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Educational Differences in Completed Fertility: A Behavioral Genetic Study of Finnish Male and Female Twins

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Abstract Despite the large body of research on educational differences in fertility, how genetic and environmental influences may contribute to educational differences in completed fertility is not well understood. This study examines the association between educational level and completed fertility in a sample of Finnish male and female twins born between 1950 and 1957 with register-based fertility follow-up until 2009. The results show that poorly educated men and highly educated women are least likely to have any children and have lower completed fertility in general. Behavioral genetics analysis suggests that the association between education and having any children in both sexes is influenced by factors shared by co-twins and that these factors are genetic rather than common environmental. No evidence of a causal pathway between education and having any children independent of these shared influences is found. These findings suggest that familial factors may play a role in the process through which educational differences in completed fertility are formed.

Keywords Behavioral genetics · Childlessness · Completed fertility · Educational differences · Male fertility

Introduction

The relationship between education and fertility, especially in women, is of major interest in demographic research on industrialized countries with low fertility rates.

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High education often associates with lower fertility levels among women; for men, the results are less consistent (Fieder and Huber 2007; Goodman and Koupil 2009; Hagestad and Call 2007; Hoem et al. 2006a, b; Hopcroft 2006; Keizer et al. 2008; Kiernan 1989; Nettle and Pollet 2008; Parr 2005, 2009; Rønsen and Skrede 2010; Skirbekk 2008; Toulemon and Lapierre-Adamcyk 2000; Weeden et al. 2006). However, there is evidence of cohort-specific variation in the associations for both sexes (Andersson et al. 2009; Kravdal and Rindfuss 2008). Although these associations are typically believed to reflect causal effects between education and fertility, this interpretation has been challenged on the grounds that educational and fertility outcomes may be jointly determined to some extent (see, e.g., Hakim 2000; Hoem et al. 2006a, b; Kravdal 2001, 2007; Monstad et al. 2008; Morgan and Rindfuss 1999; Skirbekk et al. 2006; Upchurch et al. 2002).

Causality between education and fertility may run in both directions, but some previous studies have considered education more likely to influence fertility than vice versa because it typically precedes family formation (see, e.g., Neiss et al.; Rodgers et al. 2008). However, having a child may affect education, especially if childbearing occurs at an early age (e.g., Cohen et al. 2011; Hofferth et al. 2001; Hoffman et al. 1993; McElroy 1996; Morgan and Rindfuss 1999). Having children may negatively influence educational outcomes in particular because both parenting and studying are time-consuming and potentially competing activities. Interference with educational career is thus likely to be stronger among women, who mature biologically and generally begin to have children a few years earlier than men (e.g., Kiernan and Diamond 1983; Woodward et al. 2006). Further, women's biological and social role in childbearing and early child rearing is more likely to exert a negative effect on their education (e.g., Dearden et al. 1995; Kiernan and Diamond 1983; Rijken and Liefbroer 2009:79–81; Sigle-Rushton 2005; Woodward et al. 2006).

Educational attainment can affect fertility in several ways (see, e.g., Lappegård and Rønsen 2005; Kravdal and Rindfuss 2008). Having higher education may reduce fertility because of the higher (potential) income and the correspondingly higher opportunity costs of reducing working hours or withdrawing from the labor market to care for children (e.g., Becker 1981; Gustafsson 2001; Liefbroer and Corijn 1999; Pollak and Watkins 1993). There may also be an offspring quantity-quality tradeoff: if highly educated parents invest more in each of their children than their lower-educated peers, they may settle for a smaller number (e.g., Becker 1981; Becker and Lewis 1973). However, having a higher education and a higher income may also enhance fertility for reasons of affordability, especially among men who often invest less time in child rearing and thus face lower opportunity costs (e.g., Becker 1981; Gustafsson 2001; Kravdal 2007; Liefbroer and Corijn 1999; Pollak and Watkins 1993; Vikat 2004). In addition, a higher level of education may contribute to the attractiveness as a partner, especially in men who traditionally face higher expectations of being a breadwinner than women (e.g., Becker 1981; Oppenheimer 1988).

Importantly, others have emphasized the difficulties of combining child rearing with further education and social norms that discourage having children while studying (Blossfeld and Huinink 1991; Hoem 1986; Kravdal 2001; Lappegård and Rønsen 2005). Thus, the longer the enrollment in education, the later the onset of childbearing. Postponement, in turn, may lead to lower completed fertility because of decreasing fecundity with age, especially in women, or because of social norms concerning the timing of having children among both men and women (Hagestad and Call 2007; Keizer et al. 2008; Rindfuss and Bumpass 1976). Educational attainment may also influence values and life orientation (e.g., Kontula 2008:272) and the ways of planning a childbirth and using contraceptive methods (Kravdal and Rindfuss 2008). The loosening of traditional norms and the trend toward individualism may encourage seeking fulfillment in life without children (Lestaeghe 1983; van de Kaa 1996), although such societal-level forces may affect individuals differently across educational categories (Skirbekk et al. 2006). Contextual influences—such as the flexibility of the educational system, childcare provision, and employers' attitudes toward fertile age employees, especially women—are additional influences affecting the relationship between education and fertility (Rønsen 2004; Rønsen and Skrede 2010).

The nature of causality in associations between education and fertility has also been questioned theoretically and empirically in life-course studies using general population samples (e.g., Hakim 2000; Kravdal 2007; Martín-García and Baizán 2006; Monstad et al. 2008; Morgan and Rindfuss 1999; Skirbekk et al. 2006; Tavares 2010; Upchurch et al. 2002) as well as in studies on twins (Kohler et al. 2010; Kohler and Rodgers 2003; Neiss et al. 2002; Rodgers et al. 2008). Twin studies have argued that genetic or environmental factors clustered in families of origin and thus shared by co-twins reared together may influence both educational and family outcomes. This may take the form of a preference toward either family or further education and career enhancement, for example, and thus contribute to a spurious association between the two (see, e.g., Rindfuss et al. 1980). The ability to act according to one's own preferences may also play a part (Neiss et al. 2002). Taking full account of genetic and common environmental influences while investigating associations between education and fertility is challenging in studies using general population samples because people with different levels of education vary in several respects (see, e.g., Skirbekk et al. 2006:67). Thus, unobserved characteristics may produce unobserved heterogeneity that contributes to the associations. The aim of the present study is to shed light on the nature of these associations by investigating genetic and environmental influences on educational differences in completed fertility, using a behavioral genetics design with twin data.

Behavioral Genetics Approach: Study Design and Previous Evidence

Twin studies are based on comparisons between monozygotic (MZ) twins (sharing all their genes, and being identical at the DNA sequence level) and dizygotic (DZ) twins (sharing, on average, one-half of their segregating genes). These differences mean that a behavioral genetics design can distinguish between genetic, common environmental, and unique environmental influences on traits and on associations between multiple traits (Boomsma et al. 2002; Neale and Cardon 1992). Similarity between twins arises because of genetic or environmental influences shared by co-twins. By *genetic influences*, we refer here to additive genetic influences having a correlation of 1 within MZ pairs and 0.5 within DZ pairs. *Common environmental influences* refer to all environmental influences that make twins within a pair similar. Environmental influences that produce dissimilarities in the twin pair are referred to as *unique environmental influences* and include all those that the twins do not share. By default, all measurement error is also modeled as part of this source of variance.

Rather than accounting for specific measured confounding covariates, the quantitative genetics approach typically investigates the extent to which variation in traits or covariation between traits—here, fertility and educational level—can be attributed to the three sources of variance: genetic, common environmental, and unique environmental influences. Linear structural equation modeling based on pair covariance in MZ and DZ twins can be used to estimate the extent to which variation in a trait or covariation between two traits is attributable to each of the three sources. Covariance between co-twins in a trait (cross-twin/within-trait covariance) refers to either genetic or common environmental influences on the trait. As a rule, the greater the covariance in a trait in MZ twin pairs compared with DZ twin pairs, the greater is the estimate of genetic influences on the trait. Similarly, covariance between co-twins between two traits (cross-twin/cross-trait covariance) refers to either shared genetic or shared environmental influences on the covariation of the traits, and the MZ/DZ twin pair ratio is informative of whether similarity increases because of genetic or common environmental causes.

In accordance with the classical approach to twin studies, causal effects between two traits that are independent of any shared genetic or common environmental influences are modeled as covariance between the unique environmental variances of the traits, as explained in detail later (Neale and Cardon 1992:261–86; Neale et al. 1994). In this setting, the direction of the possible effect between two traits cannot be distinguished: for example, in the context of this study, we would not be able to determine whether education had a causal effect on fertility, or vice versa. However, this definition of causality is special compared with the one more familiar in the social science literature in that the causal effects between two traits are defined only as resulting from variance sources other than those of one's genetic or environmental background (see Kohler et al. 2010). The typical social science approach to causality does not necessarily make this kind of distinction. Interactions between genetic influences with common environmental factors are also modeled as part of the genetic variance (Neale and Cardon 1992:22–23).

Our primary reason for studying educational differences in completed fertility in a twin setting is that previous twin studies have shown genetic and common environmental effects for both education and fertility, but the association between the two—especially with respect to completed fertility and fertility in men—has been less studied. Previous estimates of the contribution of interindividual genetic differences to variation in educational level based on U.S. and European twin studies have ranged from one-fifth to almost one-half of the total variance (Kohler and Rodgers 2003; Neiss et al. 2002; Rodgers et al. 2008; Silventoinen et al. 2004), and estimates of both common and unique environmental contributions also vary.

Several twin and family studies conducted in Denmark and the United States have investigated variation in fertility outcomes (Kohler and Christensen 2000; Kohler and Rodgers 2003; Kohler et al. 1999, 2010; Miller et al. 2010; Rodgers and Doughty 2000; Rodgers et al. 2001, 2007; see also Mealey and Segal 1993). Evidence of moderate genetic influences has been found for fertility outcomes, such as having any children and number of children, and also for variables more clearly related to fertility motivation, such as age at first attempt to have a child and desired number of children. These studies suggested that genetic influences are stronger for onset of fertility than total number of children, and some of them reported weaker common environmental than genetic effects (e.g., Rodgers et al. 2001).

Cohort-specific variation is also possible: genetic effects on fertility were found to be stronger in Danish twin cohorts experiencing fertility decline than for other birth cohorts (Kohler et al. 1999). However, for age at first birth, common environmental influences played a role, whereas genetic effects were not present, even in the cohort experiencing fertility decline (Rodgers et al. 2008; but see Neiss et al. 2002). Unique environmental factors were the most important, however. Given that partnership formation is closely associated with fertility behavior, it is noteworthy that certain twin studies have reported relevant genetic effects and some, but weaker, common environmental effects on marriage formation (Kohler and Christensen 2000; Mealey and Segal 1993; Trumbetta et al. 2007).

The little evidence that exists from earlier behavioral genetic studies directly or indirectly assessing the genetic and common environmental contributions to the association between level of education and fertility is somewhat inconsistent. In a Danish twin study, the same or closely related genetic influences did not contribute to number of children and level of education (Kohler and Rodgers 2003; see also Kohler et al. 1999). The common environmental influences affecting fertility were largely found to influence educational level as well, but the size of the impact remained modest. Only a small overlap of genetic or common environmental factors was found among male twins (Kohler and Rodgers 2003). However, this study was unlikely to fully account for educational differences in completed fertility given that more than one-half of the study participants were younger than 40 at the end of follow-up. A more recent study on U.S. twins reported that the negative association between education and completed fertility among women was largely attributable to overlap in the genetic variance in education and fertility, but concluded that education itself is the necessary mechanism linking genetic variance to fertility outcome (Kohler et al. 2010). Another study on U.S. women and men found no overlap of genetic variance and only modest overlap of common environmental variance between expected educational achievement in youth and number of children in adulthood (Miller et al. 2010). The estimates of variance components of expected education in this study did not correspond to previous estimates of achieved levels of education in the United States, however (Neiss et al. 2002; Rodgers et al. 2008; Silventoinen et al. 2004).

Associations between educational level and fertility have aroused interest in the demographics literature, but knowledge of the effect of genetic and common environmental influences on the association remains limited, especially for men and for completed fertility. Little behavioral genetics research exists on the education-fertility association in men. Thus, we aim to quantify educational differences in completed fertility in Finnish men and women, and to examine in a twin setting to what extent these associations are due to genetic, common environmental, and unique environmental influences. One advantage over the previous studies is that we can measure completed fertility in males as well as in females in a large twin sample. By analyzing men and women in parallel, this study also seeks to highlight any differences between the sexes in determinants of educational differences in fertility. We consider sex differences important because less is known about men than women and because prior theory suggests possibly different mechanisms for men and women. Contextual factors are likely to influence sex differences through varying gender roles, but sex-specific biological constrains also exist—importantly, the span of the fertile-age period, which places men and women in different life-course settings in relation to their education and fertility.

Previous research reported strong associations between fertility timing and number of children, and the postponement of first birth because of longer education is considered a crucial mechanism toward lower fertility (e.g., Gustafsson 2001; Rindfuss et al. 1980). From the behavioral genetics point of view, whether these two fertility outcomes show similar latent variance structure is unclear. This is interesting also from the point of view of sex: although longer education is associated with the postponement of family formation among women and men, education is associated with higher completed fertility among Finnish men but not among women (Havén 1999:161–162). Thus, we further quantify associations between educational level and age at first birth (AFB) using a behavioral genetics design to see whether similar latent variance architecture is present for this fertility outcome as compared with completed fertility among men or women.

Data and Methods

The data were derived from the older cohort of the Finnish Twin Cohort Study (Kaprio and Koskenvuo 2002). The baseline questionnaire was mailed in 1975 to all same-sex Finnish twin pairs who were born before 1958 and were both alive in 1974. A follow-up questionnaire was sent in 1981 to all twin pairs to whom the baseline questionnaire had been sent, regardless of their participation in the 1975 survey. The response rates in these surveys were 89 % and 84 %, respectively. We included the cohorts born in 1950–1957 in the sample and restricted the study to those who were not living with their co-twin in 1981 (n = 7,842). This decision was based primarily on the empirical observation that compared with the general population of Finland (Statistics Finland 2007:87–88), a relatively large proportion of these twins were childless. This finding accords with earlier indications that compared with the whole Finnish population, married men and women are slightly underrepresented in the twin data (Kaprio et al. 1979:32–36). Further, the few respondents of a triplet or quadruplet, plus those who had not given information on their education in either the 1975 or the 1981 survey (n = 22), were excluded from the analysis. The final study population consisted of 7,820 twin individuals: 3,592 men and 4,228 women.

Zygosity was assessed in the 1975 and 1981 surveys by questions concerning the similarity of appearance at an early school age. This method left a small proportion (7 %) of pairs unclassified because of missing or conflicting responses, although some were correctly classified later by means of genetic testing. The validity of this questionnaire method for classifying zygosity has been assessed in a Finnish study by using 11 highly polymorphic blood markers in a sample of 104 twin pairs classified as monozygotic (MZ) or dizygotic (DZ). The observed agreement between the results of the blood tests and the questionnaire-based method was 100 %, and the probability of misclassification of a twin pair was estimated to be less than 2 % (Sarna et al. 1978). Our analysis sample included 1,952 male and 1,986 female complete twin pairs, of which 418 were MZ and 1,035 DZ male pairs, and 583 were MZ and 1,249 DZ female pairs. Zygosity was unknown for 139 male and 154 female twin pairs.

Register-based comprehensive information on live births was available until June 2009, at which time the participants alive were 51–59 years of age. These data were linked to the baseline data using the unique personal identification number given to all Finnish citizens. Given that our information on fertility is register based, underestimation of the numbers of children born to men is possible. However, this should be unlikely to seriously affect the results because the proportion of children without a known father in Finland during the last decades of the twentieth century was small (1.3 % of children aged 0–17 years in 1997) (Kartiovaara and Säkkinen 2007).

The measure of level of education was based on the 1981 survey (when the respondents were aged 23–31), and if not available, then the 1975 survey (when they were aged 17–25). The respondents were asked, "What kind of schools and courses have you attended?"; nine response alternatives were given. Those who were still studying when reporting their level of education were assumed to have reached the next educational category given in the questionnaire. The highest level of education was then classified into four groups: primary school (6 years) or less, more than primary school (7 years), junior high school (10 years), and senior high school (12 years) or more. Having more than primary school education here means having completed primary school, plus at least one year of vocational education. The partnership variable was also based on survey information from 1975 and 1981. Respondents who reported having been married or living currently in a cohabiting union (questionnaire alternatives: "married," "remarried," "cohabiting," "divorced or separated," or "widow") were classified as being in a partnership at some point.

Binary (having vs. not having children) and multinomial logistic regression analysis (having one or two children and three or more children vs. having no children) was first used to study the associations between level of education and fertility. Taken into account in the estimation of the standard errors was that observations of twins within twin pairs are correlated by means of a survey cluster option (Williams 2000). The results of the logistic regression analyses for men and women are presented as odds ratios (OR) with their 95 % confidence intervals (CI). The Stata statistical package, version 10 (StataCorp 2007) was used for these analyses.

Next, we constructed behavioral genetic models for education and having any children (at least one child) (Neale and Cardon 1992). In quantitative genetic modeling, the variance of a phenotype—here, education and fertility—is assumed to result from a genetic component (A), an environment common to the twins (C), and an environment unique to the twins (E). There may also be variation in the dominant genetic effects (D) (as opposed to additive genetic variance, labeled here as "genetic variance"), referring to interactions between alleles in the same loci, but this component cannot be modeled simultaneously with common environmental effects if only twins reared together are included in the data. Bivariate Cholesky decomposition parameterization was used to study correlations between genetic and environmental sources of variance in education and having any children. For example, a correlation between the genetic components of education and having any children would suggest that the same or closely linked genes influence both of these traits.

By default, a causal effect between education and fertility independent of any factors shared by twins is modeled as a unique environmental correlation. This is because unique environmental correlation reflects higher correlation between education and fertility for a twin individual when compared with correlation between own education and fertility of co-twin: that is, cross-twin/cross-trait correlation. In contrast, a cross-twin/cross-trait correlation that is not lower than cross-trait correlation for a twin individual indicates that the correlation between these two traits is because of overlap in genetic (when cross-twin/cross-trait correlation is higher within MZ than DZ pairs) or common environmental factors (when there is no difference in the cross-twin/cross-trait correlations within MZ and DZ pairs). This definition of causality tests whether variation in education that is not produced by differences in genetic or common environmental factors is associated with corresponding variation in fertility (Neale and Cardon 1992:261–286; Neale et al. 1994).

We tested the statistical significance of the different types of variance components in the bivariate analyses by means of nested models, and further examined the change in model fit (chi-square values) according to the degrees of freedom between them. We also calculated Akaike information criterion (AIC) indexes to distinguish between the fit of different univariate models. Finally, the genetic modeling was repeated for the association between education and AFB. AFB was measured as the age that the participant reached during the year their first child was born. The Mx statistical package (raw data option) was used in the genetic modeling (Neale 2003).

Results

Relationship Between Educational Level and Completed Fertility

As shown in Table 1, 23 % of men and 18 % of women were childless, whereas 27 % of men and 25 % of women had three or more children. Table 2 shows the logistic regression analyses in which twins were treated as individuals. We treated our outcome fertility variables as follows. Having any children in the binary logistic regressions and having one or two children and three or more children in the multinomial models were contrasted with having no children. The lowest educational category, primary school or less, was the reference group for the main explanatory variable. In the binary model for men, those in this category were least likely to have children. All the other educational groups differed statistically significantly from this reference group, showing a greater likelihood of having children (OR = 1.40–1.62 vs. 1.00). Among women, by contrast, the two high school groups differed statistically significantly from the two primary school groups in being less likely to have children (OR = 0.56–0.61 vs. 1.00–1.01). Adjusting for partnership status somewhat attenuated the differences in both sexes in most cases.

According to the multinomial logistic regression models, the men in the lowest educational category were less likely to have one or two children (OR = 1.00 vs. 1.32–1.75) and three or more children (OR = 1.00 vs. 1.38–1.61) than other men. Adjusting for partnership status attenuated these differences except for those with high school or higher education. Among women, those in either of the two high school groups were less likely to have one or two (OR = 0.58–0.63 vs. 1.00–1.07) and three or more (OR = 0.51–0.58 vs. 0.91–1.00) children than those in either of the two primary school groups. The main effect of adjusting for partnership status here was to attenuate the difference between the groups with the highest and lowest levels of education.

Table 1 Distribution of variables (*N*, %)

	Men		Women	
	N	%	*N*	%
Completed Fertility (number of children)				
0	837	23	774	18
1–2	1,803	50	2,382	56
3+	952	27	1,072	25
Total	3,592	100	4,228	100
Level of Education[a]				
Primary school (6) or less	972	27	1,151	27
More than primary school (7)	1,305	36	1,033	24
Junior high school (10)	631	18	971	23
High school (12) or more	684	19	1,073	25
Total	3,592	100	4,228	100
Partnership				
No	1,267	35	1,195	28
Yes	2,325	65	3,033	72
Total	3,592	100	4,228	100

[a] The numbers in parentheses refer to years of education.

Behavioral Genetic Modeling

According to the results presented earlier, the associations between level of education and fertility were nonlinear in both sexes. Thus, instead of modeling the level of education as a continuous variable, sex-specific dichotomous variables were applied in the subsequent genetic analysis, using a threshold model. We modeled having primary school or less education (27 %) versus more education (73 %) among men, and having primary school education (primary school or less, or more than primary school) (51 %) versus high school education (junior high school, or high school or more) (49 %) among women.[1] In terms of fertility, the rest of the analysis focused only on having any children versus no children. We did not adjust for age in the genetic modeling because it had no effect on the estimates in the logistic regression analysis. A modest tetrachoric correlation[2] was found between education and having any children among both men (0.13; 95 % CI = 0.06, 0.20) and women (−0.18; 95 % CI = −0.23, −0.17) in the expected direction. The numbers of concordant and discordant MZ and DZ twin pairs (in terms of education/fertility) and the tetrachoric correlations of MZ and DZ (for education/fertility) twin pairs are shown in Table 3. A greater proportion of MZ than DZ twin pairs was concordant for both education and fertility, and the tetrachoric correlations were also

[1] The sex-specific categorization of the educational variable is based on the preceding results: the association between education and fertility was nonlinear in both sexes with these specific cut-off points of the variable scale, thus showing a threshold effect.

[2] Tetrachoric correlation refers to correlations calculated for dichotomous variables from an underlying assumed standard normal distribution in order to estimate either covariance between co-twins across two traits (cross-twin/cross-trait covariance) or twin-pair resemblance in a trait (cross-twin/within-trait covariance).

Table 2 Completed fertility by educational level: Odds ratios (OR) and confidence intervals (CI) from binary and multinomial logistic regression analysis

	Men					Women				
		Model 1		Model 2			Model 1		Model 2	
	N	OR	95 % CI	OR	95 % CI	*N*	OR	95 % CI	OR	95 % CI
Binary Logistic Regression Analysis	3,592					4,228				
Any children vs. no children[a]										
Primary school (6) or less		1.00		1.00			1.00		1.00	
More than primary school (7)		1.62	1.33, 1.97	1.35	1.08, 1.68		1.01	0.79, 1.30	1.11	0.85, 1.44
Junior high school (10)		1.61	1.25, 2.08	1.45	1.08, 1.95		0.61	0.49, 0.78	0.62	0.48, 0.80
Senior high school (12) or more		1.40	1.11, 1.78	1.69	1.29, 2.21		0.56	0.44, 0.69	0.73	0.57, 0.92
Multinomial Logistic Regression Analysis	3,592					4,228				
One or two vs. no children[a]										
Primary school (6) or less		1.00		1.00			1.00		1.00	
More than primary school (7)		1.75	1.42, 2.16	1.46	1.16, 1.83		1.07	0.83, 1.38	1.15	0.88, 1.51
Junior high school (10)		1.61	1.23, 2.11	1.46	1.08, 1.98		0.63	0.50, 0.81	0.64	0.49, 0.83
Senior high school (12) or more		1.32	1.03, 1.70	1.58	1.20, 2.09		0.58	0.46, 0.73	0.74	0.58, 0.95
Three or more vs. no children[a]										
Primary school (6) or less		1.00		1.00			1.00		1.00	
More than primary school (7)		1.38	1.08, 1.76	1.12	0.86, 1.46		0.91	0.68, 1.20	0.99	0.73, 1.34
Junior high school (10)		1.61	1.19, 2.18	1.43	1.02, 2.02		0.58	0.44, 0.76	0.58	0.43, 0.78
Senior high school (12) or more		1.55	1.16, 2.06	1.94	1.41, 2.67		0.51	0.39, 0.67	0.69	0.52, 0.93

Notes: Model 1: adjusted for age and level of education. Model 2: adjusted for age, level of education, and partnership.

[a] The numbers in parentheses refer to years of education.

Table 3 Number of concordant and discordant twin pairs and tetrachoric correlations (and 95 % confidence intervals (CI)) for education and having any children

	Number of MZ Pairs			Number of DZ Pairs			Tetrachoric Correlations			
	Concordant		Discordant	Concordant		Discordant				
	−/−	+/+	−/+	−/−	+/+	−/+	MZ	95 % CI	DZ	95 % CI
Men										
Education[a]	56	297	65	153	627	255	.78	.67, .86	.59	.54, .66
Any children	37	288	93	80	630	325	.51	.35, .65	.22	.11, .33
Women										
Education[b]	250	275	58	506	458	285	.95	.92, .97	.75	.70, .80
Any children	37	416	130	59	857	333	.41	.26, .55	.20	.09, .31

[a] Education refers to primary school or less (27 %) versus at least more than primary school (73 %).

[b] Education refers to at most more than primary school (52 %) versus high school or more (48 %).

higher, suggesting genetic influences on the two traits under investigation. The correlations in the DZ twin pairs were relatively weak for having any children, but more than one-half of those of MZ pairs for education, suggesting common environmental effects on education but not on having any children.

We started the modeling by comparing bivariate with saturated models to test the assumption of twin modeling. When using raw data, it is necessary to estimate a saturated model with free covariances to evaluate the fit of the ACE and other subset models. The ACE model did not differ from the saturated model for education and having any children among men ($\Delta\chi^2_{11} = 18.5$, $p = .07$, $\Delta\text{AIC} = -3.5$) or women ($\Delta\chi^2_{11} = 11.9$, $p = .37$, $\Delta\text{AIC} = -10.2$). To find the best-fitting model, we dropped the common environmental component for having any children and the common environmental and unique environmental correlation for having any children and education among men ($\Delta\chi^2_3 = .103$, $p = .99$, $\Delta\text{AIC} = -5.897$) and women ($\Delta\chi^2_3 = 6.9$, $p = .07$, $\Delta\text{AIC} = 0.97$). Parameter estimates of these best-fitting bivariate Cholesky models are presented in Table 4.

In the bivariate model for education and having any children, education in men was estimated to result mainly from genetic ($a^2 = .42$) and common environmental factors ($c^2 = .37$), whereas unique environmental factors had a somewhat smaller effect ($e^2 = .21$). Similarly, for women, educational variance was estimated to result mainly from genetic ($a^2 = .41$) and common environmental factors ($c^2 = .54$), whereas unique environmental factors had an even smaller effect than among men ($e^2 = .05$). The sources of variance in having any children, in turn, were estimated to be genetic factors (for males, $a^2 = .50$; for females, $a^2 = .39$) and environmental factors unique to the twins (for males, $e^2 = .50$; for females, $e^2 = .61$). These models further revealed statistically significant correlations between the genetic factors of education and having any children among both men ($r_A = .28$) and women ($r_A = -.44$).[3]

[3] The genetic correlation (r_A) is calculated by $r_A = \text{cov}_{A(Edu,Child)} \Big/ \left(\sqrt{\text{var}_{A(Edu)}} \times \sqrt{\text{var}_{A(Child)}}\right)$, where A refers to genetic factors, *Edu* refers to educational level, and *Child* refers to having any children. The common (r_C) and unique (r_E) environmental correlation is calculated in the same way except that *C* / *E* replaces *A*.

Table 4 Estimates of variance components for education and having any children and correlations between them with 95 % confidence intervals (CI)

	Variance Component Estimates					
	Genetic		Common Environmental		Unique Environmental	
	a^2	95 % CI	c^2	95 % CI	e^2	95 % CI
Men						
Education[a]	.42	.17, .65	.37	.19, .55	.21	.13, .31
Having any children	.50	.37, .62	na		.50	.38, .63
Women						
Education[b]	.41	.33, .52	.54	.45, .63	.05	.03, .08
Having any children	.39	.29, .49	na		.61	.50, .74
	Correlations Between Variance Components					
	r_A	95 % CI	r_C	95 % CI	r_E	95 % CI
Men	.28	.13, .51	na		na	
Women	−.44	−.63, −.28	na		na	

Note: All parameter estimates marked as na are constrained to 0 in the best-fitting model shown in this table.

[a] Education refers to primary school or less (27 %) versus at least more than primary school (73 %).

[b] Education refers to at most more than primary school (52 %) versus high school or more (48 %).

The association between education and age at first birth was linear, and thus these variables were used as continuous. The correlation between the variables was modest for men (.23; 95 % CI = .18, .27) and moderate for women (.35; 95 % CI = .32, .39). The ACE and saturated models did not differ for education and AFB for men ($\Delta\chi^2_{21}$ = 15.8, p = .78, ΔAIC = −26.1) or for women ($\Delta\chi^2_{21}$ = 13.9, p = .87, ΔAIC = −28.1). To find the best-fitting model, we dropped genetic factors for AFB and genetic and unique environmental correlations between education and AFB ($\Delta\chi^2_3$ = 3.0, p = .40, ΔAIC = –3.04) for men; for women, all parameters were statistically significant. Parameter estimates of these best-fitting bivariate Cholesky models are presented in Table 5.

In the bivariate model for education and AFB, education among men was estimated to result from genetic factors (a^2 = .36) and common (c^2 = .46) and unique (e^2 = .19) environmental factors. For women, educational variance was estimated to result from genetic factors (a^2 = .46) and common (c^2 = .38) and unique (e^2 = .16) environmental factors. For men, the sources of variance in AFB were estimated to be common (c^2 = .22) and unique (e^2 = .78) environmental factors. For women, genetic factors (a^2 = .26) and common (c^2 = .12) and unique environmental factors (e^2 = .61) were all estimated as significant sources of variance in AFB. According to these bivariate models, the association in men between education and AFB resulted from a correlation between common environmental factors (r_C = .68). In women, the association was estimated to be due to genetic (r_A = .27), common environmental (r_C = 1.00), and unique environmental (r_E = .14) correlations.

Table 5 Estimates of variance components for education and age at first birth (AFB) and correlations between them with 95 % confidence intervals (CI)

	Variance Component Estimates					
	Genetic		Common Environmental		Unique Environmental	
	a^2	95 % CI	c^2	95 % CI	e^2	95 % CI
Men						
Education	.36	.28, .44	.46	.38, .53	.19	.16, .22
AFB	na		.22	.16, .28	.78	.72, .85
Women						
Education	.46	.39, .53	.38	.32, .45	.16	.14, .18
AFB	.26	.09, .37	.12	.06, .24	.61	.55, .69
	Correlations Between Variance Components					
	r_A	95 % CI	r_C	95 % CI	r_E	95 % CI
Men	na		.68	.55, .84	na	
Women	.27	.03, .50	1.00	.68, 1.00	.0.14	.05, .23

Note: All parameter estimates marked as na are constrained to 0 in the best-fitting model shown in this table.

Discussion

Main Findings and Previous Evidence

Using a behavioral genetics design with twin data, this study assessed educational differences in completed fertility and investigated the extent to which genetic or environmental factors contribute to these differences. When we analyzed twins as individuals, we found a generally similar educational patterning in fertility to that indicated in previous studies on Finnish men and women, although a more U-shaped association (using a different educational classification) with remaining childless has been reported for this female birth cohort (Andersson et al. 2009; Havén 1999:161–162; Ruokolainen and Notkola 2007:101–104). The associations among men were similar in direction to those found in other Scandinavian countries (Goodman and Koupil 2009; Kravdal and Rindfuss 2008; Rønsen and Skrede 2010): lower educational level was associated with being less likely to have any children and to having a smaller number of children in general. The pattern among women was similar in direction to that witnessed in other Western countries (Hagestad and Call 2007; Kravdal and Rindfuss 2008; Parr 2005; Skirbekk 2008; Toulemon and Lapierre-Adamcyk 2000; Weeden et al. 2006): a high educational level was associated with being less likely to have any children and to having fewer children in general, although the differences in completed fertility were modest.

Adjusting for partnership status attenuated these differences in both sexes, with the exception of the most highly educated men. This is unsurprising given the close relationship between partnerships and fertility (e.g., Toulemon and Lapierre-Adamcyk

2000; Upchurch et al. 2002). The exception of the highest educated men may be because the partnership variable used was measured at a relatively young age and thus treated men in different educational categories differently. The higher educated tend to postpone union formation, but higher-educated Finnish men are more likely to eventually form a union (Koskenvuo et al. 1979; Nikander 1995:17–20).

The analysis proceeded with the behavioral genetic modeling of a sex-specific variable of educational level and having any children. The best fit in the bivariate models was an ACE variance structure for education and an AE structure for having any children. Thus, education was estimated to result from variation in genetic, common environmental, and unique environmental factors (in order of magnitude). The estimates of the different sources of variation in men corresponded to previous findings on level of education in the Finnish Twin Cohort, when years of education was used as a continuous measure and spanned more birth cohorts (Silventoinen et al. 2004). For women, the proportion of variance attributable to environmental factors unique to the twins was estimated as somewhat smaller than previously estimated for years of education in the Finnish Twin Cohort, spanning more birth cohorts.

Studies from other countries on variance in educational levels higher than those used here report somewhat higher estimates of unique environmental variance (Kohler and Rodgers 2003; Neiss et al. 2002; Rodgers et al. 2008; Silventoinen et al. 2004). With regard to having any children, our variance estimation seems to be roughly in line with previous scarce evidence (Kohler and Christensen 2000; Kohler et al. 1999). Genetic effects explained one-half of all the variation in men, and unique environmental effects explained another one-half; in women, the proportion of genetic variance appeared smaller. Population estimates of genetic effects may vary because of differing environmental effects, resulting in larger or smaller environmental and other sources of variance.

The bivariate genetic models also suggested a correlation between the genetic variance components of education and having any children in both sexes. The correlation differed by sex in direction and strength: it was modestly positive in men and moderately negative in women. The implication is that genetic influences may contribute to the association between educational level and having any children. These results differ from those of a previous study on Danish twins, focusing on the association between educational level and number of children, in which there was minimal overlapping of genetic variance (Kohler and Rodgers 2003; see also Kohler et al. 1999). Then again, our results resemble those reported in a previous study on U.S. women in which the basic bivariate genetic model (closest to our model) identified genetic and weaker unique environmental covariance but no significant common environmental covariance contributing to the association between education and number of children in women (Kohler et al. 2010:43–45).

We suggest at least three possible reasons for the differing results in the two European studies. On the general level, disparities in the variables used could have had an effect. First, we used a dichotomized variable for both education and fertility in the genetic modeling part of the study because the associations were found to be nonlinear, whereas the previous study used number of children as a continuous variable. These different measurement scales could have led to different results. Further, factors shared by twins may not necessarily have a similar effect on educational differences in transitions to different parities (see, e.g., Kravdal 2007).

Second, our measure of education captures educational differences at a lower level than the previous study. We assume that it is not likely that the lower level of education would have profoundly affected our results on the relevance of genetic factors behind the association between education and fertility as a whole because these factors are likely to affect educational variation in similar ways regardless of mean level of education (Silventoinen et al. 2004). However, it is also possible that in societies where educational level is higher, for example, the longer period of educational enrolment may produce stronger causal association independent of any genetic or common environmental factors between education and fertility, especially in females, for which we did not find evidence in this study.

Third, the varying age ranges of the participants in the two studies may have affected the results, especially given the well-known variation in timing of family formation according to educational level (e.g., Kontula 2008; Lappegård and Rønsen 2005). We assume that the age range of the participants in the present study allowed reliable measurement of practically completed fertility, whereas the age cohorts in the previous study were relatively young in this respect (more than one-half of participants were younger than age 40 at the end of follow-up) and thus partly reflect differences in the timing of fertility.

Finally, genetic models for education and AFB were estimated to assess whether the latent variance structure was similar compared with having any children. For men, AFB was estimated to result largely from unique and, to a lesser extent, from common environmental factors, whereas genetic factors were found to be nonsignificant. For women, AFB was estimated to result from all three variance sources: unique environmental factors accounted for the largest part of variance, and genetic and common environmental factors accounted for smaller proportions. The estimates differed from those for having any children among both sexes: common environmental factors were present for AFB and were estimated to influence the association between education and AFB. The variance estimates for AFB and the covariance estimates for the association between education and AFB in this study were rather similar to those in the two previous studies assessing this association (Neiss et al. 2002; Rodgers et al. 2008). Still, the findings on Danish female twins by Rodgers et al. (2008) differed in that in their study, genetic effects were not present for AFB, and the association between education and AFB was found to result only from common environmental factors.

Interpreting the Results

The results suggest that factors shared by twins are important for the process by which the association between educational level and having any children in both sexes evolves. Feasibly, genetic factors rather than common environmental factors play a role. Given the rich theorizing on the mechanisms linking education and fertility, it seems reasonable to suggest that any genetic influences on the association may operate primarily through a *social process* that is different for men and women. A genetically influenced social process leading to both educational and fertility outcomes may be attributable, for example, to cognitive abilities (Neiss et al. 2002; Retherford and Sewell 1989; Rodgers et al. 2008) or to personality traits (Hakim 2000:185–189; Miller 1992, 1994; Tavares 2010) that may influence preferences or abilities to act according to one’s preferences related to family formation, further education, and career choices. Young women with poor schooling or career prospects may find starting a family to be an attractive alternative strategy for marking the transition to adulthood (Morgan and Rindfuss 1999; Rindfuss et al. 1980; Upchurch et al. 2002). This argument does not seem to hold for young men, at least not to the same extent as for women, given the opposite direction of the association.

More importantly, for men, some genetically influenced characteristics correlated with low educational achievement (such as poor health) may signal poor long-term prospects for women in the partnership market and thus may contribute to high levels of childlessness among men in this educational group (Fu and Goldman 1996; Oppenheimer 1988). Other mechanisms influenced by familial factors naturally remain possible as well (see Goodman and Koupil 2009; Hakim 2000:185–89; Mealey and Segal 1993; Miller et al. 2010; Phillips et al. 2001). Furthermore, if genetic effects are present, they may contribute to the association between education and fertility in interaction with environmental factors, including enrollment in an educational institution (Kohler et al. 2010; Miller 1994; Tavares 2010). Thus, although differences in completed fertility by educational level independent of any shared genetic or common environmental factors were not found, acquiring an education may still be a necessary mechanism in the process.

We did not find evidence that common environmental factors contributed to the association between educational level and having any children. Neither was there evidence that the association between educational level and having any children would result from causal processes independent of any shared genetic or common environmental factors (see also Monstad et al. 2008; Skirbekk et al. 2006). However, the association between education and AFB was found to be influenced by common environmental factors for both sexes, and for women also by shared genetic factors and environmental factors unique to the twins. These findings imply that common environmental factors influence the associations between level of education and timing of fertility (Neiss et al. 2002; Rodgers et al. 2008). In families with higher parental socioeconomic status, life goals other than family-building, such as continuing education and career-building, are more likely encouraged (Rijken and Liefbroer 2009; Scott 2004).

The unique environmental correlation for women, but not for men, indicates that further education may directly, independent of any familial factors, postpone motherhood but not fatherhood. This implies that a woman’s life-course situation may be more crucial for the timing of the first birth than is that of a man. The association between educational level and timing of fertility is thought to reflect behavioral processes that are at least partly similar to those between educational level and having any children: educational differences in fertility in women are most pronounced in young adulthood and diminish with age (e.g., Andersson et al. 2009; Gustafsson 2001; Kravdal 2001). Although our findings may reflect true differences between these two fertility outcomes, they may also signal lack of statistical power for the fertility outcome of having any children, and thus, we hesitate to draw strong conclusions on this issue. All in all, the study’s behavioral genetics models suggest that factors shared by twins would play a role in the processes that underlie educational differences in fertility.

Genetic influences on fertility are likely to be contingent on the sociodemographic context (Kohler et al. 1999; Udry 1996), as are any familial influences in general (Billari and Philipov 2004). The most likely reason for this here is that institutional and normative contexts differ across time and place with respect to, for example, education, employment, childcare, and gender roles (Gauthier 1998; Oppenheimer and Lew 1995; Rindfuss et al. 1996, 2003). According to Udry (1996) and Kohler et al. (1999), genetic effects on fertility are most likely to appear in a normative climate that leaves room for individual decision-making. Characteristic of the Finnish birth cohort of this study is that it experienced an expansion of the national educational system and fertility postponement during its reproductive years (Andersson et al. 2009). Finland is a Nordic welfare state characterized by a high level of gender equality and comparatively generous state support for families with small children in the form of parental leave, subsidized daycare, and other economic incentives (Rønsen 2004). The share of women participating in the labor force is high, the dual-earner model is dominant, part-time work for women is uncommon, and the income effect of earnings in relation to opportunity costs is probably more important for women in Finland and other Nordic countries than elsewhere (Vikat 2004). Given the similarities in the direction of the associations found in this study to those found elsewhere, the results from this Finnish birth cohort may have implications beyond it. However, one can also speculate that in settings in which it is more difficult for women to combine family and working life than in Finland, with a higher mean educational level, the impact of education on fertility may be stronger irrespective of any familial influences.

Methodological Considerations

The strengths of this study include the twin study design as such, the high response rates in the surveys, and the exhaustive register information for practically completed fertility for women and for men. The original twin sample was not exactly representative of the general Finnish population with respect to fertility, but the final sample analyzed in this study corresponded well (Statistics Finland 2007:87–88). We also separately analyzed completed fertility using data including all subjects in the original sample with nonmissing information on education, and found that the educational distributions and associations between education and fertility were very similar to those derived from our final study population for both sexes (results not shown but available from the corresponding author).

Some concerns need to be mentioned, too. In terms of the behavioral genetic modeling part of the analyses, the assumptions behind the modeling are clearly strong. First, our model by default assumes no assortative mating by education (Neale and Cardon 1992:18–22). However, we know that this assumption is violated by the numerous studies showing evidence of such mating (e.g., Schwartz and Mare 2005). Still, this should, by default, make our results on the magnitude of the genetic contribution conservative: phenotypic assortment by education will push the genetic relatedness of DZ twins closer to that of MZ twins, and thus generate apparent common environmental variance if random mating is assumed. Second, the share of unique environmental variance in education in women remained modest, which may lead to underestimation of the causal association between education and having any children, independent of any shared genetic or common environmental factors.

A further critical point is the possibility of gene–environment interactions (Neale and Cardon 1992:22–23). Although we found no evidence that common environmental factors would have a role in terms of having any children, interaction effects between genetic predispositions and features of a social environment are indeed possible (e.g., Kohler et al. 1999; Miller 1994; Rodgers and Doughty 2000:86–90). Twins experience a special family environment in childhood: they always have at least one sibling of the same age. This may relate to their fertility desires (see Murphy and Knudsen 2002) and may also have affected resource allocation in their family of origin (see Booth and Kee 2009). Moreover, interaction effects between genotypes and environments in early adulthood and adult life may play a role in the associations between education and fertility (see, e.g., Tavares 2010; Udry 1996), and we suggest that this issue warrants further investigation.

Conclusions

The aim of this study was to contribute to the discussion on the causes of associations between education and fertility by analyzing associations between educational level and completed fertility in Finnish male and female twins. We examined whether genetic, common environmental, or unique environmental factors influenced educational differences in completed fertility. Men and women were found to have very different life-course outcomes: men with the lowest level of education and highly educated women were least likely to have children during their lifetime. For both sexes, however, the association between educational level and having any children appeared to be influenced by factors shared by twins of the same families. The analysis further suggests that genetic rather than common environmental influences were involved in the processes that produced associations between educational level and completed fertility. Factors shared by twins were also found important for the association between educational level and timing of first birth, but here, common environmental rather than genetic factors seem to be important, especially for men. For women, both common environmental and genetic factors contributed to the association between education and timing of first birth; evidence of a causal process between longer education and later timing of first birth was also found, independent of any factors shared by twins. In conclusion, familial factors seem to play a role for educational differences in completed fertility, at least in a birth cohort characterized by comparatively low level of education, modest educational differences in completed fertility, and living in a Nordic welfare state. Independent of shared genetic or common environmental effects, educational level does not appear to influence completed fertility in terms of having any children. Gender-sensitive empirical analyses of the familial determinants of educational differences in fertility appear to have the potential to inform fertility theories.

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References

Andersson, G., Rønsen, M., Knudsen, L. B., Lappegård, T., Neyer, G., Skrede, K., . . . Vikat, A. (2009). Cohort fertility patterns in the Nordic countries. *Demographic Research, 20*(article 14), 313–352. doi:10.4054/DemRes.2009.20.14

Becker, G. S. (1981). *A treatise on the family*. Cambridge, MA: Harvard University Press.
Becker, G. S., & Lewis, G. H. (1973). On the interaction between the quantity and quality of children. *Journal of Political Economy, 81,* 279–288.
Billari, F. C., & Philipov, D. (2004). *Education and the transition to motherhood: A comparative analysis of Western Europe* (European Demographic Research Paper 2004/3). Vienna: Vienna Institute of Demography, Austrian Academy of Sciences.
Blossfeld, H.-P., & Huinink, J. (1991). Human capital investments or norms of role transition? How woman's schooling and career affect the process of family formation. *American Journal of Sociology, 97,* 143–168.
Boomsma, D., Busjahn, A., & Peltonen, L. (2002). Classical twin studies and beyond. *Nature Reviews Genetics, 3,* 872–882.
Booth, A. L., & Kee, H. J. (2009). Birth order matters: The effect of family size and birth order on educational attainment. *Journal of Population Economics, 22,* 367–397.
Cohen, J. E., Kravdal, Ø., & Keilman, N. (2011). Childbearing impeded education more than education impeded childbearing among Norwegian women. *Proceedings of the National Academy of Sciences of the United States of America, 108,* 11830–11835.
Dearden, K. A., Hale, C. B., & Woolley, T. (1995). The antecedents of teen fatherhood: A retrospective case–control study of Great Britain youth. *American Journal of Public Health, 85,* 551–554.
Fieder, M., & Huber, S. (2007). The effects of sex and childlessness on the association between status and reproductive output in modern society. *Evolution and Human Behavior, 28,* 392–398.
Fu, H., & Goldman, N. (1996). Incorporating health into models of marriage choice: Demographic and sociological perspectives. *Journal of Marriage and the Family, 58,* 740–758.
Gauthier, A. H. (1998). *The state and the family: A comparative analysis of family policies in industrialized countries*. Oxford, UK: Clarendon Press.
Goodman, A., & Koupil, I. (2009). Social and biological determinants of reproductive success in Swedish males and females born 1915–1929. *Evolution and Human Behavior, 30,* 329–341.
Gustafsson, S. (2001). Optimal age at motherhood. Theoretical and empirical considerations on postponement of maternity in Europe. *Journal of Population Economics, 14,* 224–247.
Hagestad, G. O., & Call, V. R. (2007). Pathways to childlessness: A life course perspective. *Journal of Family Issues, 28,* 1338–1361.
Hakim, C. (2000). *Work-lifestyle choices in the 21st century. Preference theory*. New York: Oxford University Press.
Havén, H. (1999). *Education in Finland 1999. Statistics and indicators. SVT education 1999:4. Statistics Finland*. Helsinki, Finland: University Press.
Hoem, J. M. (1986). The impact of education on modern family-union initiation. *European Journal of Population, 2,* 113–133.
Hoem, J. M., Neyer, G., & Andersson, G. (2006a). The relationship between educational field, educational level, and childlessness among Swedish women born in 1955–59. *Demographic Research, 14*(article 15), 331–380. doi:10.4054/DemRes.2006.14.15
Hoem, J. M., Neyer, G., & Andersson, G. (2006b). Educational attainment and ultimate fertility among Swedish women born in 1955–59. *Demographic Research, 14*(article 16), 381–404. doi:10.4054/DemRes.2006.14.16
Hofferth, S. I., Reid, L., & Mott, F. L. (2001). The effects of early childbearing on schooling over time. *Family Planning Perspectives, 33,* 259–267.
Hoffman, S. D., Foster, E. M., & Furstenberg, F. F. (1993). Reevaluating the costs of teenage childbearing. *Demography, 30,* 1–13.
Hopcroft, R. L. (2006). Sex, status, and reproductive success in the contemporary United States. *Evolution and Human Behavior, 27,* 104–120.
Kaprio, J., & Koskenvuo, M. (2002). Genetic and environmental factors in complex diseases. The older Finnish twin cohort. *Twin Research, 5,* 358–365.
Kaprio, J., Koskenvuo, M., Artimo, M., Sarna, S., & Rantasalo, I. (1979). *Baseline characteristics of the Finnish Twin Registry. Materials, methods, representativeness, and results for variables special to twin studies* (Publications in Public Health M47). Helsinki, Finland: National Public Health Institutes in Helsinki, Kuopio, Oulu, Tampere and Turku.
Kartiovaara, L., & Säkkinen, S. (2007). Lasten muualla asuvat vanhemmat [The absent parents of children]. In *Suomalainen Lapsi* [The Finnish child] (pp. 109–127). Väestö 2007. Helsinki, Finland: Tilastokeskus & Stakes.
Keizer, R., Dykstra, P. A., & Jansen, M. D. (2008). Pathways into childlessness: Evidence of gendered life course dynamics. *Journal of Biosocial Science, 40,* 863–878.

Kiernan, K. E. (1989). Who remains childless? *Journal of Biosocial Science, 21,* 387–398.
Kiernan, K. E., & Diamond, I. (1983). The age at which childbearing starts—A longitudinal study. *Population Studies, 37,* 363–380.
Kohler, H.-P., Behrman, J. R., & Schnittker, J. (2010). *Social science methods for twin data: Integrating causality, endowments and heritability* (PSC Working Paper Series, 10-06). Philadelphia: University of Pennsylvania, Population Studies Center.
Kohler, H.-P., & Christensen, K. (2000). Genetic influences on fertility behavior: Findings from a Danish twin study, 1910–1923. In J. L. Rodgers, D. C. Rowe, & W. B. Miller (Eds.), *Genetic influences on fertility and sexuality. Theoretical and empirical contributions from the biological and behavioral sciences* (pp. 67–84). Norwell, MA: Kluwer Academic.
Kohler, H.-P., & Rodgers, J. L. (2003). Education, fertility, and heritability: Explaining a paradox. In K. W. Wachter & R. A. Bulatao (Eds.), *Offspring: Human fertility behavior in biodemographic perspective* (pp. 46–90). Washington, DC: The National Academies Press.
Kohler, H.-P., Rodgers, J. L., & Christensen, K. (1999). Is fertility behavior in our genes? Findings from a Danish twin study. *Population and Development Review, 25,* 253–288.
Kontula, O. (2008). The influence of education and family policies on age at first birth. In C. Höhn, D. Avramov, & I. E. Kotowska (Eds.), *People, population change and policies. Lessons from the Population Policy Acceptance Study. Volume 1: Family change* (pp. 259–75). Dordrecht, The Netherlands: Springer.
Koskenvuo, M., Sarna, S., Kaprio, J., & Lönnqvist, J. (1979). Cause-specific mortality by marital status and social class in Finland during 1969–1971. *Social Science & Medicine, 13,* 691–697.
Kravdal, Ø. (2001). The high fertility of college educated women in Norway. An artifact of the separate modelling of each parity transition. *Demographic Research, 5*(article 6), 187–216. doi:10.4054/DemRes.2001.5.6
Kravdal, Ø. (2007). Effects of current education on second- and third birth rates among Norwegian women and men born in 1964: Substantive interpretations and methodological issues. *Demographic Research, 17*(article 9), 211–246. doi:10.4054/DemRes.2007.17.9
Kravdal, Ø., & Rindfuss, R. R. (2008). Changing relationships between education and fertility: A study of women and men born 1940–1964. *American Sociological Review, 73,* 854–873.
Lappegård, T., & Rønsen, M. (2005). The multifaceted impact of education on entry into motherhood. *European Journal of Population, 21,* 31–49.
Lestaeghe, R. (1983). A century of demographic and cultural change in Western Europe: An exploration of underlying dimensions. *Population and Development Review, 9,* 411–435.
Liefbroer, A. C., & Corijn, M. (1999). Who, what, where, and when? Specifying the impact of educational attainment and labour force participation on family formation. *European Journal of Population, 15,* 45–75.
Martín-García, T., & Baizán, P. (2006). The impact of the type of education and of educational enrolment on first births. *European Sociological Review, 22,* 259–275.
McElroy, S. W. (1996). Early childbearing, high school completion, and college enrollment: Evidence from 1980 high school sophomores. *Economics of Education Review, 15,* 303–324.
Mealey, L., & Segal, N. L. (1993). Heritable and environmental variables affect reproduction-related behaviors but not ultimate reproductive success. *Personality and Individual Differences, 14,* 783–794.
Miller, W. B. (1992). Traits and developmental experiences as antecedents of childbearing motivation. *Demography, 29,* 265–285.
Miller, W. B. (1994). Childbearing motivations, desires, and intentions: A theoretical framework. *Genetic, Social and general Psychology Monologues, 120,* 223–253.
Miller, W. B., Bard, D. E., & Pasta, D. J. (2010). Biodemographic modeling of the links between fertility motivation and fertility outcomes in the NLSY79. *Demography, 47,* 393–414.
Monstad, K., Propper, C., & Salvanes, K. G. (2008). Education and fertility: Evidence from a natural experiment. *Scandinavian Journal of Economics, 110,* 827–852.
Morgan, S. P., & Rindfuss, R. R. (1999). Reexamining the link of early childbearing to marriage and to subsequent fertility. *Demography, 36,* 59–75.
Murphy, M., & Knudsen, L. B. (2002). The intergenerational transmission of fertility in contemporary Denmark: The effects of number of children (full and half), birth order, and whether male or female. *Population Studies, 56,* 235–248.
Neale, M. C. (2003). *Mx: Statistical modeling*. Richmond, VA: Department of Psychiatry.
Neale, M. C., & Cardon, L. R. (1992). *Methodology for genetic studies on twins and families*. Dordrecht, The Netherlands: Kluwer Academic.

Neale, M. C., Walters, E., Heath, A. D., Kessler, R. C., Pérusse, D., Eaves, L. J., & Kendler, K. S. (1994). Depression and parental bonding: Cause, consequence, or genetic covariance? *Genetic Epidemiology, 11,* 503–522.

Neiss, M., Rowe, D. C., & Rodgers, J. L. (2002). Does education mediate the relationship between IQ and age of first birth? A behavioural genetic analysis. *Journal of Biosocial Science, 34,* 259–275.

Nettle, D., & Pollet, T. V. (2008). Natural selection on male wealth in humans. *The American Naturalist, 172,* 658–666.

Nikander, T. (1995). *Suomalaismiehen perheellistyminen* [The family formation of a Finnish man]. SVT Väestö 1995:1. Helsinki, Finland: Tilastokeskus.

Oppenheimer, V. K. (1988). A theory of marriage timing. *American Journal of Sociology, 94,* 563–591.

Oppenheimer, V. K., & Lew, V. (1995). American marriage formation in the 1980s: How important was women's economic independence? In K. O. Mason & A. M. Jensen (Eds.), *Gender and family change in industrialized countries* (pp. 105–138). Oxford, UK: Clarendon Press.

Parr, N. J. (2005). Family background, schooling and childlessness in Australia. *Journal of Biosocial Science, 37,* 229–243.

Parr, N. J. (2009). Childlessness among men in Australia. *Population Research and Policy Review, 29,* 319–338.

Phillips, D. I., Handelsman, D. J., Eriksson, J. G., Forsén, T., Osmond, C., & Barker, D. J. (2001). Prenatal growth and subsequent marital status: Longitudinal study. *British Medical Journal, 322,* 771.

Pollak, R. A., & Watkins, S. C. (1993). Cultural and economic approaches to fertility: Proper marriage or mésalliance? *Population and Development Review, 19,* 467–496.

Retherford, R. D., & Sewell, W. H. (1989). How intelligence affects fertility. *Intelligence, 13,* 169–185.

Rijken, A. J., & Liefbroer, A. C. (2009). Influences of the family of origin on the timing and quantum of fertility in the Netherlands. *Population Studies, 63,* 79–81.

Rindfuss, R. R., & Bumpass, L. L. (1976). How old is too old? Age and the sociology of fertility. *Family Planning Perspectives, 8,* 226–230.

Rindfuss, R. R., Bumpass, L. L., & St. John, C. (1980). Education and fertility: Implications for the roles women occupy. *American Sociological Review, 45,* 431–447.

Rindfuss, R. R., Guzzo, K. B., & Morgan, S. P. (2003). The changing institutional context of low fertility. *Population Research and Policy Review, 22,* 411–438.

Rindfuss, R. R., Morgan, S. P., & Offutt, K. (1996). Education and the Changing Age Pattern of American Fertility: 1963-89. *Demography, 33,* 277–290.

Rodgers, J. L., Bard, D. E., & Miller, W. B. (2007). Multivariate Cholesky models of human female fertility patterns in the NLSY. *Behavioral Genetics, 37,* 345–361.

Rodgers, J. L., & Doughty, D. (2000). Genetic and environmental influences on fertility expectations and outcomes using NLSY kinship data. In J. L. Rodgers, D. C. Rowe, & W. B. Miller (Eds.), *Genetic influences on fertility and sexuality. Theoretical and empirical contributions from the biological and behavioral sciences* (pp. 85–106). Norwell, MA: Kluwer Academic.

Rodgers, J. L., Kohler, H.-P., Kyvik, O., Kirsten, K., & Christensen, K. (2001). Behavior genetic models of human fertility: Findings from a contemporary Danish twin study. *Demography, 38,* 29–42.

Rodgers, J. L., Kohler, H.-P., McGue, M., Behrman, J. R., Petersen, I., Bingley, P., & Christensen, K. (2008). Education and cognitive ability as direct, mediating, or spurious influences on female age at first birth: Behavior genetic models fit to Danish twin data. *American Journal of Sociology, 114*(Suppl. 1), 202–232.

Rønsen, M. (2004). Fertility and public policies—Evidence from Norway and Finland. *Demographic Research, 10*(article 6), 143–170. doi:10.4054/DemRes.2004.10.6

Rønsen, M., & Skrede, K. (2010). Can public policies sustain fertility in the Nordic countries? Lessons from the past and questions for the future. *Demographic Research, 22*(article 13), 321–346. doi:10.4054/DemRes.2010.22.13

Ruokolainen, A., & Notkola, I. L. (2007). Hedelmällisyys [Fertility]. In S. Koskinen, T. Martelin, I. L. Notkola, V. Notkola, K. Pitkänen, M. Jalovaara, . . . I. Söderling (Eds.), *Suomen Väestö* [The population of Finland] (pp. 77–114). Helsinki, Finland: Gaudeamus Helsinki University Press.

Sarna, S., Kaprio, J., Sistonen, P., & Koskenvuo, M. (1978). Diagnosis of twin zygosity by mailed questionnaire. *Human Heredity, 28,* 241–254.

Schwartz, C. R., & Mare, R. D. (2005). Trends in educational assortative marriage from 1940 to 2003. *Demography, 42,* 621–646.

Scott, J. (2004). Family, gender, and educational attainment in Britain: A longitudinal study. *Journal of Comparative Family Studies, 35,* 565–589.

Sigle-Rushton, W. (2005). Young fatherhood and subsequent disadvantage in the United Kingdom. *Journal of Marriage and Family, 67,* 735–753.

Silventoinen, K., Krueger, R. F., Bouchard, T. J., Jr., Kaprio, J., & McGue, M. (2004). Heritability of body height and educational attainment in an international context: Comparison of adult twins in Minnesota and Finland. *American Journal of Human Biology, 16,* 544–555.

Skirbekk, V. (2008). Fertility trends by social status. *Demographic Research, 18*(article 5), 145–179. doi:10.4054/DemRes.2008.18.5

Skirbekk, V., Kohler, H.-P., & Prskawetz, A. (2006). The marginal effect of school leaving age on demographic events. A contribution to the discussion on causality. In S. Gustafsson & A. Kalwij (Eds.), *Education and postponement of maternity. Economic analyses for industrialized countries* (pp. 65–85). Dordrecht, The Netherlands: Kluwer Academic.

StataCorp. (2007). *Stata statistical software: Release 10*. College Station, TX: StataCorp LP.

Statistics Finland. (2007). *Population structure and vital statistics by municipality 2006.* Official statistics of Finland OSF. Helsinki: Statistics Finland.

Tavares, L. (2010). *Who delays childbearing? The relationships between fertility, education and personality traits* (Dondena Working Paper 9). Milan, Italy: Dondena Center for Research on Social Dynamics.

Toulemon, L., & Lapierre-Adamcyk, É. (2000). Demographic patterns of motherhood and fatherhood in France. In C. Bledsoe, S. Lerner, & J. I. Guyer (Eds.), *Fertility and the male life-cycle in the era of fertility decline. International studies in demography* (pp. 325–336). New York: Oxford University Press.

Trumbetta, S. L., Markowitz, E. M., & Gottesman, I. I. (2007). Marriage and genetic variation across the lifespan: Not a steady relationship? *Behavioral Genetics, 37,* 362–375.

Udry, R. J. (1996). Biosocial models of low-fertility societies. *Population and Development Review, 22* (Suppl.), 325–336.

Upchurch, D. M., Lillard, L. A., & Panis, C. W. (2002). Nonmarital childbearing: Influences of education, marriage and fertility. *Demography, 39,* 311–329.

van de Kaa, D. J. (1996). Anchored narratives: The story and findings of half a century of research into the determinants of fertility. *Population Studies, 50,* 389–432.

Vikat, A. (2004). Women's labor force attachment and childbearing in Finland. *Demographic Research*, Special Collection 3(article 8), 177–212. doi:10.4054/DemRes.2004.S3.8

Weeden, J., Abrams, M. J., Green, M. C., & Sabini, J. (2006). Do higher-status people really have fewer children? Education, income, and fertility in the contemporary U.S. *Human Nature, 17,* 377–392.

Williams, R. (2000). A note on robust variance estimation for cluster-correlated data. *Biometrics, 56,* 645–646.

Woodward, L. J., Fergusson, D. M., & Horwood, L. J. (2006). Gender differences in the transition to early parenthood. *Development and Psychopathology, 18,* 275–294.