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The Fertility Pattern of Twins and the General Population Compared: Evidence from Danish Cohorts 1945–64

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The Fertility Pattern of Twins and the General Population Compared: Evidence from Danish Cohorts 1945–64

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Abstract

Twin studies provide an important possibility for demographers to analyze patterns of heritability and to estimate structural models with controls for endowments. These possibilities are increasingly used in the context of fertility and related behaviors. A close congruence between the fertility patterns of twins and that of the general population, however, is an essential pre-condition in order to generalize the results of twin-based investigations of fertility and related behaviors to the general population. In this paper we therefore compare the fertility of Danish twins born 1945–64 to the fertility pattern of the general population born during the same period. Our analyses find a very close correspondence between the fertility pattern of twins and of the general population. There exist only few statistically significant differences, and the primary difference pertains to the fact that female twins have a slightly later onset of childbearing than non-twins. There are virtually no relevant differences between the fertility patterns of dizygotic and monozygotic twins.

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1 Introduction

Social scientists frequently rely on natural- or quasi-‘experiments’ in order to infer determinants of human behavior, or interrelations between processes that affect human behavior, which are inherently unidentified with standard survey data. This identification problem in survey data arises because

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these data usually consist of random or stratified samples of a population, along with a set of—mostly individual-level—socioeconomic variables. Such data quickly reach their limitations when analysts are interested in potential genetic influences on human behavior (e.g., Plomin 1990), or when unobserved heterogeneity is a potentially important determinant of behavioral patterns (e.g., Manski 1995; Rosenzweig and Wolpin 2000).

A classic natural experiment used in the social sciences to overcome these limitation is the *twin experiment*, i.e., the fact that in between 1 and 1.5 percent of cases a pregnancy results in a multiple birth—including twins, triplets and quadruplets—instead of a singleton birth (e.g., Derom et al. 1995; Kyvik et al. 1996, 1995). Among multiple births, data on twins are particularly useful for at least two reasons. First, twins grow up concurrently in the same household and thus share many environmental influences mediated by the parental household. Second, twins occur in two different 'types' as monozygotic (identical) twins and dizygotic (fraternal) twins. While the former are genetically identical and share all genes, the latter share on average only 50% of their genes as do usual siblings. Hence, twin studies do not only provide means to observe individuals who have grown up in the same household (or 'shared environment'), but also to observe individuals who share genetic influences to a different extent. This unique property of the 'twin experiment' allows researches to shed light on a variety of questions, including the central issue in the social sciences of whether 'nature' or 'nurture' is most important in determining human traits and behaviors (Hamer and Copeland 1998; Plomin 1990; Plomin et al. 1997).

In the field of demography, twins have been extensively used in the analysis of mortality and longevity, and in particular for assessing the relevance of genetic and environmental influences on human survival (Herskind et al. 1996; Iachine et al. 1999; Yashin and Iachine 1997). On the other hand, the use of twin data in the analysis of fertility is still in its infancies. Only recently have several studies based on Danish twin cohorts started to compare the correlation in the fertility of monozygotic and dizygotic twins. These studies argue that genetic influences consistent with variation of fertility behavior and motivations are an important aspect in understanding fertility decisions (Kohler and Christensen 2000; Kohler, Rodgers, and Christensen 1999; Rodgers, Hughes, Kohler, Christensen, Doughty, Rowe, and Miller 2001; Rodgers, Kohler, Kyvik, and Christensen 2001). Moreover, the studies suggest that research on these genetic influences is increasingly important because these factors seem to be especially relevant in contemporary low fertility settings with consciously controlled reproduction.

While the methodology used in the above studies focuses on the heritability of demographic behaviors/outcomes, and is hence similar to the standard methodology in behavioral genetics (Neale and Cardon 1992), the use of twin studies is not restricted to such applications. For instance, medical researchers have used twins to investigate whether differences in the intra-uterine environment, such as provided by the presence and absence of a co-twin and its sex, affects fecundity or the degree of masculinization later in life (Christensen et al. 1998; Gaist et al. 2000). Economists have used the occurrence of a twin birth as an random event that is uncorrelated with other behaviors determining fertility, and they have used this event in instrumental variable estimations of the interrelation between fertility behavior and labor market decisions, investments in children, etc. (Bronars and Grogger 1994; Rosenzweig and Wolpin 1980a,b). Another application of twin data builds on the economic research on the returns to human capital (Ashenfelter and Rouse 1998; Behrman and Rosenzweig 1999, 2002; Behrman et al. 1994, 1996) that uses monozygotic twins, i.e., twins who share the same genes and have grown up in the same parental household, to control for unobserved heterogeneity that may distort the inference of fundamental relations between fertility and its determinants. We have also used a similar approach to improve the estimation of how the age at first birth, and other determinants of early fertility, are related to completed fertility (Kohler, Skytthe, and Christensen 2001).

Most of the above approaches investigate the fertility and its proximate determinants of a special population, namely the population of (same sex) dizygotic and monozygotic twins, and then draw inferences about the fertility pattern in the general population. The population of twins, however, differs in important aspects from the remaining population, and twin studies have been criticized for being potentially biased (Bryan 1992; Lewontin et al. 1985). Quite obviously, twins have a different prenatal environment than singleton births, and twins necessarily grow up in families with at least one sibling (unless, of course, the co-twin dies or is raised separately). Less obvious differences in socioeconomic conditions between the twin and the general population are related to the fact that the probability of delivering twins increases with maternal age and that the secular trends in twinning rates between MZ and DZ twins differ (Bortolus et al. 1999; Kyvik et al. 1995; Westergaard et al. 1997). Since these systematic differences between the twin population as compared to the general population are likely to be correlated with determinants of fertility behavior, the fertility pattern and behavior of twins may differ in important aspects from that of the general population. For instance, the number of siblings has been shown to positively correlate with fertility, even after controlling for various characteristics of the parental household (Murphy 1999; Murphy and Knudsen 2002).

In order to evaluate the relevance of research on twin fertility, and in order to assess the validity of inferences from the twin population about the general population, it is essential to investigate the extent to which the fertility pattern of the twin population is comparable to the fertility behavior of the general population. While for the above reasons we do not expect that there is equality in the fertility patterns between these populations, we do hope to find close relationship, i.e., patterns in fertility level, trends and determinants that closely mirror each other. In this paper we therefore provide a comparison of the fertility behavior of Danish cohorts (males and females) born between 1945 and 1964 with the respective cohorts in the Danish Twin-Fertility database. The former data are provided by the Fertility of Women and Couples in Denmark (FWCD) data set, and the latter data are obtained from a link of the Danish Twin register with the Danish Central Person Register. In particular, we investigate whether the twin population differs from the general population with respect to: (a) the completed fertility level and the fertility level at age 30, 35 and 40 years; (b) the extent of childlessness at age 30, 35 and 40 years; (c) the age at first birth; and (d) the interrelation between the age at first birth and completed fertility.

Our analyses find a very close correspondence between the fertility level and its change across cohorts in both the twin and the general population. There exist only few statistically significant differences; the primary difference pertains to the fact that female twins seem to have a slightly later onset of childbearing, which may be due to sibling influences since twins always have at least one sibling (e.g., see also Murphy and Knudsen 2002).[1] There are virtually no relevant differences between the fertility patterns of MZ and DZ twins.

2 Data Sources

The following comparison is based on the Danish Twin-Fertility database, providing information about the fertility of twins in the Danish Twin Register, and the population-based database of the Fertility of Women and Couples in Denmark providing comprehensive information of the fertility of the Danish population. Both data sets are created from national population-based registers using the Person Number as an unique identifier that facilitates linkages between registers (Eurostat/Statistics Denmark 1995).

The Person number was introduced in Denmark April 1968 as part of the Civil Registration System (CRS). This registration system encompasses persons who have lived in Denmark since April 2, 1968 and have registered with the national registration offices. Every person alive at or born after April 2, 1968 who has a registered residence in Denmark has been assigned a unique identifier, the Person Number, which contains information on the birth date and sex of the person. The CRS contains links between parents and children, but the number of valid links decreases considerably for children born before 1960, and links are almost missing for children born before 1953.

The *Fertility of Women and Couples in Denmark (FWCD)* data is a national data set including information on all women born in the period from January 1, 1930 to December 31, 1981 and with a registered residence in Denmark at least on one January 1 during the years 1980–1994. In addition, the data include information on co-residing male partners during the period 1980–94 and the children born to either of them. The creation and the content of the FWCD data has been described in detail elsewhere (Knudsen and Murphy 1999). For the purpose of this comparison, we restricted the data to the birth cohorts 1945–64 with a residence in Denmark on January 1, 1994.

Since the data set is intended for the study of women and couples, we augmented the FWCD data with information on males who were not included by the above selection criteria. With this extension, the FWCD data allows a comprehensive study of the male and female fertility for the cohorts 1945–64.

The FWCD data used in the below comparisons is derived from the Danish Fertility Database (FTDB), which comprises data on births (time and number) together with annual data on socio-demographic characteristics of both women and men, regardless of whether or not they have children (Knudsen 1998).

The population of children is primarily identified from the Danish Civil Registration System (CRS) and from the Medical Register of Births and Deaths (MRBD; see Knudsen and Olsen 1998) and includes all children in Denmark with at least one parental reference to one of the adults in the population (either to a mother or to a father). Children in the FTDB are born from 1942 onwards, but due to the proportion of missing references in the first years of the registers, the links between children and parents are considered valid and with almost full coverage only for children born from 1960 and parents born from 1945 (Knudsen 1993). Moreover, the information on the birth year of the women and the children are derived from the Person Number. The age at the birth of the first child and any subsequent child are retrieved from the MRBD to FTDB and originally calculated on the basis of the Person Numbers of mother and child. Likewise, the registration of whether the child was live born and whether it was a multiple birth were retrieved from the MRBD.[2]

The *Danish Twin-Fertility Database (DTFD)* has been created by linking the Danish Twin Register, which is a population-based register of twins born in Denmark 1870 to 1992, with the information on births in the Danish Civil Registration System (CRS). The identification of twin pairs in the Danish Twin Register is based on the Civil Registration System (CRS) (Kyvik et al. 1996). Twins from the birth cohorts 1931 to 1952 were identified based on the fact that twins are almost always born on the same date and in the same parish, and are given the same surname. From CRS all sets of persons fulfilling these criteria were extracted and their twin status was confirmed by either mailed questionnaires to living persons or verification in birth registers in case of death or emigration. Twins from birth cohorts 1953 to 1982 were ascertained utilizing the link between mother and children in CRS. Two persons who were linked to the same mother and born within 3 days were considered twins. Due to the decreasing number of valid links the number of twin pairs identified decreases for twins from 1960 and earlier (Kyvik et al. 1996, 1995). The zygosity of same-sexed twins was determined by the questionnaire method using the same method for the two cohorts. Based on four questions about the similarity of the twins the pair is assigned as either monozygotic (identical), dizygotic (fraternal) or of uncertain zygosity. The method has been proved to determine the zygosity correctly in approximately 95% of the twin pairs (Hauge 1981). The zygosity of opposite-sexed twins does not need to be verified since these twins are always dizygotic.

The DTFD data are generated by merging the fertility information in the CRS with the Danish Twin Register. In particular, a birth was assigned to a twin in the Twin Register if the information on this birth in the CRS contained at least one parental reference to a person, father or mother, who is part of the twin register.[3] The links in CRS between children and parents represent the legal parenthood, and the register contains no information about the biological parents of adopted children. Therefore it is not possible to distinguish between biological and adoptive parents in the data set. However only about 1.2% of the children born in the study period are adopted, according to the official statistics. Besides the reference to the parents, the information about each child in the CRS include year of birth, sex, vital status, and, if not alive, year of death, and these data included in the DTFD.

The children included in DTFD were either alive at April 2, 1968 (the date when the CRS was established) or are born after that date. Infant deaths before April 2, 1968 are not included in the data set since these events are not registered in the CRS. However, only relatively few births for the cohorts 1945 and later have occurred prior to 1968, and with an infant mortality rate about 20 per 1000 live births in the 1960's the number of missing children due to infant deaths is very low. Hence, for twins born after 1945 the link with the CRS provides an almost comprehensive coverage of the fertility, and the quality of the fertility information in DTFD can be considered as very high.

3 The Fertility of Danish Twin Cohorts 1945–64 as Compared to the Danish Population

We focus in our analyses on cohorts born during the period 1945–1964, and we concentrate on individuals who have given births to only singletons in order to eliminate potentially non-volitional variation in the number of children due to an unanticipated multiple birth.[4] Moreover, we restrict the twin population to the subset of twins in complete same-sex MZ or DZ twin pairs because this is the most relevant subset of the data that is used for both heritability analyses and structural models based on within-twin-pair estimators.

The analyses are conducted separately for the birth cohorts 1945–49, 1950–54, 1955–59 and 1960–64. In order to achieve comparability across cohorts, we measure fertility at three different ages at 30, 35 and 40 years. Fertility after age 40 is not included in these comparisons. In addition, since the *FWCD* data include only fertility until 1994, we censor the fertility experience of twins at the beginning of 1994. For cohorts that are below age 40 at 1 January 1994, that is for cohorts born from 1954 onwards, we only include births up to the end of 1993 in the calculations of the age at first birth. Moreover, we do not include cohorts born from 1954 onwards in fertility measures for age 40 and we do not include cohorts born after 1959 in fertility measures for age 35.

Table 1 reports the respective number of twins and the size of the birth cohorts. In particular, the size of these 5-year birth cohorts varies between 345,000 and 390,000 individuals, and the size of the twin cohorts vary between 3,000 and 4,100 twins (in complete same-sex pairs). Except for the last period 1960–64, there are about 30% more males in complete same-sex twin pairs as females. Moreover, the ratio of MZ to DZ twins increases from about .5 in the early cohorts to slightly above .6 in recent cohorts, which is due to a decline in the DZ twinning rate. This decline has been observed for the period from the 1930's to the 1970's, and it persists even after adjustments for changes in maternal age (e.g., see Olsen and Rachootin 1983). The cause of this decline is not known. Some see it as a decline in fecundity and others as a positive avoidance of risky pregnancies. Starting in the 1980's there is a renewed increase in DZ twinning again due to fertility treatments. The MZ rate, however, is very constant in different populations and time periods. Only recently there has been some evidence that fertility treatment can increase this rate as well (e.g. Schachter et al. 2001; Sills et al. 2000), but the availability of these methods is too recent to affect the MZ twinning rates in the birth cohorts investigated in this paper.

In the subsequent analyses, it was not possible to exactly identify the Danish non-twin population since information about twin status is not available in the FWCD. The information for the overall populations from the *FWCD* data set therefore contains individuals that were born as singletons and individuals that were born in multiple births. Since the twin population constitutes only 1% of the Danish populations in the cohorts 1945–64, this overlap is negligible and does not substantively affect our results.[5] We also ignore this overlap in our tests for significant differences between the twin and the overall population, while we do account in these tests for the fact that the twins within the same pair contribute correlated observations.[6]

3.1 Childlessness and Age at First Birth

Tables 2 and 3 report the sex-specific proportions of individuals in the Danish population and in the twin population that is still childless at ages 30, 35 and 40 years. Women in the cohort 1945–54 had their children relatively early. Childlessness at age 30 is only 15% (see Table 2), and 95% of all women in this cohort who had children by the age of 40 had their first child prior to age 30. In younger cohorts there has been a marked delay of childbearing, leading to higher levels of childless at relatively young ages (see also Knudsen 1993). For instance, childlessness at age 30 has increased to 27% in the cohorts born 1955–59 and to 31% in the cohorts born 1960–64. This delay of first births is partially compensated by later fertility, and the increases in childlessness at higher ages are less marked than at younger ages. The female twin population does not differ in this overall trend of childlessness. The level of childlessness at age 40 is basically identical for twins and the population, and the twin cohorts also experience a marked increase in childlessness at younger ages. There are also no systematic differences in the patterns of childlessness between monozygotic and dizygotic twins.

In general, therefore, there is a broad agreement between the female twin and non-twin population, and between female DZ and MZ twins, with regard to childlessness. The only pattern that is suggested by the analyses in Table 2 is a slightly later onset of fertility for twins than for the non-twin population: childlessness at age 30 is 15.6% in the overall female population born 1945–49, and it is 18.6% in the female twin population. Similarly, it is 27% in the female population born 1955–59 and 33.6% in the female twin population born in the same period. The differences, however, seem to diminish at later ages. The reasons for this difference cannot be identified in our data, which do not include socioeconomic characteristics, but they may be due to sibling influences as found, for instance, in Murphy and Knudsen (2002).

The slightly later onset of fertility for female twins is further supported by the last two columns in Table 2 that reports the age at first birth. This age at first birth is based on children born up to the age of 40, and for cohorts that are below age 40 on 1 January 1994, it includes births until the beginning of 1994. In almost all female cohorts the age at first birth is somewhat higher in the twin population, with a difference ranging from .1 to 1.2 years, and this difference is mostly statistically significant.

The patterns of childlessness for the male twin population and overall male population are reported in Table 3. While the level of childlessness is somewhat higher for males than for females at all ages, which is due to a later pattern of childbearing for men and a somewhat larger number of men than women at these ages in the population, the overall pattern is similar: there has been an increase in childlessness at age 30 (and 35) due to a delay in childbearing, and these increases are partially compensated by a shift towards late first-birth fertility. This pattern is similar to the twin and general population, and there are no relevant systematic differences in the level of childlessness. Similar to our results for the female population, twins tend to have a slightly latter pattern of entering parenthood. This is reflected in a somewhat higher age at first birth. For males, however, this difference is not statistically significant or substantially relevant for twins than for non-twins. Moreover, there are no statistically significant or otherwise systematic differences between male MZ and DZ twins in their pattern of first-birth childbearing.

3.2 Number of children at different ages and Completed Fertility

Tables 4 and 5 report the average number of children for the twin and general population at age 30, 35 and 40. For females, the number of children at age 40 can be considered as an approximation of completed fertility since there is still relatively small, but albeit rapidly growing, number of births above age 40.[7]

Female cohorts born 1945–49 attained a cohort fertility at age 40 of 1.93 children per woman, and this fertility level declined to 1.8 for the cohort born 1950–54 (Table 4). The cohort fertility at age 35 declined from 1.87 (cohorts born 1945–49) to 1.64 (cohorts born 1955–59), and fertility at age 30 declined from 1.66 (cohorts born 1945–49) to 1.21 (cohorts born 1960–64). This decline of fertility at age 30 is in part due to the delay of childbearing. It is therefore likely that the decline in completed cohort fertility will be substantially less than the decline in fertility at age 30 due the adoption of an older pattern of childbearing in the youngest cohort.

Most important for the purpose of our analysis in this paper is the fact that there are no important differences in the fertility pattern of female twins and the female overall population. Female cohort fertility at age 35 and 40 neither differs in a statistically significant nor in a substantively relevant manner, and the only difference occurs at age 30 where twins tend to have slightly lower fertility than non-twins. This pattern is consistent with and related to the already mentioned later onset of fertility in twins as compared to the overall population (see our discussion in the previous section).

The last two columns in Table 4 also reports the parity progression probabilities for female cohorts born during 1945–49 and 1950–54 (taking into account births up to age 40). About 80% of women progress from the first to the second child in both sets of cohorts, and there is no relevant difference for the twin population. About 34% of women in the older cohorts, and about 30% of women in the younger cohort, progress from the second to the third child, and this pattern is again shared by both the female twin and female overall population.

There are some small differences in the fertility pattern of female DZ and MZ twins that are statistically, but not substantively relevant. Moreover, these differences are not systematic across cohorts. For instance, MZ twins tend to have a somewhat lower probability of progressing from the second to the third child in the cohorts 1945–54, and they tend to have somewhat higher fertility at age 35 and 40 in the cohorts 1950–54. If all cohorts are combined, these differences between MZ and DZ twins vanish. Our findings for male cohorts largely agree with the above discussion. The fertility level for male cohorts at all ages is somewhat lower than that of females, and this difference is most pronounced at age 30 and diminishes at age 40 (Table 5). These differences between female and male cohort fertility levels are due to the somewhat later age pattern of male fertility and due to age-differences within couples.[8] This difference is primarily due to the male-female differences in the first birth since the male parity progression probabilities in the last two columns of Table 5 are almost equal to the female parity progression probabilities in Table 4. These characteristics of male cohort fertility are also common to both the twin and general population, and there are no relevant differences in between MZ and DZ twins. The only exception in this context is the somewhat higher fertility of male MZ twins, as compared to DZ twins, at age 35 in the cohorts born 1955–59.

4 Postponement effects: the relation between the age at first birth and completed cohort fertility

In recent years there has been a renewed interest in the relation between the age at first birth and completed cohort fertility in order to assess the implications of delayed childbearing and completed cohort fertility (Billari and Kohler 2002; Frejka and Calot 2001a,b; Kohler, Billari, and Ortega 2001; Kohler and Ortega 2001; Kohler, Skytthe, and Christensen 2001; Morgan and Rindfuss 1999). The investigation of this issue has a long tradition in demography (e.g., Bumpass and Mburugu 1977; Bumpass et al. 1978; Heckman et al. 1985; Marini and Hodsdon 1981; Presser 1971; Trussell and Menken 1978), and these studies have established a systematic relation between a delayed onset of fertility and a reduced level of completed fertility.

In Kohler, Skytthe, and Christensen (2001) we have recently used fixed-effect analyses with monozygotic twins pairs in order to overcome potential problems related to unobserved characteristics. In particular, we have used within-MZ twin estimators to properly estimate the *postponement effect*, i.e., the reduction in fertility that is causally associated with a delay in childbearing, in order to obtain better estimates of the causal impact of delayed childbearing. Under certain assumptions within-MZ twin estimates allow the identification of the true postponement effect even when individuals differ with respect to their child-preferences, fecundity and ability. The analyses in Kohler et al. (2001) analyses confirm the existence of a relevant postponement effect for both males and females. On average, an additional year of delay in childbearing reduces completed fertility by 3% for females and 3.4% for males. If interactions with birth years are included, a clear trend towards a reduced relevance of this postponement effect in younger cohorts emerges for both males and females. The failure to account for unobserved factors such as preferences for children or economic ability can substantially distort these estimates of the postponement effect and its change over time. On one hand, ordinary least square regression (OLS) substantially underestimates the relevance of first-birth timing for completed fertility for cohorts born around 1945. In addition, standard OLS estimations also underestimate the pace at which this effect is reduced in younger birth cohorts: the decline in the magnitude of the postponement effect is up to twice as large in the within-MZ estimation as in the OLS results.

In this paper, we extend these analyses and additionally investigate this postponement effect in both the twin and general Danish population. In particular, in Table 6 we report the coefficient on the age-at-first birth, β_1, of a simple regression of fertility at age 40 on the age at first birth as

$$N_i = \beta_0 - \beta_1 \cdot AFB_i + \varepsilon_i,$$

where β_0 is the constant, AFB_i is the age at first birth and N_i the number of children at age 40 of individual i, ε_i is a disturbance term and the coefficient β_1 measures the postponement effect. We perform this analyses for twins born 1945–53, that is, the subset of twins for whom fertility at age 40 is observed prior to 1994. Moreover, we include only individuals with a first birth up to an age of 32. This mirrors the respective assumptions in Kohler, Skytthe, and Christensen (2001) and Kohler, Billari, and Ortega (2001), and it avoids problems associated with a potentially non-linear relation between the AFB and completed fertility at relatively late ages of childbearing.

The results in Table 6 reveal a postponement effect for females of about 7.3% in cohorts born 1945–49 and of 6.0% in born cohorts 1950–53 for the overall Danish population. These effects are not substantially different for the twin and general population in the older cohorts, while the postponement effect is slightly smaller for female twins as compared to female non-twins in the younger cohorts. The postponement effect for males in the overall population is equal to 6.7% in cohorts born 1945–49 and 5.7% in cohorts born 1950–53. This postponement effect for males is somewhat smaller for the twin than the overall population in the younger cohorts, and it is slightly larger for MZ twins as compared to DZ twins in the cohorts born 1945–49. These differences in the postponement effect between the twin and overall population, and between DZ and MZ twins, however, are relatively modest and they do not have substantive implications for using the fertility of twins.

5 Conclusions

Twin data provide an important tool for investigating the heritabilities of human traits or behaviors, and for controlling for unobserved biological and other endowments in structural analyses of traits or behaviors. These potentials of twin data are increasingly utilized also for demographic research and in the context of fertility and related behaviors. Without further analyses, however, we should not take for granted that the results obtained from twin data can be readily applied and transferred to the overall population. This caution in transferring results is necessitated by the fact that twins do not constitute a random draw of all children. Twins are more likely to be born prematurely and to have lesser birthweights than non-twins, and twins always grow up with at least one sibling (unless, or course, they are raised apart). In addition, DZ twins are born more frequently to older mothers, and in recent years twin births—and especially DZ twins—are frequently associated with in-vitro fertilization (IVF) or other fertility treatments. In order to assess the relevance of these aspects associated with being a twin, we investigate in this paper whether "being a twin" renders the fertility pattern of the twin population different from that of the non-twin population. In particular, a close congruence between the fertility patterns of twins and that of the general population constitutes an essential precondition in order to generalize the results of twin-based investigations into bio-social determinants of fertility to the general population.

In our analyses we compare the twins in the Danish twin register born during 1945–64 to the overall Danish population born during the same period. We restrict these analyses to members of complete same-sex twin pairs because this is the most frequently used subset of the twin data. The fertility of the twin and general population is obtained from the Danish Twin-Fertility Database (DTFD) and the Fertility of Women and Couples in Denmark (FWCD) data. Our comparisons are based on several measures of fertility, including the level of childlessness at ages of 30, 35 and 40 years, the age at the first birth, the level of cohort fertility at ages of 30, 35 and 40 years, the parity progression ratios from the first to the second and from the second to the third child, and finally the relation between the age at entering parenthood and completed fertility.

The results of our analyses reveal a broad agreement between the fertility pattern of the Danish twin and non-twin population. Both twins and non-twins exhibit the same trends across cohort and across age, and there are very few statistically significant differences in the various fertility measures calculated for these two populations. Moreover, the existing differences between twins and non-twins are usually not substantively relevant even if they turn out to be statistically significant. An exception to this finding pertains to a slightly later onset of fertility in female twins as compared to non-twins, which is significant and regular across cohort in our analyses, and this difference may be caused by sibling influences. Finally, our analyses reveal that the fertility of dizygotic and monozygotic twins is very similar and there are virtually no systematic and/or relevant differences in the fertility pattern of DZ and MZ twins.

The absence of important differences in fertility patterns in these analyses of the twin and overall population in Denmark born 1945–64, and the absence of important differences between DZ and MZ twins, therefore supports the use of Danish twin data for investigating aspects of fertility behavior that are not identifiable in standard survey or registration data, and it suggests that the specific aspects of being a member of a twin pair in itself does not have important influences on the timing and level of fertility during the life-course.

Our finding that the fertility of the twin cohorts is relatively similar to that of the general population, however, does not necessarily imply that the assumptions underlying the various methods applied in twin studies hold. Our study investigated whether the twin and the general population follow similar trends in the fertility level and pattern. This finding is a prerequisite for making inferences about the general fertility pattern from the analysis of twin fertility.[9] Nevertheless, this finding does not imply that further assumptions which are necessary, for instance, to infer heritabilities from a comparison of MZ and DZ twins, also hold. These assumptions cannot be verified in general and their plausibility needs to be assessed in each specific context.

Notes

[1] In particular, Murphy and Knudsen (2002) find a stronger correlation between the fertility pattern of parents and their daughter as compared to sons. This is consistent with our finding of a somewhat later fertility of female twins since twin mothers tend to be somewhat older than mothers of singletons, and this fact causes twins to have a later age at birth if there is intergenerational transmission.

[2] The FWCD data set also includes still born children, and this information is considered valid for cohorts born from 1973 onwards. Still born children are not included in the analyses conducted in this paper since these children are not available in the twin data; see Note 3.

[3] Still born children are not included in the data set, since no Personal Number is assigned to them.

[4] If twinning is not heritable, then excluding twin births merely results in slightly lower estimates for cohort fertility since twins constitute, to some extent, "extra" unanticipated children. In this case, focusing on singletons has no implications for our analyses and even yields better estimates of "desired" fertility since individuals with unanticipated quantum-variations are excluded. If twinning is heritable, as seems to be the case for DZ twins and to a lesser extent for MZ twins (e.g., Bulmer 1970; Lichtenstein et al. 1996), then twins would have a higher genetic dispositions to give births to twins as parents born as singletons and this would constitute a reason for them to have higher fertility. Excluding parents who give births to twins, therefore, eliminates this effect and reflects more appropriately the comparison of "desired fertility" between twins and non-twins.

[5] Despite the fact that we compare differences in fertility outcomes between "twins" and the "general population", our analyses identifies fertility differences between twins and non-twins because "general population" = "twins" + "non-twins". Not identifying the exact non-twin population in the *FWCD* data set merely results in an underestimate of the difference, but this effect is minuscule if only about 1–1.5% of the general population are twins.

[6] In particular, we base significant tests on regressions of the variable of interest on dummies for being a twin (or dummies for being a monozygotic twin conditional on being a twin), and we estimate the standard errors of the coefficients using White's (1980) heteroscedasticity-robust variance estimator with an additional account for correlated observations within twin pairs.

[7] In 1980, for instance, births at ages 40+ contributed less than 0.83% to the period total fertility rate, and this contribution increased to 1.48% in 1994, representing a relative increase of 75% as compared to 1980, and the contribution of 40+ fertility increased to 1.8% in 1999, that is a more than two-fold increase since 1980 (the data for these calculations has been obtained from Council of Europe 2000).

[8] That is, if males marry women that tend to be younger, than the appropriate comparison group

for male cohort fertility is not the female cohort born in the same year (or five-year interval), but a cohort that is born at a somewhat later period.

[9] In the application of standard twin methodology (Neale and Cardon 1992), the resemblance in the mean level of a phenotype, such as fertility, is less important because the heritability patterns are estimated with deviations of the individual phenotype from the mean level. Differences in the mean level of a phenotype are therefore differenced out.

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Table 1: Sample sizes for the Danish population and twin data used in the analyses

	Cohort				
	1945–49	**1950–54**	**1955–59**	**1960–64**	**Total**
Females					
Population	191,780	171,404	169,517	179,527	712,228
Twins	1,677	1,296	1,487	2,117	6,577
DZ twins	1,090	861	966	1,255	4,172
MZ twins	587	435	521	862	2,405
Males					
Population	197,870	176,499	175,472	185,906	735,747
Twins	2,256	1,783	2,000	1,997	8,036
DZ twins	1,507	1,220	1,251	1,232	5,210
MZ twins	749	563	749	765	2,826
Females and males combined					
Population	389,650	347,903	344,989	365,433	1,447,975
Twins	3,933	3,079	3,487	4,114	14,613
DZ twins	2,597	2,081	2,217	2,487	9,382
MZ twins	1,336	998	1,270	1,627	5,231

Table 2: Females: childlessness and age at first birth

		Proportion still childless at			**Age at first birth**	
Females		**age 30**	**age 35**^{a}	**age 40**^{b}	mean^c	Std. Dev.
Cohort						
1945–49	Population	0.156	0.118	0.108	23.03	4.13
	Twins	0.186***	0.126	0.110	23.79***	4.36
	DZ twins	0.194	0.134	0.117	23.78	4.42
	MZ twins	0.170	0.112	0.097	23.81	4.24
1950–54	Population	0.209	0.156	0.137	23.63	4.32
	Twins	0.223	0.158	0.134	24.31***	4.33
	DZ twins	0.225	0.167	0.143	24.23	4.28
	MZ twins	0.218	0.140	0.117	24.46	4.43
1955–59	Population	0.270	0.187		24.14	4.19
	Twins	0.336***	0.236***		25.35***	4.00
	DZ twins	0.337	0.241		25.21	3.96
	MZ twins	0.334	0.225		25.60	4.06
1960–64	Population	0.308			24.35	3.40
	Twins	0.302			24.45	3.42
	DZ twins	0.299			24.28	3.46
	MZ twins	0.306			24.70^{++}	3.35
All cohorts	Population	0.234	0.150	0.120	23.73	4.08
	Twins	0.265***	0.167***	0.120	24.42***	4.06
	DZ twins	0.265	0.175	0.127	24.33	4.08
	MZ twins	0.263	0.152^{+}	0.105^{+}	24.59^{++}	4.03

Tests for significant differences: Results of tests for differences between overall population and twins: * $p \leq 0.10$; ** $p \leq 0.05$; *** $p \leq 0.01$. Results test for differences between dizygotic and monozygotic twins: $^{+}$ $p \leq 0.10$; $^{++}$ $p \leq 0.05$; $^{+++}$ $p \leq 0.01$. *Further notes:* (a) does *not* include cohorts born 1954 or later; (b) does *not* include cohorts born 1959 or later; (c) includes births up to age 40 that occur prior to 1994.

Table 3: Males: childlessness and age at first birth

		Proportion still childless at			**Age at first birth**	
Males		**age 30**	**age 35**^{a}	**age 40**^{b}	mean^{c}	Std. Dev.
Cohort						
1945–49	Population	0.31	0.23	0.21	25.630	4.501
	Twins	0.30	0.22	0.20	25.714	4.366
	DZ twins	0.31	0.22	0.20	25.733	4.437
	MZ twins	0.28	0.21	0.19	25.678	4.226
1950–54	Population	0.39	0.28	0.24	26.384	4.565
	Twins	0.38	0.26*	0.23	26.520	4.511
	DZ twins	0.38	0.27	0.24	26.547	4.491
	MZ twins	0.37	0.26	0.20	26.462	4.557
1955–59	Population	0.46	0.32			
	Twins	0.47	0.31			
	DZ twins	0.48	0.34			
	MZ twins	0.44	0.26^{+++}			
1960–64	Population	0.50				
	Twins	0.49				
	DZ twins	0.50				
	MZ twins	0.49				
All cohorts	Population	0.41	0.27	0.22	26.071	4.174
	Twins	0.41	0.26**	0.21*	26.218**	4.130
	DZ twins	0.41	0.27	0.21	26.225	4.181
	MZ twins	0.40	0.24^{++}	0.19	26.206	4.037

Tests for significant differences: Results of tests for differences between overall population and twins: * $p \leq 0.10$; ** $p \leq 0.05$; *** $p \leq 0.01$. Results test for differences between dizygotic and monozygotic twins: $^{+}$ $p \leq 0.10$; $^{++}$ $p \leq 0.05$; $^{+++}$ $p \leq 0.01$. *Further notes:* (*a*) does *not* include cohorts born 1954 or later; (*b*) does *not* include cohorts born 1959 or later; (*c*) includes births up to age 40 that occur prior to 1994.

Table 4: Females: fertility at age 30, 35 and 40 years and parity progression ratios

		Number of children at age			**Parity Progression Ratio**	
Females		**age 30**	**age 35^{a}**	**age 40^{b}**	**1 to 2^{c}**	**2 to 3^{c}**
Cohort						
1945–49	Population	1.66	1.87	1.94	0.820	0.338
	Twins	1.59**	1.84	1.91	0.811	0.336
	DZ twins	1.61	1.85	1.92	0.820	0.362
	MZ twins	1.55	1.81	1.88	0.794	0.287^{++}
1950–54	Population	1.45	1.70	1.80	0.791	0.304
	Twins	1.39**	1.68	1.80	0.806	0.281
	DZ twins	1.38	1.64	1.75	0.800	0.269
	MZ twins	1.40	1.75^{+}	1.89^{++}	0.817	0.305
1955–59	Population	1.30	1.64			
	Twins	1.14***	1.49***			
	DZ twins	1.14	1.48			
	MZ twins	1.13	1.50			
1960–64	Population	1.21				
	Twins	1.24				
	DZ twins	1.25				
	MZ twins	1.23				
All cohorts	Population	1.41	1.75	1.88	0.808	0.324
	Twins	1.33***	1.69***	1.86	0.809	0.315
	DZ twins	1.34	1.68	1.85	0.812	0.326
	MZ twins	1.32	1.71	1.88	0.803	0.294

Tests for significant differences: Results of tests for differences between overall population and twins: * $p \leq 0.10$; ** $p \leq 0.05$; *** $p \leq 0.01$. Results test for differences between dizygotic and monozygotic twins: $^{+}$ $p \leq 0.10$; $^{++}$ $p \leq 0.05$; $^{+++}$ $p \leq 0.01$. *Further notes:* (*a*) does *not* include cohorts born 1954 or later; (*b*) does *not* include cohorts born 1959 or later; (*c*) parity progression ratios do *not* include cohorts born 1954 later and do *not* include births after age 40.

Table 5: Males: fertility at age 30, 35 and 40 years and parity progression ratios

		Number of children at age			Parity Progression Ratio	
Males		**age 30**	**age 35^a**	**age 40^b**	**1 to 2^c**	**2 to 3^c**
Cohort						
1945–49	Population	1.21	1.54	1.68	0.797	0.320
	Twins	1.23	1.58	1.72	0.797	0.335
	DZ twins	1.20	1.55	1.69	0.789	0.337
	MZ twins	1.28	1.63	1.77	0.813	0.332
1950–54	Population	1.00	1.37	1.57	0.767	0.309
	Twins	1.01	1.39	1.59	0.754	0.324
	DZ twins	1.00	1.38	1.57	0.769	0.311
	MZ twins	1.03	1.41	1.62	0.725	0.350
1955–59	Population	0.85	1.30			
	Twins	0.84	1.31			
	DZ twins	0.81	1.26			
	MZ twins	0.89	1.41^{++}			
1960–64	Population	0.79				
	Twins	0.82				
	DZ twins	0.82				
	MZ twins	0.82				
All cohorts	Population	0.97	1.41	1.63	0.785	0.316
	Twins	0.98	1.44^{*}	1.67^{*}	0.781	0.331
	DZ twins	0.97	1.42	1.65	0.782	0.327
	MZ twins	1.00	1.50^{++}	1.71	0.779	0.339

Tests for significant differences: Results of tests for differences between overall population and twins: * $p \leq 0.10$; ** $p \leq 0.05$; *** $p \leq 0.01$. Results test for differences between dizygotic and monozygotic twins: $^{+}$ $p \leq 0.10$; $^{++}$ $p \leq 0.05$; $^{+++}$ $p \leq 0.01$. *Further notes:* (a) does *not* include cohorts born 1954 or later; (b) does *not* include cohorts born 1959 or later; (c) parity progression ratios do *not* include cohorts born 1954 later and do *not* include births after age 40.

Table 6: Postponement effect: the reduction in fertility that is associated with a one-year delay in the age at first birth (the postponement effect, β_1, is statistically significant at the 5% level in all analyses, and at the 1% or higher level in most analyses, and we therefore indicate only statistically significant differences between the twin and overall population, and between DZ and MZ twins)

		Postponement effect^a	
		Coefficient β_1	Std. Error
Females			
1945–49	Population	0.073	(0.0006)
	Twins	0.073	(0.0060)
	DZ twins	0.074	(0.0070)
	MZ twins	0.069	(0.0110)
1950–53	Population	0.060	(0.0007)
	Twins	0.047^{*}	(0.0071)
	DZ twins	0.041	(0.0081)
	MZ twins	0.059	(0.0134)
Males			
1945–49	Population	0.067	(0.0006)
	Twins	0.067	(0.0058)
	DZ twins	0.058	(0.0066)
	MZ twins	0.088^{++}	(0.0112)
1950–53	Population	0.057	(0.0008)
	Twins	0.043^{*}	(0.0076)
	DZ twins	0.049	(0.0090)
	MZ twins	0.032	(0.0138)

Tests for significant differences: Results of tests for differences between overall population and twins: * $p \leq 0.10$; ** $p \leq 0.05$; *** $p \leq 0.01$. Results test for differences between dizygotic and monozygotic twins: $^{+}$ $p \leq 0.10$; $^{++}$ $p \leq 0.05$; $^{+++}$ $p \leq 0.01$. *Further notes:* (*a*) fertility is measured at age 40.