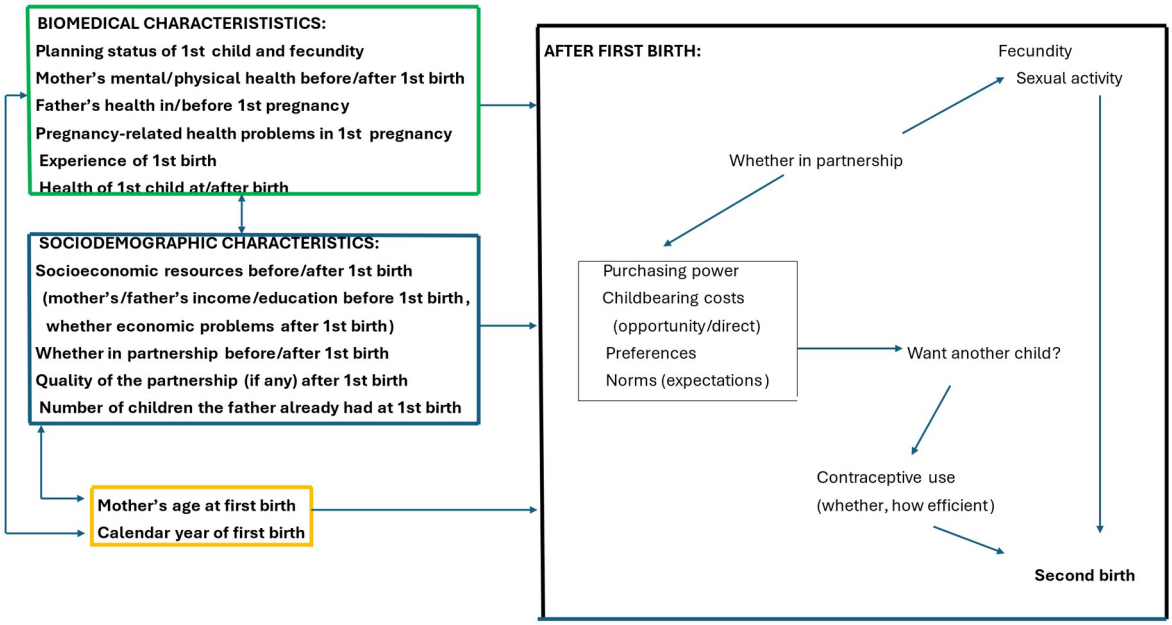
Wiebe, J. C., Santana, A., Medina-Rodríguez, N., Hernández, M., Nóvoa, J., Mauricio, D., & Wägner, A. M. (2014). Fertility is reduced in women and in men with type 1 diabetes: results from the Type 1 Diabetes Genetics Consortium (T1DGC). *Diabetologia*, 57(12), 2501-2504.

Wiik, K. A., & Dommermuth, L. (2014). Who remains unpartnered by mid-life in Norway? Differentials by gender and education. *Journal of Comparative Family Studies*, 45(3), 405-424.

Wood, J. W. (1994). *Dynamics of Human Reproduction: Biology, Biometry, Demography*. New York : Aldine de Gruyter.

Zeman, K., Beaujouan, É., Brzozowska, Z., & Sobotka, T. (2018). Cohort fertility decline in low fertility countries: Decomposition using parity progression ratios. *Demographic Research*, 38, 651-690.

Figure 1. Illustration of the conceptual framework



Note: Variables in bold are included in the analysis. In the labels for these variables, the words 'after first birth' refer to 6 months after first birth. (The variable 'whether in partnership' (currently) was included in a supplementary hazard model analysis.) The underlying theoretical idea is that each of the biomedical or sociodemographic variables may affect at least one of the more proximate fertility determinants (in the larger box) that operate after first birth, and to a larger extent after the 6 months when some of the biomedical and sociodemographic variables are measured. Alternatively, the biomedical and sociodemographic variables may be considered as earlier versions - or indicators of earlier versions - of those proximate determinants (e.g, time to first pregnancy indicates fecundity before first birth, while it is fecundity at a later stage that is the relevant proximate determinant for a second birth). Obviously, there are additional selection factors. For example, factors not shown in the figure may affect both one or more of the biomedical characteristics and the second-birth probability.

...

Table 1. Effects (with standard errors) of various sociodemographic and biomedical characteristics on the probability of having a second child within 10 years, among women interviewed in MoBa in 1999-2009 [a]

	Proportion (%) in the category[a]	Model 1: All biomedical variables plus mother's age at first birth and year of first birth	Model 2: All socio-demographic variables plus mother's age at first birth and year of first birth	Model 3: All variables plus mother's age at first birth and year of first birth	Model 3: Outcome: 3 years instead of 10 years [b]
Planning status of first child and indicators of fecundity					
Planning status, time to pregnancy (ttp) and whether ART (Ref: Planned, child naturally conceived, ttp 1-11 months or unreported)					
Unplanned	18.7	-0.078*** (0.004)		-0.041*** (0.004)	- -
Planned, child conceived after ART	2.9	-0.055*** (0.010)		-0.058*** (0.010)	
Planned, child natural conceived, ttp ≥12 months	7.3	-0.028*** (0.006)		-0.023*** (0.006)	0
Mother's depression/anxiety before/after first birth					
Whether the mother shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)					
6-7	31.6	-0.013*** (0.004)		-0.008* (0.004)	- -
≥8	17.4	-0.050*** (0.005)		-0.026*** (0.005)	- -
Number of weeks with postnatal depression (Ref: 0)					
1-5	9.6	-0.008 (0.006)		-0.005 (0.005)	-
≥6	6.5	-0.063*** (0.007)		-0.056*** (0.007)	- -
Mother's physical health before/after first birth					
Pre-pregnancy chronic physical diseases					
Stomach disease (Ref: No)	3.3	-0.013 (0.009)		-0.007 (0.009)	
Musculoskeletal disease (Ref: No)	2.8	-0.032*** (0.010)		-0.020* (0.010)	0
Hypertension or diabetes (Ref: No)	1.2	-0.045*** (0.015)		-0.038** (0.015)	0
Sexually transmitted or gynaecological disease (Ref: No)	27.5	-0.013*** (0.004)		-0.004 (0.004)	
BMI before the first pregnancy (Ref:<25)					
≥25 and < 30	19.8	-0.016*** (0.004)		-0.007 (0.004)	

≥30	8.2	-0.063*** (0.006)		-0.040*** (0.006)	
General physical health 6 months after birth (Ref: Very good)					
Good	54.5	-0.009* (0.003)		-0.003 (0.003)	-
Poor or very poor	2.9	-0.054*** (0.010)		-0.044*** (0.010)	- -
Father's health in/before first pregnancy					
Whether the father shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)					
6-7	16.0	-0.004 (0.005)		-0.002 (0.004)	
≥8	6.7	-0.019*** (0.007)		-0.006 (0.007)	
Father's pre-pregnancy chronic physical diseases					
Prolonged/repeated back, neck of shoulder pain (Ref: No)	9.0	-0.028*** (0.006)		-0.011 (0.006)	
Hypertension, other CVD or diabetes (Ref: No)	2.3	-0.046*** (0.011)		-0.034** (0.010)	0
Migraine or other headache (Ref: No)	7.1	-0.020*** (0.006)		-0.012* (0.006)	0
Pregnancy-related health problems in first pregnancy					
Hypertension that started in pregnancy (Ref: No)	2.5	0.000 (0.010)		-0.009 (0.010)	
Gestational diabetes (Ref: No)	0.7	0.019 (0.020)		0.022 (0.019)	
Pre-eclampsia or eclampsia (Ref: No)	5.0	-0.005 (0.008)		-0.006 (0.007)	
Oedema (Ref: No)	15.0	-0.018*** (0.005)		-0.014** (0.004)	0
Long-lasting nausea and vomiting (Ref: No)	10.1	-0.014** (0.005)		-0.016** (0.005)	- -
Severe muscle or joint pain (Ref: No)	15.3	-0.010* (0.005)		-0.005 (0.005)	-
On sick leave in pregnancy, after week 30 (Ref: No)					
Partly	28.4	0.006 (0.004)		0.005 (0.004)	
Fully	25.1	-0.020*** (0.004)		-0.006 (0.004)	
Experience of first birth					
Whether caesarean section (Ref: No)					
Yes, emergency	12.1	-0.041*** (0.005)		-0.037*** (0.005)	
Yes, planned, breech and other not normal positions	2.0	-0.017 (0.011)		-0.015 (0.011)	-
Yes, planned, normal (including very few unknown)	1.4	-0.065*** (0.014)		-0.060*** (0.014)	- -
Whether birth worse than as expected (Ref: No) -	23.3	0.001 (0.004)		0.001 (0.004)	-
Health of first child at/after birth					

Whether low birth weight or preterm (Ref: No)					
Either low birth weight or preterm	8.1	-0.009 (0.006)		-0.006 (0.006)	-
Both	2.3	-0.022* (0.011)		-0.017 (0.011)	-
Whether a malformation (Ref: No)	1.2	-0.004 (0.015)		-0.008 (0.015)	
Whether Apgar score 5 minutes after birth is <7 (Ref: No)	1.4	-0.007 (0.014)		-0.009 (0.014)	
Whether a relatively serious health problems 6 months after birth (Ref: No)	17.6	0.004 (0.005)		0.003 (0.004)	
Whether the child has colic (Ref: No)	12.6	-0.019*** (0.005)		-0.019*** (0.005)	
Number of hours the child sleeps 6 months after birth (Ref: ≥ 15 hours)					
≤12 hours	21.6	-0.019*** (0.005)		-0.011* (0.005)	- -
13-14 hours	54.1	-0.004 (0.004)		-0.005 (0.004)	-
Score on an indicator of how demanding the child is (Ref: ≤16)					
17-21	31.1	0.005 (0.004)		0.004 (0.004)	
≥ 22	32.5	0.005 (0.004)		0.006 (0.004)	
Socioeconomic resources before/after first birth					
Mother's annual income two years before birth (NOK) (Ref: ≥250000)					
0	10.8		-0.016* (0.007)	-0.008 (0.007)	-
1-149999	28.8		-0.024*** (0.005)	-0.018*** (0.005)	- -
150000-249999	36.2		-0.017*** (0.004)	-0.014** (0.004)	- -
Father's annual income two years before birth (NOK) (Ref: ≥300000)					
0	6.5		-0.014 (0.007)	-0.013 (0.007)	
1-199999	31.9		-0.005 (0.004)	-0.004 (0.004)	
200000-299999	31.7		-0.012** (0.004)	-0.010* (0.004)	- -
Mother's education two years before birth (Ref: Upper tertiary)					
Not completed secondary	11.2		-0.128*** (0.008)	-0.107*** (0.008)	
Completed secondary	27.1		-0.082*** (0.006)	-0.070*** (0.006)	
Lower tertiary	48.3		-0.023*** (0.005)	-0.020*** (0.005)	0
Father's education two years before birth (Ref: Upper tertiary)					
Not completed secondary	17.1		-0.080*** (0.007)	-0.069*** (0.007)	- -
Completed secondary	38.8		-0.044*** (0.006)	-0.037*** (0.005)	- -
Lower tertiary	30.2		-0.019*** (0.005)	-0.017*** (0.005)	- -
Whether economic problems 6 months after birth (Ref: Never/rarely had problems, and can manage unexpected expense)					
Cannot manage unexpected expense or have sometimes/often had problems	20.4		-0.034*** (0.004)	-0.022** (0.004)	

Partnership before/after first birth and father's older children					
Partnership before/after birth (Ref: Married)					
Cohabiting	55.3		0.003 (0.003)	0.003 (0.004)	-
Single in pregnancy or at birth, but partnered 6 months after birth	4.3		-0.043*** (0.008)	-0.033*** (0.008)	- -
Partnered at birth, but single 6 months after birth	2.1		-0.115*** (0.012)	-0.102*** (0.012)	- -
Single at birth and 6 months after birth	2.3		-0.269*** (0.012)	-0.231*** (0.012)	- -
Perceived relationship quality 6 month after birth (Ref: 10-12)					
13-18	33.0		-0.009* (0.004)	-0.005 (0.004)	
≥19 (lowest quality)	26.7		-0.056*** (0.004)	-0.042*** (0.004)	- -
Number of children the father already had at first birth (Ref: 0):					
1	5.9		-0.086*** (0.007)	-0.085*** (0.007)	Less neg.
≥2	4.4		-0.184*** (0.008)	-0.181*** (0.008)	Less neg.
Model fit as measured by R-square[c]		0.149	0.184	0.198	

Notes:

*p<0.05; **p<0.01; ***p<0.001

[a] Linear probability models were estimated. All models included the mother's age at first birth and the year of the birth of the first child. For many variables, there was also a separate missing category. For simplicity, the effect coefficients for the missing categories are not shown.
See details in Appendix 1 about how the variables are defined and constructed.

[b] The symbol -- means that the association was at least 0.010 stronger (more negative) in the models for a 3-year probability than in the models for a 10-year probability, but significant in both models;
- means that the association with the 3-year probability was significantly negative, as opposed to no significant association with the 10-year probability;
0 means that there was no significant association with the 3-year probability, as opposed to a significant negative association with the 10-year probability.
'Less neg' means that the association with the 3-year probability was markedly less negative.

[c] R-square if only mother's age at and year were included: 0.109

ONLINE SUPPLEMENT:

Appendix 1 (including Table A1.1)

Appendix 2 (including Tables A2.1 and A2.2)

APPENDIX 1: VARIABLE DEFINITIONS AND CONSTRUCTIONS, AND HANDLING OF MISSING VALUES

General notes:

'Pregnancy' refers to the pregnancy leading up to the birth of the first child. 'Child' refers to that child, and 'father' refers to the father of that child.

Planning status of first child and indicators of fecundity:

Planning status, time to pregnancy (ttp) and whether ART: Information about whether the first child was conceived by means of ART was taken from the Medical Birth Register, while the other information was taken from MoBa. The ttp category 1-11 months also includes a quite small group with unreported ttp (8% of all in this category). 1.0% were put in an additional missing category.

Mother's depression/anxiety before/after first birth:

Whether the mother shows signs of depression or anxiety in 15th pregnancy week: The information was taken from a series of 5 MoBa questions that constitute a short version of the Hopkin symptom list for depression and anxiety. Each of the questions have an answer scale with 4 grades. The grades (1-4) were summed. A high total grade indicates a relatively high level of depression/anxiety. The categories were defined by dividing those who did not have the lowest possible score (5) into two categories of similar size. 3.1% were put in an additional category for missing, which means that at least one of the 5 questions has not been answered.

Number of weeks with postnatal depression: The information was taken from a MoBa question asked 6 months after first birth. The categories were defined by dividing those with some postnatal depression into two categories of similar size. 1.5% were put in an additional missing category.

Mother's physical health before/after first birth:

Pre-pregnancy chronic physical diseases:

The focus was on the following diseases, and they are denoted as chronic because they may re-occur if not properly treated, or may lead to long-lasting health problems. Information was taken from a question in the MoBa interview in the 15th week of pregnancy, unless MBR is added in parenthesis, which means that the information was taken from the Medical Birth Register. The diseases are referred to as pre-pregnancy diseases because, even if reported in the 15th week of pregnancy, they have probably in most cases had their onset before the pregnancy.
-Stomach disease: Whether one of these diseases: hepatitis/jaundice, gall stones, duodenal/stomach ulcer, IBD, celiac disease.
-Musculoskeletal disease: Whether one of these diseases: rheumatoid arthritis (MBR), lupus, sciatica, myalgia.
-Hypertension or diabetes: Whether hypertension (MBR) or diabetes (MBR).
-Sexually transmitted or gynaecological disease: Whether one of these diseases: ovary/fallopian tube infection, endometriosis, myoma, genital herpes, chlamydia, ovarian cyst, cervical cell changes, venereal warts/condyloma, gonorrhea.
Various other (groups of) diseases which there is information about in MoBa are relatively rare and/or had weak effects (in the simplest model) on subsequent fertility.

BMI before the first pregnancy: The information was taken from MoBa questions in the 15th pregnancy week. The categories were based on the standard definitions of overweight and obesity. There was no significant difference in second-birth probabilities between those with BMI < 21 (25% of the mothers) and the others with BMI < 25. Individuals whose height or weight was not reported, or was reported to be < 100 cm or < 25 kg, respectively, were put in a missing category (2.1%).

General physical health 6 months after birth: The information was taken from a MoBa question. 0.7% were put in an additional category for missing.

Father's health in/before first pregnancy:

Whether the father shows signs of depression or anxiety in 15th pregnancy week: The information was taken from a series of 5 MoBa questions that constitute a short version of the Hopkin symptom list for depression and anxiety (the same as for women, i.e. ignoring 3 other questions a smaller proportion of the women were asked). Each of the questions have an answer scale with 4 grades. The grades (1-4) were summed. A high total grade indicates a relatively high level of depression/anxiety. The categories were defined by dividing those who did not have the lowest possible score (5) into two categories of similar size. 21.0% were put in an additional category for missing, which means that at least one of the 5 questions was not answered – including the possibility that the father did not participate in the survey.

Father's pre-pregnancy chronic physical diseases: The focus was on the following diseases, and they are denoted as chronic because they may re-occur if not properly treated, or may lead to long-lasting health problems. Information was taken from the MoBa questions in the 15th pregnancy

week. The diseases are referred to as pre-pregnancy diseases because, even if reported in the 15th week of pregnancy, they have probably in most cases had their onset before the pregnancy.
-Prolonged/repeated back, neck of shoulder pain: Whether one of these diseases.
-Hypertension, other CVD or diabetes: Whether one of these diseases.
-Migraine or other headache: Whether one of these diseases
The other (groups) of diseases which there is information about in MoBa were either smaller or were more weakly associated with fertility in the simplest models, except that the relatively large group with allergy/asthma had significantly elevated fertility.
An indicator of whether the father was interviewed was also added to the models. 19.6% were not interviewed. The three variables were set to 0 if the father was not interviewed.

Pregnancy-related health problems in first pregnancy:

Hypertension that started in pregnancy: The information was taken from the Medical Birth Register.

Gestational diabetes: The information was taken from the Medical Birth Register.

Pre-eclampsia or eclampsia: The information was taken from the Medical Birth Register.

Oedema: The information was taken from a MoBa question asked in 30th week of pregnancy but covering also earlier weeks. Several conditions were addressed in the questionnaire. Oedema and long-lasting nausea are relatively common. Others that are almost as common turned out to be less strongly associated with the second-birth probability in the simplest model (pregnancy itch, headache/migraine), while some that are even more common (constipation, unusual fatigue/drowsiness, heartburn, and leg cramps) were found to be unrelated to the second-birth probability.

Long-lasting nausea and vomiting: See comment about oedema.

Severe muscle/joint pain: The information was taken from a MoBa question exclusively about muscle and joint pain (with distinction between severe and less severe) asked in 30th week of pregnancy, but covering also earlier weeks. The following types of pain were considered: pain in the small of the back, pain in one of the pelvic/sacroiliac joints at the back, pain in both these joints, pain over the coccygeal bone, pain in the buttocks, pain over the pubic bone, pain in the groin, and other back pains. Having less severe pain was not associated with the second-birth probability in the simplest models.

On sick leave in pregnancy, after week 30: The information was taken from MoBa questions asked 6 months after birth. 9.9% were put in an additional missing category.

Experience of first birth:

Whether caesarean section: The information was taken from the Medical Birth Register. For 1% of the women in emergency category, it was not reported whether the caesarean was emergency or planned.

Whether birth as expected: The information was taken from MoBa. 13.5% were put in a missing category.

Health of first child at/after first birth:

Whether low birth weight or preterm: The information was taken from the Medical Birth Register.

Whether a malformation: The information was taken from the Medical Birth Register.

Whether Apgar score 5 minutes after birth is <7: The information was taken from the Medical Birth Register.

Whether a relatively serious health problems 6 months after birth: The information was taken from MoBa questions asked 6 month after birth about: hip disorder, impaired hearing, impaired vision, delayed motoric development, too little wight gain, too much weight gain, abnormal head circumference, heart defect, testicles not descended, asthma, atopic eczema, hives, food allergy, and (other) malformations. None of these were associated with the second-birth probability in the simplest model, but almost significant associations appeared for two that are neither among the least common nor the most common (delayed motoric development, food allergy) A large group (35.1%) were put in a category for missing because there was at least one question the mother did not answer.

Whether the child has colic: The information was taken from a series of MoBa questions asked 6 months after birth about: common cold, throat infection, ear infection, pseudocroup, bronchitis/RS/pneumonia, gastric flu, urinary tract infection, febrile convulsions, other convulsions, colic and nappy rash. 3.4% were put in a category for missing because they did not answer the question on colic. Only two of the least common other diseases were significantly associated with low second-birth probabilities in the simplest model (throat infection, febrile convulsions).

Number of hours the child sleeps 6 months after birth: The information was taken from a MoBa question asked 6 month after birth. 0.6% were put in an additional missing category

Score on an indicator of how demanding the child is: The information was taken from a series of 10 MoBa questions asked 6 month after birth (about, for example, the amount of crying, the amount of attention needed, and whether the child smiles/laughs often). The answers to each of them are on a 7-graded scale. The last question was not used because of a large proportion missing. Thus, the maximum possible score (indicating a very demanding child) was 63. Three categories of similar size were defined. If the highest of these three categories was split into two sub-categories of similar size, there were clearer indications of a reduced second-birth probability for the highest of these two compared to the reference group, but the difference was not significant even in the simplest model. 5.5% were put in an additional category for missing because there was at least one question the mother did not answer.

Socioeconomic resources before/after first birth:

Mother's annual income two years before birth: The information was taken from register data on so-called 'alminnelig inntekt'. The categories were defined by dividing those with an income > 0 into three categories of similar size. 0.7% were put in an additional category for missing.

Father's annual income two years before birth: Same as for mothers. 1.8% were put in an additional category for missing.

Mother's education two years before birth: The information was taken from register data.

Father's education two years before birth: Same as for mothers.

Whether economic problems 6 months after birth: The information was taken from a MoBa question about whether the mother had had problem with managing the basic expenses during the last 6 months, and a MoBa question about whether she could manage an unexpected expense of 10000 NOK (dichotomized into yes vs no or don't know). A large majority of those who had sometimes or often had problems also could not manage an unexpected expense of 10000. 0.7% were put in an additional category for missing, which means that at least one of the questions was not answered.

Partnership before/after first birth and father's older children

Partnership before/after birth: The information about status at birth was taken from the Medical Birth Register, and statuses in the 15th week of the pregnancy and 6 months after birth were taken from MoBa. This is a detailed specification of the 5 categories: i) having a partner in the 15th pregnancy week, being married at birth, and having still a partner 6 months after birth (reference category), ii) having a partner in the 15th pregnancy week, being cohabitant at birth, and having still a partner 6 months after birth, iii) being single in the 15th pregnancy week and/or at birth, but having a partner 6 months after birth, iv) having a partner at birth, but being single 6 months after birth, and v) being single at birth as well as 6 months after birth.

Perceived relationship quality 6 months after birth: The information was taken from a series of 10 questions in the MoBa interview 6 months after birth, each of them having an answer scale with 6 grades. The grades (1-6) were summed, after reversal where necessary (so that a high grade means low relationship quality). Women who were neither married nor cohabiting 6 month after birth (the last two categories of the partnership variable) were put in the reference category (i.e. high quality). Three categories of similar size were defined. 4.3% were in an additional category for missing, which means that at least one of the 10 questions was not answered even though the mother was in a partnership.

Number of children the father already had at first birth: The information was taken from register data.

ADDITIONAL COMMENT ON MISSING VALUES

In addition to including a special 'missing' category for some of the variables, we tried two alternative strategies: First, we did a MAR imputation with a FCS discriminant function method, where each missing value was imputed based on equations including all other variables (using Proc Mi and Proc Mianalyze in the SAS software). The results were almost identical (see Appendix Table A1.1). It is not obvious what kind of assumptions one should have made in a NMAR (i.e., non-random) imputation. Second, we excluded all observations where there was at least one missing value, which reduced the number of observations by 42%. The estimates were then different, but not very much.

Appendix Table A1.1. Effects (with standard errors) of various sociodemographic and biomedical characteristics on the probability of having a second child within 10 years, among women interviewed in MoBa in 1999-2009 [a]

	As Model 3 in Table 3, but with MAR imputation	As Model 3 in Table 1, but with exclusion of all individuals with at least one missing value[b]	Model 3 in Table 1
Planning status of first child and indicators of fecundity			
Planning status, time to pregnancy (ttp) and whether ART (Ref: Planned, child naturally conceived, ttp 1-11 months or unreported)			
Unplanned	-0.041*** (0.005)	-0.034*** (0.006)	-0.041*** (0.004)
Planned, child conceived after ART	-0.057*** (0.010)	-0.058*** (0.012)	-0.058*** (0.010)
Planned, child natural conceived, ttp ≥12 months	-0.022*** (0.006)	-0.032*** (0.007)	-0.023*** (0.006)
Mother's depression/anxiety before/after first birth			
Whether the mother shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)			
6-7	-0.008* (0.004)	-0.004 (0.004)	-0.008* (0.004)
≥8	-0.024*** (0.005)	-0.012* (0.006)	-0.026*** (0.005)
Number of weeks with postnatal depression (Ref: 0)			
1-5	-0.005 (0.005)	-0.006 (0.007)	-0.005 (0.005)
≥6	-0.055*** (0.007)	-0.055*** (0.008)	-0.056*** (0.007)
Mother's physical health before/after first birth			
Pre-pregnancy chronic physical diseases			
Stomach disease (Ref: No)	-0.006 (0.009)	-0.009 (0.011)	-0.007 (0.009)
Musculoskeletal disease (Ref: No)	-0.020* (0.010)	-0.021 (0.012)	-0.020* (0.010)
Hypertension or diabetes (Ref: No)	-0.039*** (0.015)	-0.045* (0.018)	-0.038** (0.015)
Sexually transmitted or gynaecological disease (Ref: No)	-0.004 (0.004)	-0.010* (0.004)	-0.004 (0.004)
BMI before the first pregnancy (Ref:<25)			
≥25 and < 30	-0.017 (0.004)	-0.005 (0.005)	-0.007 (0.004)

≥30	-0.040*** (0.006)	-0.033*** (0.007)	-0.040*** (0.006)
General physical health 6 months after birth (Ref: Very good)			
Good	-0.003 (0.003)	-0.003 (0.004)	-0.003 (0.003)
Poor or very poor	-0.044*** (0.010)	-0.048*** (0.013)	-0.044*** (0.010)
Father's health in/before first pregnancy			
Whether the father shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)			
6-7	-0.004 (0.005)	-0.005 (0.005)	-0.002 (0.004)
≥8	-0.009 (0.007)	-0.013 (0.007)	-0.006 (0.007)
Father's pre-pregnancy chronic physical diseases			
Prolonged/repeated back, neck of shoulder pain (Ref: No)	-0.011 (0.006)	-0.010 (0.006)	-0.011 (0.006)
Hypertension, other CVD or diabetes (Ref: No)	-0.034** (0.010)	-0.027* (0.012)	-0.034** (0.010)
Migraine or other headache (Ref: No)	-0.013* (0.006)	-0.013 (0.007)	-0.012* (0.006)
Pregnancy-related health problems in first pregnancy			
Hypertension that started in pregnancy (Ref: No)	-0.009 (0.010)	0.000 (0.012)	-0.009 (0.010)
Gestational diabetes (Ref: No)	0.022 (0.019)	0.003 (0.025)	0.022 (0.019)
Pre-eclampsia or eclampsia (Ref: No)	0.006 (0.007)	-0.013 (0.010)	-0.006 (0.007)
Oedema (Ref: No)	-0.014** (0.004)	-0.011 (0.006)	-0.014** (0.004)
Long-lasting nausea and vomiting (Ref: No)	-0.016** (0.005)	-0.020** (0.007)	-0.016** (0.005)
Severe muscle or joint pain (Ref: No)	-0.005 (0.005)	-0.005 (0.006)	-0.005 (0.005)
On sick leave in pregnancy, after week 30 (Ref: No)			
Partly	0.004 (0.004)	0.005 (0.005)	0.005 (0.004)
Fully	-0.006 (0.004)	-0.006 (0.005)	-0.006 (0.004)
Experience of first birth			
Whether caesarean section (Ref: No)			
Yes, emergency	-0.037*** (0.005)	-0.044*** (0.007)	-0.037*** (0.005)
Yes, planned, breech and other not normal positions	-0.015 (0.011)	-0.011 (0.014)	-0.015 (0.011)
Yes, planned, normal (including very few unknown)	-0.060*** (0.014)	-0.056** (0.018)	-0.060*** (0.014)
Whether birth worse than as expected (Ref: No)	0.001 (0.004)	0.001 (0.005)	0.001 (0.004)
Health of first child at/after birth			

Whether low birth weight or preterm (Ref: No)			
Either low birth weight or preterm	-0.007 (0.006)	-0.006 (0.007)	-0.006 (0.006)
Both	-0.017 (0.011)	0.002 (0.014)	-0.017 (0.011)
Whether a malformation (Ref: No)	-0.011 (0.015)	-0.004 (0.018)	-0.008 (0.015)
Whether Apgar score 5 minutes after birth is <7 (Ref: No)	-0.010 (0.014)	0.001 (0.017)	-0.009 (0.014)
Whether a relatively serious health problems 6 months after birth (Ref: No)	0.005 (0.004)	0.005 (0.005)	0.003 (0.004)
Whether the child has colic (Ref: No)	-0.018*** (0.004)	-0.020** (0.006)	-0.019*** (0.005)
Number of hours the child sleeps 6 months after birth (Ref: ≥ 15 hours)			
≤12 hours	-0.011* (0.005)	-0.008 (0.006)	-0.011* (0.005)
13-14 hours	-0.005 (0.004)	-0.002 (0.005)	-0.005 (0.004)
Score on an indicator of how demanding the child is (Ref: ≤16)			
17-21	0.004 (0.004)	0.005 (0.005)	0.004 (0.004)
≥ 22	0.004 (0.004)	0.003 (0.005)	0.006 (0.004)
Socioeconomic resources before/after first birth			
Mother's annual income two years before birth (NOK) (Ref: ≥250000)			
0	-0.009 (0.007)	-0.013 (0.009)	-0.008 (0.007)
1-149999	-0.019*** (0.005)	-0.014* (0.006)	-0.018*** (0.005)
150000-249999	-0.014* (0.004)	-0.013* (0.005)	-0.014** (0.004)
Father's annual income two years before birth (NOK) (Ref: ≥300000)			
0	-0.013 (0.007)	-0.009 (0.009)	-0.013 (0.007)
1-199999	-0.003 (0.004)	-0.001 (0.005)	-0.004 (0.004)
200000-299999	-0.010* (0.004)	-0.007 (0.005)	-0.010* (0.004)
Mother's education two years before birth (Ref: Upper tertiary)			
Not completed secondary	-0.107*** (0.008)	-0.114*** (0.010)	-0.107*** (0.008)
Completed secondary	-0.069*** (0.006)	-0.076*** (0.008)	-0.070*** (0.006)
Lower tertiary	-0.019*** (0.005)	-0.023*** (0.006)	-0.020*** (0.005)
Father's education two years before birth (Ref: Upper tertiary)			
Not completed secondary	-0.072** (0.007)	-0.054*** (0.008)	-0.069*** (0.007)
Completed secondary	-0.038*** (0.006)	-0.025*** (0.007)	-0.037*** (0.005)
Lower tertiary	-0.018*** (0.005)	-0.008 (0.006)	-0.017*** (0.005)
Whether economic problems 6 months after birth (Ref: Never/rarely had problems, and can manage unexpected expense)			
Cannot manage unexpected expense or have sometimes/often had problems	-0.022*** (0.004)	-0.018*** (0.006)	-0.022** (0.004)

Partnership before/after first birth and father's older children			
Partnership before/after birth (Ref: Married)			
Cohabiting	0.003 (0.004)	-0.001 (0.004)	0.003 (0.004)
Single in pregnancy or at birth, but partnered 6 months after birth	-0.033*** (0.008)	0.003 (0.011)	-0.033*** (0.008)
Partnered at birth, but single 6 months after birth	-0.103*** (0.012)	-0.079*** (0.015)	-0.102*** (0.012)
Single at birth and 6 months after birth	-0.233*** (0.012)	-0.230*** (0.025)	-0.231*** (0.012)
Perceived relationship quality 6 month after birth (Ref: 10-12)			
13-18	-0.005 (0.004)	-0.004 (0.005)	-0.005 (0.004)
≥19 (lowest quality)	-0.040*** (0.004)	-0.040*** (0.005)	-0.042*** (0.004)
Number of children the father already had at first birth (Ref: 0):			
1	-0.084* (0.007)	-0.086*** (0.009)	-0.085*** (0.007)
≥2	-0.179*** (0.008)	-0.172*** (0.010)	-0.181*** (0.008)
Number of observations	37459	21623	37459

Notes:

*p<0.05; **p<0.01; ***p<0.001

[a] Linear probability models were estimated. The mother's age at birth and year of first birth were included in all models. See details in the first part of Appendix1 about how the variables were defined and constructed.

[b] R-square values: The model including age and year: 0.104; age, year and biomedical variables: 0.135; age, year and socioeconomic variables: 0.160; age, year, biomedical variables and socioeconomic variables (the model shown here): 0.175.

APPENDIX 2: TABLES A2.1 AND A2.2

Appendix Table A2.1. Effects (with standard errors) of various biomedical characteristics on the probability of having a second child within 10 years, among women interviewed in MoBa in 1999-2009 [a]

	As Model 1 in Table 1, i.e. all biomedical variables plus mother's age at first birth and year of first birth	Model 4: All variables in one **block** (as indicated by bold types) plus mother's age at first birth and year of first birth
Planning status of first child and indicators of fecundity		
Planning status, time to pregnancy (ttp) and whether ART (Ref: Planned, child naturally conceived, ttp 1-11 months or unreported)		
Unplanned	-0.078*** (0.004)	-0.097*** (0.004)
Planned, child conceived after ART	-0.055*** (0.010)	-0.063*** (0.010)
Planned, child natural conceived, ttp ≥12 months	-0.028*** (0.006)	-0.040*** (0.006)
Mother's depression/anxiety before/after first birth		
Whether the mother shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)		
6-7	-0.013*** (0.004)	-0.022*** (0.004)
≥8	-0.050*** (0.005)	-0.077*** (0.005)
Number of weeks with postnatal depression (Ref: 0)		
1-5	-0.008 (0.006)	-0.015** (0.006)
≥6	-0.063*** (0.007)	-0.079*** (0.007)
Mother's physical health before/after first birth		
Pre-pregnancy chronic physical diseases		
Stomach disease (Ref: No)	-0.013 (0.009)	-0.027** (0.009)
Musculoskeletal disease (Ref: No)	-0.032*** (0.010)	-0.045*** (0.010)

Hypertension or diabetes (Ref: No)	-0.045*** (0.015)	-0.063*** (0.015)
Sexually transmitted or gynaecological disease (Ref: No)	-0.013*** (0.004)	-0.022*** (0.004)
BMI before the first pregnancy (Ref:<25)		
≥25 and < 30	-0.016*** (0.004)	-0.020** (0.004)
≥30	-0.063*** (0.006)	-0.078*** (0.006)
General physical health 6 months after birth (Ref: Very good)		
Good	-0.009* (0.003)	-0.022*** (0.003)
Poor or very poor	-0.054*** (0.010)	-0.100*** (0.010)
Father's health in/before first pregnancy		
Whether the father shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)		
6-7	-0.004 (0.005)	-0.013** (0.005)
≥8	-0.019*** (0.007)	-0.041*** (0.007)
Father's pre-pregnancy chronic physical diseases		
Prolonged/repeated back, neck of shoulder pain (Ref: No)	-0.028*** (0.006)	-0.036*** (0.006)
Hypertension, other CVD or diabetes (Ref: No)	-0.046*** (0.011)	-0.058*** (0.011)
Migraine or other headache (Ref: No)	-0.020*** (0.006)	-0.024*** (0.007)
Pregnancy-related health problems in first pregnancy		
Hypertension that started in pregnancy (Ref: No)	0.000 (0.010)	-0.005 (0.010)
Gestational diabetes (Ref: No)	0.019 (0.020)	-0.004 (0.020)
Pre-eclampsia or eclampsia (Ref: No)	-0.005 (0.008)	-0.026*** (0.008)
Oedema (Ref: No)	-0.018*** (0.005)	-0.033*** (0.005)
Long-lasting nausea and vomiting (Ref: No)	-0.014** (0.005)	-0.023*** (0.005)
Severe muscle or joint pain (Ref: No)	-0.010* (0.005)	-0.031*** (0.005)
On sick leave in pregnancy, after week 30 (Ref: No)		
Partly	0.006 (0.004)	0.007 (0.004)
Fully	-0.020*** (0.004)	-0.034*** (0.004)
Experience of first birth		
Whether caesarean section (Ref: No)		
Yes, emergency	-0.041*** (0.005)	-0.054*** (0.005)
Yes, planned, breech and other not normal positions	-0.017 (0.011)	-0.025* (0.012)

Yes, planned, normal (including very few unknown)	-0.065*** (0.014)	-0.097*** (0.014)
Whether birth worse than as expected (Ref: No)	0.001 (0.004)	-0.014** (0.004)
Health of first child at/after birth		
Whether low birth weight or preterm (Ref: No)		
Either low birth weight or preterm	-0.009 (0.006)	-0.023*** (0.006)
Both	-0.022* (0.011)	-0.048*** (0.011)
Whether a malformation (Ref: No)	-0.004 (0.015)	-0.008 (0.015)
Whether Apgar score 5 minutes after birth is <7 (Ref: No)	-0.007 (0.014)	-0.022 (0.014)
Whether a relatively serious health problems 6 months after birth (Ref: No)	0.004 (0.005)	-0.001 (0.005)
Whether the child has colic (Ref: No)	-0.019*** (0.005)	-0.034*** (0.005)
Number of hours the child sleeps 6 months after birth (Ref: ≥ 15 hours)		
≤12 hours	-0.019*** (0.005)	-0.028*** (0.005)
13-14 hours	-0.004 (0.004)	-0.006 (0.004)
Score on an indicator of how demanding the child is (Ref: ≤16)		
17-21	0.005 (0.004)	0.002 (0.004)
≥ 22	0.005 (0.004)	-0.004 (0.004)

Notes:

*p<0.05; **p<0.01; ***p<0.001

[a] Linear probability models were estimated. The mother's age at birth and year of first birth were included in all models. See details in Appendix1 about how the variables were defined and constructed.

Appendix Table A2.2. Effects (with standard errors or 95% confidence intervals) of various sociodemographic and biomedical characteristics on the probability of having a second child within 3 or 10 years, or on the second-birth rate, among women interviewed in MoBa in 1999-2009 [a]

	Hazard model, all variables[b] (odds ratios, 95% CI)	Hazard model, all variables plus whether lived with co-parent[b] (odds ratios, 95% CI)	As Model 3 in Table 1 except that the outcome is a birth within 3 years rather than 10 years[c]	As Model 3 in Table 1
Planning status of first child and indicators of fecundity				
Planning status, time to pregnancy (ttp) and whether ART (Ref: Planned, child naturally conceived, ttp 1-11 months or unreported)				
Unplanned	0.81*** (0.78-0.84)	0.82*** (0.80-0.85)	-0.087*** (0.007)	-0.041*** (0.004)
Planned, child conceived after ART	0.81*** (0.75-0.88)	0.80*** (0.74-0.86)	-0.065*** (0.015)	-0.058*** (0.010)
Planned, child natural conceived, ttp ≥12 months	0.93*** (0.89-0.97)	0.92*** (0.88-0.96)	-0.014 (0.010)	-0.023*** (0.006)
Mother's depression/anxiety before/after first birth				
Whether the mother shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)				
6-7	0.96** (0.94-0.99)	0.96** (0.94-0.99)	-0.020*** (0.006)	-0.008* (0.004)
≥8	0.89*** (0.86-0.92)	0.90*** (0.87-0.93)	-0.037*** (0.007)	-0.026*** (0.005)
Number of weeks with postnatal depression (Ref: 0)				
1-5	0.94** (0.90-0.97)	0.93*** (0.90-0.97)	-0.033*** (0.009)	-0.005 (0.005)
≥6	0.78*** (0.74-0.81)	0.78*** (0.74-0.82)	-0.086*** (0.010)	-0.056*** (0.007)
Mother's physical health before/after first birth				
Pre-pregnancy chronic physical diseases				
Stomach disease (Ref: No)	0.97 (0.91-1.04)	0.97 (0.91-1.04)	-0.012 (0.014)	-0.007 (0.009)
Musculoskeletal disease (Ref: No)	0.95 (0.88-1.02)	0.94 (0.87-1.01)	-0.001 (0.015)	-0.020* (0.010)
Hypertension or diabetes (Ref: No)	0.90 (0.80-1.01)	0.88* (0.78-0.99)	-0.020 (0.023)	-0.038** (0.015)
Sexually transmitted or gynaecological disease (Ref: No)	1.00 (0.98-1.03)	1.02 (0.99-1.05)	0.004 (0.006)	-0.004 (0.004)
BMI before the first pregnancy (Ref:<25)				
≥25 and < 30	0.99 (0.96-1.02)	0.98 (0.96-1.01)	0.004 (0.006)	-0.007 (0.004)
≥30	0.88*** (0.84-0.92)	0.86*** (0.83-0.91)	-0.041*** (0.009)	-0.040*** (0.006)
General physical health 6 months after birth (Ref: Very good)				

Good	0.97*** (0.94-0.99)	0.96*** (0.93-0.98)	-0.016* (0.005)	-0.003 (0.003)
Poor or very poor	0.78*** (0.73-0.85)	0.77*** (0.71-0.83)	-0.101*** (0.015)	-0.044*** (0.010)
Father's health in/before first pregnancy				
Whether the father shows signs of depression or anxiety in 15th pregnancy week (Ref: Total grade=5)				
6-7	0.98 (0.95-1.02)	0.99 (0.96-1.03)	-0.009 (0.007)	-0.002 (0.004)
≥8	0.95* (0.90-0.99)	0.96 (0.91-1.01)	-0.016 (0.010)	-0.006 (0.007)
Father's pre-pregnancy chronic physical diseases				
Prolonged/repeated back, neck of shoulder pain (Ref: No)	0.96 (0.92-1.00)	0.96* (0.92-1.00)	-0.011 (0.009)	-0.011 (0.006)
Hypertension, other CVD or diabetes (Ref: No)	0.88** (0.81-0.95)	0.87*** (0.81-0.95)	-0.004 (0.017)	-0.034** (0.010)
Migraine or other headache (Ref: No)	0.95* (0.90-0.99)	0.94* (0.90-0.99)	-0.011 (0.009)	-0.012* (0.006)
Pregnancy-related health problems in first pregnancy				
Hypertension that started in pregnancy (Ref: No)	0.98 (0.91-1.05)	0.97 (0.90-1.05)	0.010 (0.016)	-0.009 (0.010)
Gestational diabetes (Ref: No)	1.05 (0.91-1.21)	1.05 (0.90-1.21)	0.013 (0.030)	0.022 (0.019)
Pre-eclampsia or eclampsia (Ref: No)	0.97 (0.92-1.02)	0.97 (0.91-1.02)	-0.010 (0.012)	-0.006 (0.007)
Oedema (Ref: No)	0.97 (0.94-1.01)	0.97 (0.94-1.01)	-0.002 (0.007)	-0.014** (0.004)
Long-lasting nausea and vomiting (Ref: No)	0.94** (0.91-0.98)	0.94** (0.91-0.98)	-0.026** (0.008)	-0.016** (0.005)
Severe muscle or joint pain (Ref: No)	0.96* (0.93-0.99)	0.96* (0.93-1.00)	-0.017* (0.007)	-0.005 (0.005)
On sick leave in pregnancy, after week 30 (Ref: No)				
Partly	1.03 (1.00-1.06)	1.02 (0.99-1.05)	0.011 (0.006)	0.005 (0.004)
Fully	1.00 (0.97-1.03)	1.00 (0.97-1.03)	0.008 (0.007)	-0.006 (0.004)
Experience of first birth				
Whether caesarean section (Ref: No)				
Yes, emergency	0.85*** (0.82-0.89)	0.85*** (0.82-0.88)	-0.043*** (0.008)	-0.037*** (0.005)
Yes, planned, breech and other not normal positions	0.89*** (0.82-0.97)	0.88*** (0.81-0.95)	-0.048*** (0.018)	-0.015 (0.011)
Yes, planned, normal (including very few unknown)	0.75*** (0.68-0.84)	0.75*** (0.67-0.83)	-0.095*** (0.021)	-0.060*** (0.014)
Whether birth worse than as expected (Ref: No)	0.98 (0.95-1.01)	0.99 (0.96-1.02)	-0.016** (0.006)	0.001 (0.004)
Health of first child at/after birth				
Whether low birth weight or preterm (Ref: No)				
Either low birth weight or preterm	0.95* (0.91-1.00)	0.95* (0.91-0.99)	-0.021* (0.009)	-0.006 (0.006)

Both	0.89** (0.82-0.96)	0.87** (0.80-0.95)	-0.049** (0.017)	-0.017 (0.011)
Whether a malformation (Ref: No)	0.99 (0.89-1.11)	0.99 (0.89-1.11)	0.009 (0.023)	-0.008 (0.015)
Whether Apgar score 5 minutes after birth is <7 (Ref: No)	0.98 (0.89-1.09)	1.00 (0.90-1.11)	-0.007 (0.022)	-0.009 (0.014)
Whether a relatively serious health problems 6 months after birth (Ref: No)	1.00 (0.97-1.04)	1.00 (0.97-1.03)	-0.005 (0.007)	0.003 (0.004)
Whether the child has colic (Ref: No)	0.94*** (0.91-0.98)	0.94*** (0.91-0.98)	-0.019* (0.008)	-0.019*** (0.005)
Number of hours the child sleeps 6 months after birth (Ref: ≥ 15 hours)				
≤12 hours	0.93*** (0.90-0.97)	0.93*** (0.90-0.96)	-0.026*** (0.008)	-0.011* (0.005)
13-14 hours	0.96* (0.94-0.99)	0.96** (0.93-0.99)	-0.014* (0.006)	-0.005 (0.004)
Score on an indicator of how demanding the child is (Ref: ≤16)				
17-21	1.01 (0.98-1.04)	0.99 (0.96-1.02)	-0.003 (0.006)	0.004 (0.004)
≥ 22	1.02 (0.98-1.05)	1.00 (0.97-1.03)	0.002 (0.007)	0.006 (0.004)
Socioeconomic resources before/after first birth				
Mother's annual income two years before birth (NOK) (Ref: ≥250000)				
0	0.88*** (0.84-0.93)	0.87*** (0.82-0.91)	-0.058*** (0.011)	-0.008 (0.007)
1-149999	0.90*** (0.87-0.93)	0.90*** (0.86-0.93)	-0.040*** (0.008)	-0.018*** (0.005)
150000-249999	0.92*** (0.89-0.95)	0.92*** (0.89-0.95)	-0.027*** (0.007)	-0.014** (0.004)
Father's annual income two years before birth (NOK) (Ref: ≥300000)				
0	0.97 (0.92-1.02)	1.00 (0.95-1.05)	-0.009 (0.011)	-0.013 (0.007)
1-199999	0.98 (0.95-1.02)	0.99 (0.96-1.02)	-0.007 (0.007)	-0.004 (0.004)
200000-299999	0.94*** (0.91-0.97)	0.94*** (0.91-0.97)	-0.025*** (0.007)	-0.010* (0.004)
Mother's education two years before birth (Ref: Upper tertiary)				
Not completed secondary	0.68*** (0.64-0.72)	0.69*** (0.65-0.73)	-0.093*** (0.012)	-0.107*** (0.008)
Completed secondary	0.77*** (0.74-0.81)	0.77*** (0.74-0.81)	-0.067*** (0.010)	-0.070*** (0.006)
Lower tertiary	0.94** (0.91-0.98)	0.94** (0.91-0.98)	-0.012 (0.008)	-0.020*** (0.005)
Father's education two years before birth (Ref: Upper tertiary)				
Not completed secondary	0.73*** (0.69-0.76)	0.75*** (0.71-0.79)	-0.091*** (0.010)	-0.069*** (0.007)
Completed secondary	0.82*** (0.79-0.85)	0.82*** (0.79-0.86)	-0.068*** (0.009)	-0.037*** (0.005)
Lower tertiary	0.89*** (0.86-0.93)	0.89*** (0.86-0.93)	-0.040*** (0.008)	-0.017*** (0.005)
Whether economic problems 6 months after birth (Ref: Never/rarely had problems, and can manage unexpected expense)				
Cannot manage unexpected expense or have sometimes/often had problems	0.92*** (0.89-0.95)	0.94*** (0.91-0.97)	-0.026*** (0.007)	-0.022** (0.004)

Partnership before/after first birth and father's older children				
Partnership before/after birth (Ref: Married)				
Cohabiting	0.92*** (0.89-0.94)	0.93*** (0.91-0.96)	-0.057*** (0.006)	0.003 (0.004)
Single in pregnancy or at birth, but partnered 6 months after birth	0.85*** (0.80-0.91)	0.99 (0.93-1.05)	-0.064*** (0.013)	-0.033*** (0.008)
Partnered at birth, but single 6 months after birth	0.65*** (0.60-0.71)	0.60*** (0.55-0.66)	-0.125*** (0.018)	-0.102*** (0.012)
Single at birth and 6 months after birth	0.41*** (0.37-0.45)	0.34*** (0.31-0.38)	-0.293*** (0.019)	-0.231*** (0.012)
Perceived relationship quality 6 month after birth (Ref: 10-12)				
13-18	0.96** (0.93-0.99)	0.97* (0.94-1.00)	-0.011 (0.006)	-0.005 (0.004)
≥19 (lowest quality)	0.82*** (0.79-0.85)	0.88*** (0.85-0.90)	-0.059*** (0.007)	-0.042*** (0.004)
Number of children the father already had at first birth (Ref: 0):				
1	0.80*** (0.76-0.84)	0.81*** (0.77-0.85)	-0.035*** (0.011)	-0.085*** (0.007)
≥2	0.55*** (0.52-0.59)	0.55*** (0.51-0.58)	-0.125*** (0.012)	-0.181*** (0.008)
Whether the mother lived with the father at the beginning of current calendar year (Ref=Yes)[d]		0.39*** (0.00-0.00)		

Notes:

*p<0.05; **p<0.01; ***p<0.001

[a] Mother's age at first birth and year of first birth were included in all models. See details in Appendix 1 about how the variables were defined and constructed.
[b] For each woman, a series of 3-month observation intervals was constructed, starting 6 months after the first birth (when no one had had a second child) and ending when a second birth took place, at the end of the 9th calendar year after the year of the first birth, or at the end of the year when the woman turned 45, whatever came first. As in the other analysis, it was conditioned on residence in Norway at the end of the 9th year. Time since first birth was included with one-year categories. (An indicator of whether the first child was dead at the beginning of the 3-month interval, which is a very rare situation associated with high subsequent second-birth rate, was not included, as an initial analysis showed that it had no impact on the other estimates.)
[c] R-square values: The model including age and year: 0.022; age, year and biomedical variables: 0.058; age, year and socioeconomic variables: 0.068; age, year, biomedical variables and socioeconomic variables (the model shown here): 0.084.
[d] This is a time-varying variable only included in the hazard models. It refers to the situation the most recent 1 January before the start of the 3-month observation interval. Individuals were placed in the reference category if the 3-month interval started in the year of birth (in which case the most recent 1 January would be before the birth), and if they were not in a union 6 months after birth. This has implications for the interpretation of the estimated effects of not living in a union 6 months after birth: These estimates reflect a difference between those who were not in a union 6 months after birth and those who were in a union at that time and still are in a union.

...

[1]**ENDNOTES**

It is not obvious theoretically how one should expect income to affect fertility. High purchasing power for a man may be expected to strengthen the interest in having a child if childbearing costs are fixed, but that is not necessarily the case. If the income is high, the parents may want to or feel obliged to spend more on each child. In settings where it is common for women to stay home with a child after a period with paid parental leave (if any), one would expect a different impact of women's income: an income effect such as for men may be counteracted by higher opportunity costs for the most well-paid. Having current economic problems (reported by the women in our data) may be considered as – like low income for a man – leading to low purchasing power over the next years and thus possibly a reduced subsequent fertility.

[2] Parents' IDs are included in the Population Register for almost everyone born in Norway after about 1953 (as well as many immigrants), which makes it possible to construct birth histories for Norwegian women and men born after about 1935, including the mothers in MoBa.

[3] Thus, those having the first child in 2009 were observed until the end of 2018, which is the last year covered by the data available to us.

[4] To elaborate, the fecundity quite shortly before the first birth is likely a good indicator of the fecundity the first few years after the first birth (except for the typically low fecundity in the first months, not least because of breastfeeding). However, among women with the same pre-birth fecundity, it is possible that those with the highest age at first birth have the lowest fertility more years into the future. For example, a woman who became a mother when she was 35 may have lower fecundity the 6th, 7th and 8th year after the first birth than a woman with the same pre-birth fecundity who became a mother when she was 25. In other words, age at first birth may have an effect on subsequent fecundity, and thus fertility, net of the fecundity before the first birth. Furthermore, our measures of pre-birth fecundity are crude, so there may be much variation in actual pre-birth fecundity within each of the categories we have defined. Given the general reduction of fecundity across age, it is likely that, within a category, women who are older at first birth have had the lowest fecundity before that birth. To summarize, there are two reasons why a higher age at first birth may be linked to lower subsequent fecundity and fertility even when our fecundity indicators are included in the model: i) a higher age indicates a particularly low actual fecundity around the time of first birth, an ii) a higher age may lead to a sharper drop in actual fecundity in the subsequent years.

[5] Some of the health indicators refer to certain diseases before the first birth, but the estimated effect of age at first birth on subsequent fertility may nevertheless reflect health issues, because the symptoms of these diseases may become worse as the age increases and individuals may also develop new diseases. With regard to the economic resources, there is likely to be an accumulation over age that is not fully captured by our few indicators.

[6] Note also that, if age at first birth is a mediating factor, a methodological problem arises. The reason is that many unobserved factors, such as being very fond of interacting with small children, probably influence both age at first birth and subsequent fertility. Let us, for example, consider a chronic physical disease that increases the age at first birth. At a given age at first birth, individuals with the chronic disease will tend to be very fond of interacting with small children (or have a high score on other unobserved factors that generally raise birth rates), which also leads to a higher second- and higher-order birth probability. This correlation contributes positively to the estimated effect of the chronic disease on the second-birth probability when it is controlled for age at first birth. In other words, the estimated effect of the chronic disease reflects the effect of the unobserved factor on fertility. This problem is known in epidemiology as collider bias (both the chronic disease and the unmeasured factors affect age at first birth). In demography, the problem has been dealt with by estimating joint models for first and higher-order births with common unobserved factors (Kravdal and Rindfuss 2008), but the data used in this study did not allow such a procedure to be used. Fortunately, the bias is only large when variables that have very strong impact on first-birth timing are considered.

[7] All women with a first birth those years and living in Norway 10 years afterwards were included in this calculation.

[8] Because those not living in a union were put in the reference category for relationship quality, the estimated effects of being single must be interpreted as the difference in second-birth probability between the single and those who lived in high-quality unions. However, given the relative size of the effects, the single clearly also had lower second-birth probabilities than those in low-quality unions.

[9] To see this, assume that a model for the second-birth rate includes only time since first birth (T) and one other variable (X). If the odds ratio for a certain category of X compared to the reference category is less than one, for example 0.8, it may

reflect that the odds of having a second child as a function of T are parallel for the two categories (i.e., the effect of an interaction between T and X, if added, would be estimated to be zero), but that the odds are 20% lower at every T for the not-reference category. One would, of course, predict a lower probability of ever having a second birth for women in the category with the reduced odds. However, one would actually also predict that a somewhat smaller proportion of those who ever have a second child would have that child within, say, 3 years. An odds ratio 0.8 can also be estimated in a situation where one category has much lower odds than the reference category in the first years after birth, but so much higher odds later that the probabilities of ever having a second birth are the same. Clearly, if an interaction between X and T had been included in this case, the estimated effect of this interaction would not be zero.

[10] In principle, the estimated effect of the current relationship situation partly reflects that some of those who had a second birth within the 3-month observation interval were pregnant with that child before 1 January the year the interval started, which may have had an impact on the union status. Clearly, a much larger problem would arise if we had included an indicator of union stability sometime after first birth in the linear probability models, because we would then to an even larger extent have captured effects *of* second births *on* union stability. However, when we nevertheless did that, we found that the 10-year second-birth probability was 18 percentage point lower among mothers who did not live with the father of their first child 1st January the 10th year after the first birth.

[11] When a non-linear model such as this is estimated, addition of a variable that is uncorrelated with those already included, will strengthen the effects of the latter (Mood 2010). Thus, when we see weaker effects, it is definitely the case that the variable we add 'explains something'. More specifically, low union quality is linked with disruption, and disruption is linked with - and likely also to a large extent causes - low second-birth probabilities.

[12] The R-square is the average of the predicted outcome for observations where the actual outcome is 1 minus the corresponding average when the actual outcome is 0.

[13] For similar reasons we included the dummy for whether the father took part in the interview (in the 15th week of the pregnancy) among the sociodemographic variables rather than the biomedical. Additionally, we created new indicators of father's health where women not in a union 6 months after birth were put in the reference category, because in this case the father's health likely had less impact. These steps did not change the R-square values.

[14] See notes 4 and 5.