Effect of Paternal and Maternal Grandparents' Education on Children's Educational Attainment：The Case of Japan

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父方と母方の祖父母の学歴が子どもの教育達成に及ぼす影響
—日本の事例—

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Abstract： This study scrutinizes the differential effects of paternal and maternal grandparents' education on children's educational attainment using a novel method that combines structural equation modeling and multiple imputation of a representative dataset in Japan. Most of the previous three-generation mobility studies did not consider both lineages. Although a few studies analyzed four grandparents simultaneously, they covered only Western societies, and the results were mixed. Thus, it is worth examining East Asian societies such as Japan, which has a cultural difference in family systems from Western counterparts. Methodologically, we employed SEM with multiple imputation to overcome serious estimation biases in previous studies, which used OLS regressions to ignore missing information on grandparents' education. A representative Japanese dataset in 2006 with an analytical sample of 1,966 children showed that maternal grandparents' education directly affects children's educational attainment. This was robust even when education was measured by credentials instead of years of schooling or using another dataset. This paper makes a major contribution by highlighting the salience of maternal genealogy in multigenerational mobility by the simultaneous estimation of paternal and maternal grandparents. The difference between the findings of this study, which used Japanese data, and those of the previous studies, which were located in Western societies, might be attributed to cultural differences in family systems. The methodological contribution of this study is that while the previous studies omitted missing values, possibly leading to biased results, we introduced SEM with multiple imputation to realize less-biased estimation in the three-generation mobility studies.
Keywords： multigenerational mobility, grandparents, multiple imputation, education, Japan

要旨：この研究の目的は，親の学歴の影響を考慮したうえで，父方母方祖父母四人のうち誰の学歴が孫の教育達成に影響を及ぼすのかを明らかにすることである．これまでの階層再生産研究では，親世代と子ども世代の地位の関連を推定する二世代間の階層再生産研究が中心であった．近年では，家族に起因する不平等の継続性を明らかにするために，親にも親がいることを考慮した，祖父母世代をも含めた三世代間階層再生産研究が増えている．しかし，これまでの三世代間階層再生産研究のほとんどは，父方母方の祖父祖母の違いを考慮して分析していなかった．ただし，四人の祖父母を同時に分析モデルに含め祖父母の学歴が孫の教育達成に及ぼす影響を推定している研究も少なからず存在する．しかし，これらの研究の多くは米国などの西洋圏を対象としてきており，どの祖父母が影響を及ぼすのかについて，結果はまちまちであった．また，西洋圏の社会とは，家族制度や，文化的な違いがある社会では，どのようになっているかはあまり明らかになっていない．そこで，本研究では，西洋圏の社会とは異なる可能性がある東アジア圏に位置する日本社会を対象とし，父方母方祖父母四人の学歴を考慮したうえで，三世代間の学歴再生産研究をおこなう．使用するデータセットは，2006年に調査が実施された「世帯内分配・世代間移転に関する調査」である．この調査は，調査対象者にたいして，その親と子どもの情報を尋ねている．三世代間階層研究のためには，子どもを分析単位とする必要があるので，データセットを再構成した．結果として，分析サンプルは，1,966ケースとなった．分析には，構造方程式モデリングをもちいた．また，祖父母の学歴についての欠測が多いため，欠測を補完する多重代入法をもちいた．分析の結果として，親の学歴を考慮してもなお，母方祖父の学歴が孫の教育達成に直接，正の影響があることが明らかとなった．本研究の貢献は二つある．第一に，父方と母方の祖父母四人を同時にモデルに組み込み，三世代間における系譜を考慮し，母方祖父の重要性を明らかにしたことである．第二に，東アジア圏に位置する日本社会を対象としたことである．西洋社会を対象とした先行研究の結果とは異なった結果が得られたが，これは，家族制度の文化的な違いに起因する可能性がある．
キーワード：多世代間階層再生産，祖父母，多重代入法，学歴，日本

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1. Introduction

Although the literature on three-generational mobility has developed since Mare's epoch-making work (Mare, 2011), most studies have analyzed the effect of either paternal or maternal grandparents, mainly due to the limitation of datasets. They either analyzed only paternal grandparents (Hertel & Groh-Samberg, 2014 ; Knigge, 2016), focused on one grandparent with the highest education out of all four (Ziefle, 2016), or separately estimated the effects of paternal and maternal grandparents within a dataset (Celhay & Gallegos, 2015 ; Chiang & Park, 2015). However, a simultaneous estimation of the effects of both paternal and maternal grandparents is essential because maternal grandparents are more likely to communicate with their grandchildren than their paternal counterparts (Danielsbacka & Tanskanen, 2012 ; Eisenberg, 1988). Therefore, the associations between grandparents and grandchildren cannot be properly assessed without analyzing both lineages simultaneously (Sheppard & Monden, 2018).

A few studies have analyzed all four grandparents simultaneously. Ferrie et al. (2021) analyzed census data in the US to report a significant effect of only paternal male grandparents on male grandchildren. On the other hand, Warren and Hauser (1997) examined data from the US to find no significant effect of grandparents. Neidhöfer and Stockhausen (2019) reached the same conclusion using data from the US, the UK, and Germany. Since these studies employed data from Euro-American societies, it is worth examining East Asian societies such as Japan, which has a cultural difference in family systems.

Regarding analytical strategies, Warren and Hauser (1997) employed both OLS regression and structural equation modeling, whereas Ferrie et al. (2021) and Neidhöfer and Stockhausen (2019) used only regressions with cluster-robust standard errors. Regressions examining the direct effects of grandparents while controlling for parents might underestimate the former because some of the effects of the grandparents may be misattributed to parents (Hallsten & Pfeffer, 2017). A major challenge in this subject is the occurrence of missing values, or partially complete data. Warren and Hauser (1997) approached this issue by eliminating all such cases, risking a biased estimation. Thus, this study analyzes a Japanese dataset by structural equation modeling with multiple imputation to estimate the effects of paternal and maternal grandparents simultaneously.

This simultaneous estimation is better carried out by measuring status at the individual level instead of the household level. For this reason, this study takes educational attainment as a measure. There has been a continuing debate regarding a proper measure of social status, mainly between a household model, focusing on the occupation of a male breadwinner (Goldthorpe, 1983) or the highest earner of either sex (Erikson, 1984), and an individual model (Stanworth, 1984). In the context of two-generational mobility, the household model might be an adequate measure of status since it involves pooling earnings for child-rearing under the sexual division of labor. However, in the context of multigenerational mobility, a household model might overlook characteristics passed down over generations, such as genetic traits (Mare, 2011). In this regard, educational attainment, which is an outcome of learning ability as well as a cause of occupation and income, is the most appropriate measure.

This study scrutinizes the differential effects of paternal and maternal grandparents' education on children's educational attainment using a novel method that combines structural equation modeling and multiple imputation of a representative dataset in Japan.

2. Previous research

2.1. Previous research on three-generational mobility

Previous studies on three-generational mobility have both confirmed the effects of grandparents on children and also found no such effects. These variations in findings are caused by time, place, particular institutional arrangements, samples, and populations participating (Mare, 2011). For instance, previous studies conducted in the United States (US) (Olivetti, Paserman, & Salisbury, 2018 ; Ferrie et al., 2019 ; Warren & Hauser, 1997 ; Jæger, 2012) showed different findings, caused by the difference in time and size of the target area. Olivetti et al. (2018) found grandparent effects by analyzing the Decennial Censuses of the United States for the period 1850-1940. Similarly, Ferrie et al. (2021) found grandparent effects by analyzing the US using linked data spanning 1940-2015. In contrast, Warren and Hauser (1997) and Jæger (2012), who found no grandparent effects, analyzed the Wisconsin Longitudinal Study, which covers a narrower area than the census, and the respondents were born around 1939. Different results were also found in the Sweden (Helgertz & Dribe, 2021 ; Stuhler, 2014 ; Hällsten & Pfeffer, 2017), and the Netherlands (Knigge, 2016 ; Bol & Kalmijn, 2016). Moreover, grandparent effects were found in Taiwan (Chiang & Park, 2015), Japan (Aramaki, 2012), China (Cao & Li, 2019 ; Zeng & Xi, 2014), the United Kingdom (UK) (Zhang, 2017), Chile (Celhay & Gallegos, 2015), Finland (Erola & Moisio, 2007), Philippines (Quisumbing, 1997), and Germany (Braun & Stuhler, 2018), whereas no grandparent effects were found in Turkey (Aydemir & Yazici, 2019), with using harmonized household survey data in Germany, the UK and the US (Neidhöfer & Stockhausen, 2019). In addition, a study by Colagrossi et al. (2020) on 28 European Union countries found mixed results.

Moreover, previous studies have found inconsistent results regarding paternal and maternal grandparent effects. These differences stemmed from particular institutional arrangements. In the US, previous studies that simultaneously analyzed paternal and maternal grandparents found different findings. Warren and Hauser (1997) found no effect of grandparents' education on children's education and occupation. However, Olivetti et al., (2018) found effect of paternal grandfather's income on the grandson, and maternal grandfather's income on the granddaughter. Ferrie et al., (2019) found effect of paternal grandfather on grandson's educational attainment. Furthermore, Cao and Li (2019) studied Chinese educational attainment by adding up the grandparents' years of schooling, and found that paternal grandparent education affected children's educational attainment more strongly than maternal education. In the UK, maternal grandparents' socioeconomic class affected children's class (Zhang, 2017). In Sweden, Helgertz and Dribe (2021) used an occupation and income measure, and found that paternal and maternal grandfathers affected positively children. However, Stuhler (2014) found no effects of four grandparent on children' education. Further, Neidhöfer and Stockhausen (2019) found no effect of the education of four grandparents on children's educational attainment, using data from the US, the UK, and Germany.

These differences were also caused because of employing different measures. For instance, in the Philippines, Quisumbing (1997) found that maternal grandmother's education, paternal grandmother's owned land, and maternal grandfather's owned land positively affected children's educational attainment.[1] In the UK, Moulton et al. (2017) mentioned the effects of paternal grandmother out of four grandparents on children's class aspirations. Moreover, a previous study using data from Australia found that paternal grandfathers having university qualification increased numeracy among 8-9-year-old children, and paternal and maternal grandmothers with university qualification improved reading among this population (Hancock et al., 2016). As Hancock et al. (2016) stated, grandparents transfer human capital to their grandchildren.

When we summarized previous studies that simultaneously analyzed both lineages, we found that there were effects of each grandparent on their children, resulting in inconsistent findings. Hence, when analyzing the impact of lineages, we considered the characteristics of the subject country. Previous studies using class, income, and capital as measures found the paternal and maternal grandfathers' impact, but some studies found the grandmothers' capital effect. Moreover, previous studies using ability and aspiration as measures also found the grandmothers' impact. As Hancock et al. (2016) mentioned, grandparents transfer human capital to children through the relationship between grandparents and children (Bengtson 2001). According to similar family sociology results, maternal grandparents invest more in children than paternal grandparents (Coall & Hertwig, 2010 ; Danielsbacka & Tanskanen, 2012), and the maternal grandmother has the closest relationship among the four grandparents (Eisenberg, 1988). In short, in each country, there was a difference in the way each grandparent affected children. Therefore, we should consider the country's historical background, as Olivetti et al. (2018) rejected the inheritance advantage of a paternal family in the U.S. at that time, using a timespan of data, statistical comparison, and a consideration of the legal system.

2.2. Japanese context

The Japanese literature on three generational mobilities discovered both direct grandparents' effects and cumulative effects. Yasuda (1971) found a direct effect of paternal grandparents on sons in an occupational class by analyzing only the paternal grandfathers, fathers, and sons. Moreover, using Social Stratification and Social Mobility (SSM) in 1955 and 1985, Kataoka (1990) found a cumulative effect of a relatively lower education and higher education in SSM 1955 and a relatively lower education in SSM 1985, when only paternal grandfather, father, and son were examined. Kataoka (1990) also found a direct effect of paternal grandfathers on grandsons, while the grandparents effect weakened over time. Aramaki (2012) found the cumulative effects of both grandparents and parents having relatively higher education, using National Family Research of Japan 2008. In addition, Aramaki (2012) noted the effect that maternal grandfathers have on their daughters' educational achievement, when only maternal grandparents, father, mother and daughter were examined. Furthermore, Aramaki (2019) found the impact of grandparents on children using data from Survey of Education, Social Stratification, and Social Mobility in Japan, 2013.

Japan had a unique family system known as "ie seido," which is an inheritance system based on a stem family with a patrilineal focus. Therefore, paternal grandfathers may have an impact on children. "Ie seido" existed until the postwar period and was characterized by features like patriarchy, with the oldest son inheriting the family name, property, and authority (Banzai, 1999). At that time, the Japanese family was a stem family, which included paternal grandparents who lived together with the successor's family for procreation (Morioka, 1993). Moreover, "ie seido" was abolished after the war and existed as the underlying nature of the modern Japanese family, and had a significant influence on the internal aspects of the present Japanese family system (Kuma-

[1] Quisumbing (1997) found that maternal grandfathers' education negatively affected children's educational attainment. Negative grandparent effects were also founded by Chiang and Park (2015).

gai, 1986). Because "ie seido" had existed earlier, previous studies found the paternal grandparent's effect, whereas Yasuda (1971) stated that when the grandfather's social class affected the children and the social class represented the grandfather's material and spiritual heritage, we should consider the paternal grandparent's effect fostered by the material inheritance system with a patrilineal focus.

Hypothesis 1. Paternal grandparents' educational background affected the children's educational achievement.

However, because previous studies have recently emphasized not only the paternal but also the maternal grandparents' relationships with children, the maternal grandparents may also have an impact on the children. As mentioned earlier, family sociology highlights the maternal grandparents' relationship with children. Moreover, previous studies (Knigge, 2016 ; Zeng & Xi, 2014 ; Bengtson, 2001) on multigenerational mobility often mentioned a capital transfer to children as a result of the interaction with children. In Japan, recent studies have mentioned the increasing contact and assistance of maternal grandparents (Liping, 2008 ; Shirahase, 2005). In addition, Yasuda (2018) mentioned that maternal grandparents provide more economic, upbringing, and emotional assistance than paternal grandparents during the children's childhood and in the pubescent stage. Therefore, maternal grandparents' education may affect their children's educational achievement. In fact, Aramaki (2012) noted the effect that maternal grandfathers have on their daughters' educational achievement.

Hypothesis 2. Maternal grandparents educational background affected the children's educational achievement.

3. Data and methods

3.1. Data

We used Japanese data from the Survey on Intrahousehold Sharing and Intergenerational Transfer, 2006 (SISIT) conducted by the Institute for Research on Household Economics. A nationwide, two-stage random sample of N=2,814 was recruited from married women aged 30-59. The SISIT asked the respondents ; their spouses, fathers, and mothers ; the spouses' fathers, and mothers ; and respondents' first to third children about their educational background. We used these variables as well as the sex, birth year, number of siblings, and birth order of children in the analysis. We created a dataset that is an analytical unit for the respondents' children aged ≥22.[2] Moreover, we omitted cases not listing the sex of children. Finally, we used the analytical dataset's sample of N=1,966.

3.2. Variables

We used children's years of schooling as "first children : educational background," "second children : educational background," and "third children : educational background" as dependent variables. We defined "lower secondary" as "9 years," "upper secondary," "crammer,"[3] and "vocational school" as "12 years," "junior college/ technical college" as "14 years," and "university/graduated" as "16 years."

We used the years of schooling of respondents ; their spouses, fathers, and mothers ; and the spouses' fathers and mothers as independent variables. We defined "not entered school" as "0 year," "1-3 grade of elementary school" as "3 years," "4-6 grades of elementary school" as "6 years," "lower secondary" as "9 years," "upper secondary," "crammer," and "vocational school" as "12 years," "junior college/technical college" as "14 years," and "university/graduated" as "16 years."

Moreover, we used sex, birth year, number of siblings, and birth order of children as controlling variables. We defined female as 0, and male as 1 for the sex of children, birth year from 1966 to 1984, number of siblings as 1 to 8, and birth order as 1 to 3.

3.3. Analytical method

Because linage is complicated, we used path analysis as a structural equation model (SEM) with only observed variables. Path analysis was used in previous studies on the effect of paternal and maternal grandparents' occupation on grandchildren's education and occupation (Zhang, 2017), and the effect of paternal and maternal grandparents' class on grandchildren's class aspirations (Moulton et al., 2017). Moreover, SEM was used in previous studies regarding the effect of four grandparents on grandchildren's occupational status (Warren & Hauser, 1997), and the effect of grandparents' socioeconomic

[2] Takahashi and Watanabe (2017) mentioned that if the imputation model did not include the dependent variable, results might be distorted. Young and Johnson (2010) pointed out the dependent variable should be included in the imputation model. We omitted cases that had no children aged ≥22, and we included cases that included children aged ≥22 but were missing children's educational background.

[3] Crammer schools are supplementary educational institutions that prepare students for university entrance examinations. Some upper secondary school students attend crammer schools to increase their chances of passing exams for their desired universities while still enrolling in upper secondary school. If some individuals fail these exams, they often enroll in crammer schools after graduating from upper secondary school. In these schools, students spend one or more years preparing to retake examinations.

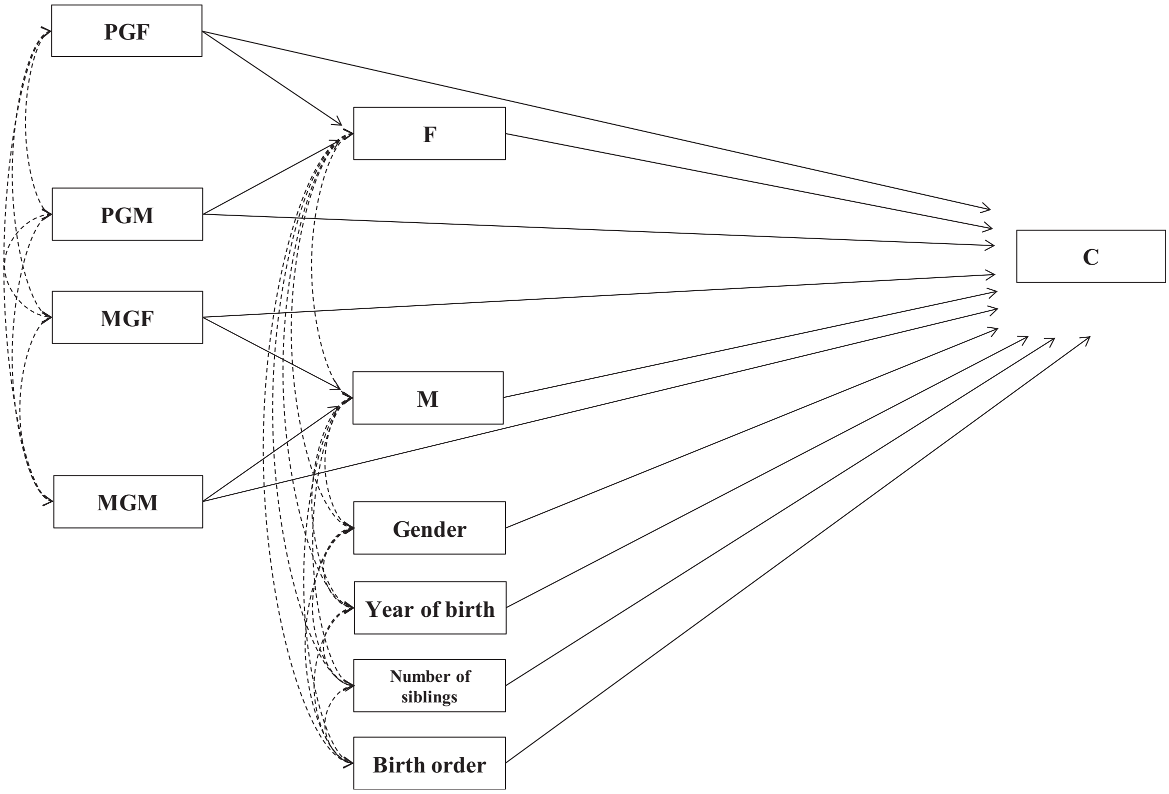

Fig. 1. Design of path model, *Note* : PG : paternal grandparent, MG : maternal grandparent, F : father, M : mother, C : children. The Dash lines represent a correlation. The solid lines represent causation.

Table 1
Descriptive statistics

	N	Mean	S.E.	Missing rate	Range
Grandparent's years of schooling					
Paternal grandfather	312	10.40	2.70	84.13%	6-16
Paternal grandmother	635	9.69	2.35	67.70%	0-16
Maternal grandfather	434	10.67	2.52	77.92%	0-16
Maternal grandmother	817	10.00	2.40	58.44%	0-16
Parent's years of schooling					
Father	1,859	13.06	2.24	5.44%	9-16
Mother	1,863	12.35	1.42	5.24%	9-16
Children					
Children's years of schooling	1,872	13.86	1.94	4.78%	9-16
Gender of children (males = 1)	1,966	0.51	0.50	0.00%	0-1
Year of birth	1,966	1978.37	3.96	0.00%	1966-1984
Number of siblings	1,910	2.51	0.77	2.85%	1-8

status on grandchildren's reading and math scores (Grant, 2005). Furthermore, Mare (2011) pointed out that the effects of parents and ancestors might differ. In short, we used path analysis as SEM to analyse the effect of paternal and maternal grandparents on grandchildren, because of the complicated causal structure.

The path analysis model is shown in Fig. 1. The solid line represents the causation. The dashed line represents the correlation. We assumed the effect of parents' years of schooling, grandparents' years of schooling, children's sex, birth year, number of siblings, and birth order on children's years of schooling. We assumed the effect of paternal grandparents' years of schooling on the father's years of schooling. We assumed the effect of maternal grandparents' years of schooling on the mother's years of schooling. Finally, we assumed correlation between the following variables : parent's years of schooling, children's sex, birth year, number of siblings, and birth order.

Moreover, we did not employ a multilevel model despite this dataset having a hierarchical structure with several children in a household (i.e., respondents' level). This is because the average cases in level 1 (= siblings) was 1.88, and the design effect, which indicates a multilevel model need not be adopted if it is ＜2, was 1.39 (Mass & Hox, 2002) ; although the intraclass correlation was 0.44.

However, since this dataset had many missing values, we filled them using multiple imputation (MI) (Rubin, 1987).[4] Only 74 cases were included. The missing values for each variable ranged from 4.78% to 84.13% (Table 1). Most of the missing information was that of the deceased grandparents. Deceased grandparents' cases have biases, as mentioned by Mare (2011). Recall bias (Mare, 2011) is also a source of missing information. In addition, we used the mice 3.13.0 package (Van Buuren & Groothuis-Oudshoorn, 2011) of the statistical software R, with seed=1 and the number of imputations, M =1,000.[5] To assume missing data at random, we used auxiliary variables, such as parents' age and occupation.[6]

Moreover, we conducted a robustness check and complete case analysis. In robustness check, we changed the year of schooling into four categories[7] that were 0-9 years as "lower secondary,". 12 years as "upper secondary," 14 years as "junior college/ technical college," and 16 years as "university or more." In addition, we confirmed the same results when using another representative Japanese dataset, National Family Research of Japan 2003, which was conducted in 2004. A nationwide, two-stage stratified random sample of N=6,302 was recruited from men and women aged 28-77.[8] Finally, to compare the results obtained with MI, we conducted a complete case analysis that used list-wise omitting the cases with missing values.

4. Results

4.1. Descriptive statistics

Younger generations had a higher mean number of years of schooling (Table 1). In each generation, men had a higher mean number of years of education than women. Since the number of years of schooling for the grandparent generation was around 10 years, there was a line of separation between lower secondary (degree of 9 years) and upper secondary (degree of 12 years) levels of education. The mean number of years of schooling for fathers was 13.06 years, while for mothers, it was 12.35 years. Since the number of schooling years for the parent generation was >12 years, there was a line of separation between the upper secondary (degree of 12 years) and tertiary (degree of over 14 years) levels of education. As the mean number of schooling years for children was 13.86 years, there was the border of whether going on to higher education between upper secondary (degree of 12 years) and tertiary (degree of over 14 years) ; it has higher years of schooling than the first and parent generations. In short, since there was a difference between the grandparent, parent, and children's generations with regard to higher education, the comparative worth of educational background might differ in each generation.

We used variables, such as sex, year of birth, number of siblings, and birth order. Since we used 1 for men and 0 for women,[9] with the mean being 0.51, the sex ratio was almost the same. The birth years ranged from 1966 to 1984. The mean of the year of birth was 1978.37. When we convert years into age, the range is 28-40, and the mean is about 28, as there were many young age cases. The number of siblings ranged between 1 and 8. The mean number of siblings was 2.51. The birth order was 1-3. The mean birth order was 1.58.

4.2. SEM results

The analysis revealed significant effects of pater-

[4] Because it is easier to incorporate auxiliary variable into the model (Graham et al., 2007), and maximum likelihood and MI will always yield highly similar results when the input data and models are the same, and the number of imputations, M, being sufficiently large (Collins, Schafer, & Kam, 2001), we did not employ the full information maximum likelihood, but MI.

[5] Hershberger and Fisher (2003) mentioned if standard normal deviate is 2.58, and amount of error is 0.1, a total of 885.30 imputations are required. Graham et al. (2007) mentioned MI should use many more imputations than previously recommended. Bonder (2008) mentioned that if the fraction of missing information equals 0.7, the necessary number of imputations is 114, and if the fraction of missing information equals 0.9, the necessary number of imputations is 258. In contrast, Takahashi and Ito (2014) pointed out that if the missing rate is more or less, we get the same number of imputations, that is, 100 or more. However, because previous studies pointed out that the greater the number of imputations, the better, we set the number of imputations to 1,000.

[6] We used auxiliary variables that were respondent's year of birth, occupation, employment status, annual income, number of living siblings, residence status, parents and spouse's parents frequency of conversation (There is option that is whether having passed away) and living together (There is option that is whether having passed away), spouse's year of birth, occupation, employment status, annual income and number of alive siblings, parents and spouse's parents year of birth, parents occupation when the respondent was 15 years old, educational aspiration of children, and city size.

[7] SEM need numerical variables to an endogenous variable to assume normal distribution. However, if the number of categories was 4 to 5, and category have ordered, we could conduct SEM with categorical variables (Toyoda 2014 ; Johnson & Creech, 1983).

[8] We used the years of schooling of respondents, their children, spouses, fathers, and mothers, and the spouses' fathers, and mothers, as dependent variables. We defined "not entered school" as "0 year," "lower secondary" as "9 years," "upper secondary," and "vocational school" as "12 years," "junior college/ technical college" as "14 years," "university" as "16 years," and "graduated" as "18 years." All deceased grandparents educational background is missing. Descriptive statistics is presented in Table A 1 in the Appendix. We used sex, birth year, number of siblings, and birth order of children as controlling variables. We defined female as 0 and male as 1 for sex of children, birth years as 1944−1981, number of siblings as 1−7, and the birth order as 1−3. We used auxiliary variables that were the respondent's year of birth, occupation, employment status, number of living siblings, residence status, parents and spouse's parent's frequency of conversation and living together, spouse's year of birth, occupation, and employment status, parents and spouse's parent's year of birth, household annual income, and city size.

[9] SEM can be conducted with binary variable if binary variable is exogenous (Toyoda 2014).

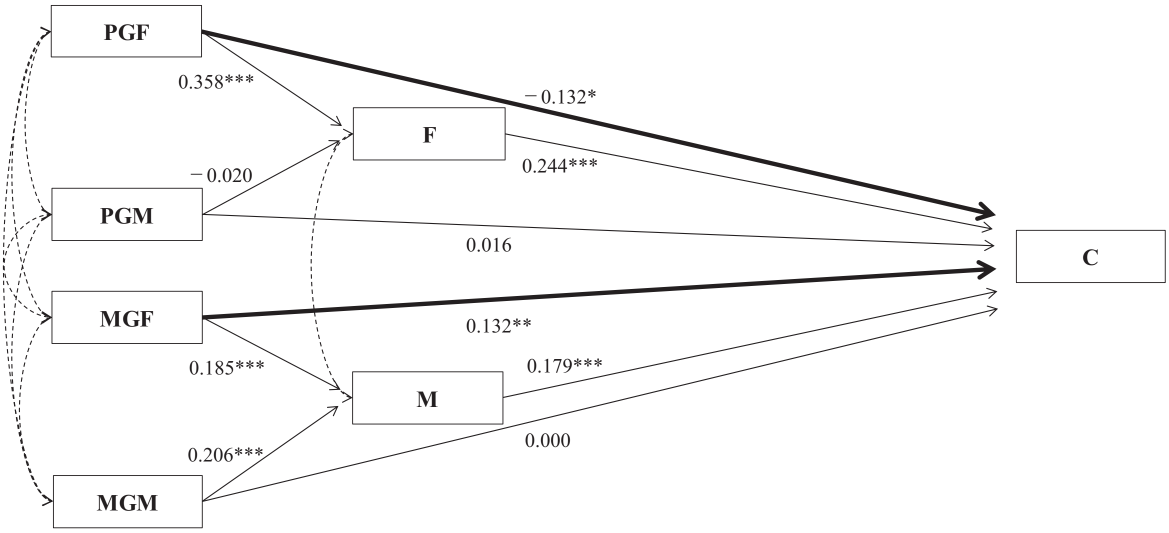

Fig. 2. Result of SEM using SISIT, *Note* : N=1,966, CFI=0.969, RMSEA=0.033, SRMR=0.054. *p<0.05, **p <0.01, ***p<0.001. PG : paternal grandparent, MG : maternal grandparent, F : father, M : mother, C : children.The Dash lines represent a correlation.The solid lines represent causation.The bold solid lines represent significant effects of grandparents' education.The figure does not show controlling variables such as sex, year of birth, number of siblings, and birth order.

nal and maternal grandfathers' education on children (Fig. 2, Table 2). Specifically, the coefficient of paternal grandfather's years of schooling was −0.13, which was significant at $p=0.05$. The maternal grandfather's coefficient was 0.13, at a significance level of $p=0.01$. These effects remained even after controlling for the direct and indirect effects of the educational background of the father, mother, and paternal and maternal grandmother.[10]

For model fitness (Table 3), Comparative fit index (CFI) = 0.969, Root mean square error of approximation (RMSEA) = 0.033, and Standardized root mean squared residual (SRMR) = 0.056, indicated a sufficient goodness of fit. Notably, a good SEM model requires a CFI of ≥0.95, SRMR ≤0.08 (Hu & Bentler, 1999), and RMSEA ≤0.05 (Browne & Cudeck, 1992).

4.3. Robustness check

4.3.1. Converting education years into categories.

For a robustness check (Fig. 3), the maternal grandfather's positive effect remained significant, even when the years of schooling were substituted by four categories of educational attainment : primary, secondary, short-term tertiary, and tertiary. However, the effect of the paternal grandfather was not significant in this setting. For model fitness (Table 3), CFI = 0.982, RMSEA = 0.026, and SRMR = 0.049, indicated a sufficient goodness of fit.

4.3.2. Using other data.

Furthermore, the positive effect of the maternal grandfather was confirmed using another Japanese representative dataset, National Family Research of Japan 2003. The effect of the paternal grandfather, however, was not significant in this setting (Fig. 4). For model fitness (Table 3), CFI = 0.913, RMSEA = 0.033, and SRMR = 0.083 values indicated sufficient goodness of fit only for RMSEA.

4.3.3 Complete case analysis

No grandparents affected grandchildren's years of schooling when we analyzed the cases omitting missing values listwise. The coefficient of paternal grandfather's years of schooling was -0.266, which was not significant at $p=0.1$ (Fig. 5). Moreover, the coefficient of maternal grandfather's years of schooling was -0.022, which was not significant at $p=0.1$. The father's years of schooling only affected the children's years of schooling.

The cases omitting missing values have significant bias because the sample size used in the complete case analysis was 74. Much bias seems to be caused by the fact that respondents were married women, because maternal grandparents' years of schooling had a higher missing rate than paternal grandparents. This is because respondents did not know their parents' educational background, or poor communication with their spouse's parents compared to the respondent's parent caused recall bias, as mentioned by Mare (2011). Moreover, in the complete case analysis, even though some grandparents' years of

[10] We get almost the same result according to which the maternal grandfather's coefficient was at a significance level of p=0.05, with full information maximum likelihood using auxiliary variable (Appendix Table A 2).

Table 2
Results of SEM

	SISIT			SISIT(4 categories)		
	Estimate		S.E.	Estimate		S.E.
On children's years of schooling						
Father's years of schooling	0.244	***	0.043	0.227	***	0.041
Mother's years of schooling	0.179	***	0.042	0.186	***	0.040
Paternal grandfather's years of schooling	−0.132	*	0.052	−0.062		0.052
Paternal grandmother's years of schooling	0.016		0.056	−0.025		0.053
Maternal grandfather's years of schooling	0.132	**	0.048	0.094	*	0.047
Maternal grandmother's years of schooling	0.000		0.054	0.006		0.048
Children's gender	0.020		0.036	0.032		0.034
Children's year of birth	0.055		0.038	0.048		0.036
Children's birth order	−0.021		0.039	−0.019		0.037
Children's number of siblings	−0.068	†	0.041	−0.067	†	0.037
On father's years of schooling						
Paternal grandfather's years of schooling	0.358	***	0.041	0.344	***	0.047
Paternal grandmother's years of schooling	−0.020		0.044	0.061		0.046
On mother's years of schooling						
Maternal grandfather's years of schooling	0.185	***	0.041	0.214	***	0.045
Maternal grandmother's years of schooling	0.206	***	0.043	0.208	***	0.046
Covariances						
Father's years of schooling with						
Mother's years of schooling	0.331	***	0.036	0.334	***	0.033
Children's year of birth	0.075	*	0.036	0.089	**	0.034
Children's number of siblings	−0.017		0.036	−0.003		0.034
Children's birth order	−0.020		0.036	−0.022		0.034
Children's gender	0.053		0.036	0.043		0.034
Mother's years of schooling with						
Children's year of birth	0.160	***	0.035	0.166	***	0.033
Children's number of siblings	−0.033		0.038	−0.018		0.033
Children's birth order	−0.036		0.036	−0.038		0.033
Children's gender	0.007		0.036	0.004		0.033
Paternal grandfather's years of schooling with						
Paternal grandmother's years of schooling	0.682	***	0.045	0.626	***	0.053
Maternal grandfather's years of schooling	0.485	***	0.046	0.358	***	0.045
Maternal grandmother's years of schooling	0.409	***	0.043	0.328	***	0.043
Paternal grandmother's years of schooling with						
Maternal grandfather's years of schooling	0.424	***	0.045	0.433	***	0.047
Maternal grandmother's years of schooling	0.626	***	0.050	0.486	***	0.048
Maternal grandfather's years of schooling with						
Maternal grandmother's years of schooling	0.709	***	0.052	0.617	***	0.051
Children's birth order with						
Children's number of siblings	0.269	***	0.041	0.269	***	0.038
Children's year of birth with						
Children's number of siblings	0.060		0.039	0.060	†	0.036
Children's birth order	0.222	***	0.037	0.222	***	0.035
Children's gender with						
Children's year of birth	0.010		0.040	0.010		0.037
Children's number of siblings	−0.031		0.040	−0.031		0.037
Children's birth order	−0.040		0.039	−0.040		0.037
Observations	1,966			1,966		

Note : †<0.1, *p<0.05, **p<0.01, ***p<0.001 (two-tailed tests).

NFRJ			SISIT(complete case)		
Estimate		S.E.	Estimate		S.E.
0.278	***	0.037	0.393	***	0.100
0.176	***	0.038	−0.084		0.143
−0.064		0.044	−0.266		0.167
0.059		0.045	0.267	†	0.156
0.086	*	0.044	−0.022		0.121
−0.016		0.043	0.062		0.136
0.125	***	0.030	−0.100		0.112
−0.066	*	0.033	0.109		0.124
−0.006		0.033	0.035		0.152
−0.090	**	0.032	0.088		0.095
0.233	***	0.040	0.211		0.132
−0.025		0.040	−0.095		0.119
0.254	***	0.037	0.171	†	0.103
−0.027		0.036	0.401	**	0.147
0.453	***	0.031	0.291	***	0.074
0.250	***	0.030	−0.077		0.092
−0.024		0.033	−0.024		0.128
−0.034		0.031	0.091		0.104
0.011		0.031	0.176	†	0.107
0.339	***	0.031	0.030		0.071
−0.013		0.033	−0.027		0.087
−0.048		0.032	0.063		0.079
−0.004		0.031	−0.042		0.086
1.116	***	0.108	0.416	***	0.094
0.459	***	0.070	0.362	**	0.123
0.599	***	0.083	0.327	***	0.095
0.480	***	0.072	0.296	*	0.125
0.604	***	0.087	0.448	**	0.105
0.916	***	0.099	0.622	***	0.113
0.352	***	0.036	0.381	*	0.177
−0.043		0.038	−0.087		0.130
0.110	***	0.033	0.135	†	0.082
0.007		0.033	−0.101		0.097
−0.019		0.033	0.120		0.148
0.003		0.033	0.138		0.113
6,162			74		

schooling were missing, those cases were omitted. Most of deceased grandparents was the missing information. However, the cases wherein grandparents had passed away did not respond to grandparent information. This also resulted in a smaller sample size.

5. Discussion

Table 4 summarizes the results of the analysis, which indicates that hypothesis 2 was supported.

Answering the research question. In Japan, maternal grandfather's education affects children's education and controls parents' education.

This study makes a major contribution by highlighting the importance of maternal genealogy in multigenerational mobility through the simultaneous estimation of both paternal and maternal grandparents. Although some previous studies examined paternal and maternal grandfathers separately Olivetti, Paserman, & Salisbury, 2018 ; Helgertz & Dribe 2021 ; Zhang, 2017), a few studies (Ferrie et al., 2021 ; Warren & Hauser, 1997 ; Neidhöfer & Stockhausen, 2019) analyzed all four grandparents. Studying the independent impact of grandfathers and grandmothers or paternal and maternal lineages is important (Pfeffer, 2014), and Beller (2009) underlined the importance of studying the father's and mother's status simultaneously and its impact on two -generational mobility. We observed the impact of the maternal grandfather's education on the children's educational achievement when all four grandparents were analyzed simultaneously. This result was not obtained when an analysis of the paternal grandfather or analysis of only one lineage was performed.

Furthermore, the disparity between the findings of this study, which used Japanese data, and those of previous studies, which were conducted in Western societies, might be attributed to cultural differences in family systems. Previous studies analyzing data from Western societies have noted the paternal grandfather's effect (Ferrie et al., 2021)[11] and a null effect (Warren & Hauser, 1997 ; Neidhöfer & Stockhausen, 2019). This study uses Japanese data from East Asia to find the maternal grandfather's effect. In Japan, "ie seido," that is, patriarchy and the stem

[11] Ferrie et al., (2021) analyzed the effects of all four grandparents on children separated by the gender of the children. Therefore, in the Appendix, we analyzed the effects of all four grandparents on children separated by gender of children. Thus, using SISIT, the results indicated that the impact of the maternal grandfather on the son was significant at 0.01 and the impact of the paternal grandfather on the daughter was at a significance level of 0.1. However, using NFRJ, the results indicate that the impact of the maternal grandfather on the daughter was at a significance level of 0.1 (Table A 3, Table A 4). Thus, the results were inconsistent.

123 *aaa*

Table 3
Fit indicators

	SISIT	SISIT(4 categories)	NFRJ	complete case(SISIT)
χ^2	62.399***	154.546***	45.669***	23.630
CFI	0.969	0.982	0.913	0.976
RMSEA	0.033	0.026	0.033	0.050
SRMR	0.056	0.049	0.083	0.092

Note : df=20, †<0.1, *p<0.05, **p<0.01, ***p<0.001.

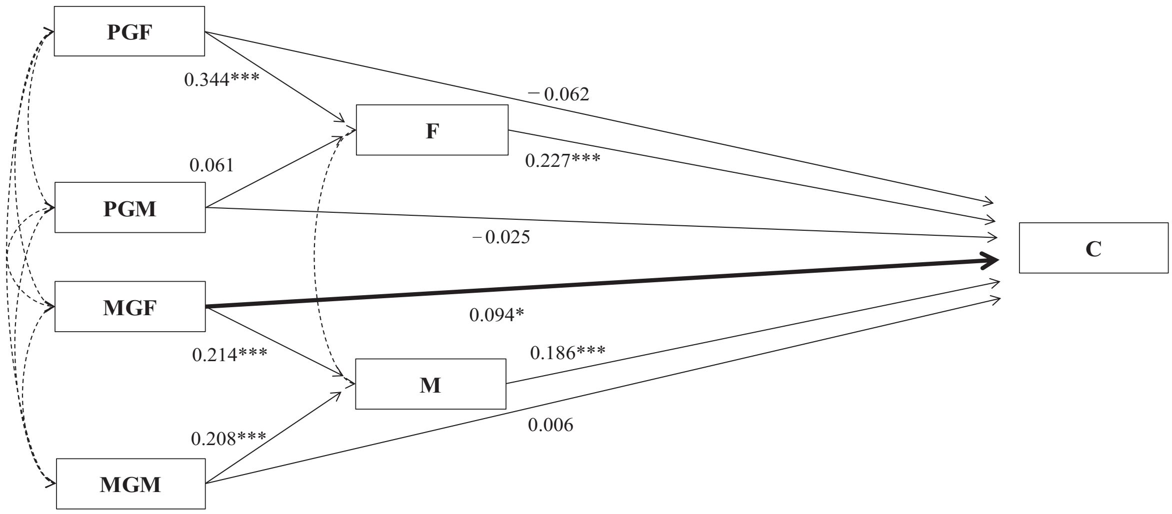

Fig. 3. Result of SEM using by SISIT (4 categories), *Note* : N=1,966, CFI=0.982, RMSEA=0.026, SRMR=0.049. *p<0.05, **p<0.01, ***p<0.001. PG : paternal grandparent, MG : maternal grandparent, F : father, M : mother, C : children. The Dash lines represent a correlation.The solid lines represent causation.The bold solid lines represent significant effects of grandparents' education.The figure does not show controlling variables such as sex, year of birth,number of siblings, and birth order.

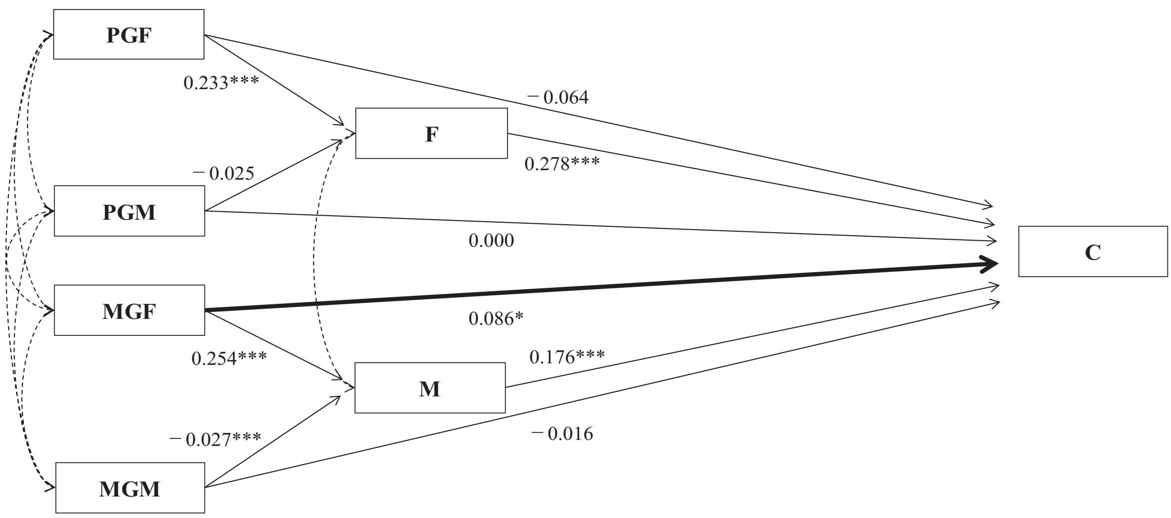

Fig. 4. Result of SEM using by NFRJ, *Note* : N=6,162, C FI=0.913, RMSEA=0.033, SRMR=0.083. *p<0.05, **p<0.01, ***p<0.001. PG : paternal grandparent, MG : maternal grandparent, F : father, M : mother, C : children.The Dash lines represent a correlation.The solid lines represent causation.The bold solid lines represent significant effects of grandparents' education.The figure does not show controlling variables such as sex, year of birth, number of siblings, and birth order.

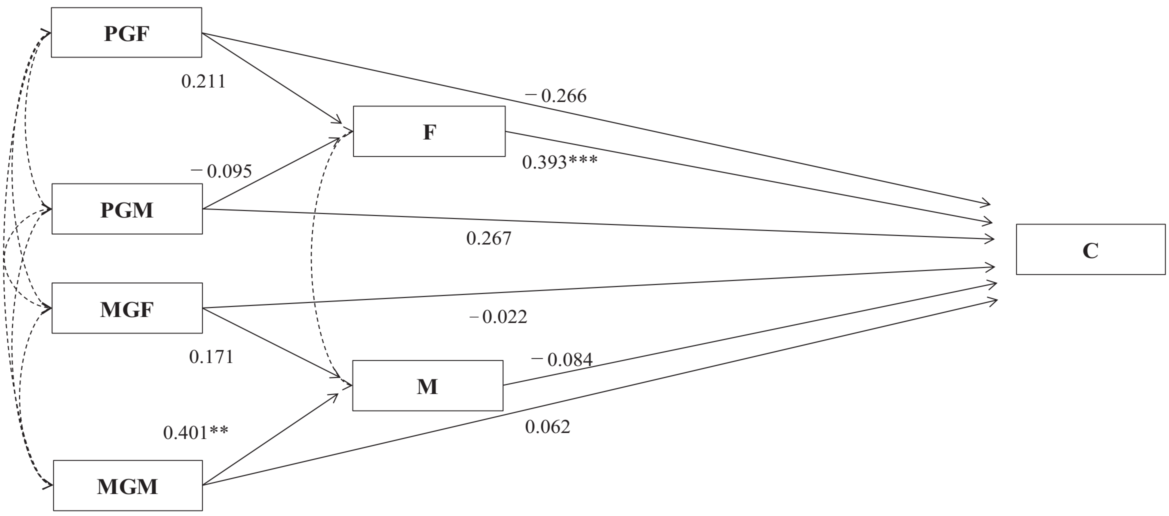

Fig. 5. Result of SEM with complete case analysis, *Note* : N=74, CFI=0.976, RMSEA=0.050, SRMR=0.092.* p<0.05, **p<0.01, ***p<0.001. PG : paternal grandparent, MG : maternal grandparent, F : father, M : mother, C : children. The Dash lines represent a correlation.The solid lines represent causation.The bold solid lines represent significant effects of grandparents' education.The figure does not show controlling variables such as sex, year of birth, number of siblings, and birth order.

Table 4
Summary of grandparent's years of schooling effect

	SISIT	SISIT(4 categories)	NFRJ	complete case(SISIT)
Paternal grandfather's years of schooling	✓	−	−	−
Paternal grandmother's years of schooling	−	−	−	−
Maternal grandfather's years of schooling	✓	✓	✓	−
Maternal grandmother's years of schooling	−	−	−	−

family system with a patrilineal focus, existed before the war. Although this system was abolished after WW II, equal rights for both sexes in the family became legal (Kumagai 1986), "ie seido" existed as the basis of the modern family and had a significant influence on the internal aspects of the present Japanese family (Kumagai, 1986). However, because some studies (Shi, 2008 ; Shirahase 2005 ; Yasuda, 2018) observed the increasing assistance of maternal grandparents, this finding on the impact of the maternal grandfather on children might represent a change in the concept of male dominance, eventually leading to its obsolescence.

It is also worth noting that, although previous studies excluded the missing values, possibly leading to biased results, we used MI, which is a statistically valid correction, to conduct a three-generation mobility study with reduced bias. Mare (2011) noted that data using multigenerational mobility analysis is biased due to survivor and recall biases. In this scenario, when we excluded the missing values from the study, the results may have resulted in biased conclusions. Although the dataset that we used contained many missing values due to the survival and recalling biases, we used MI to make use of valuable data with the information for all four grandparents, which is a statistically valid correction. Therefore, researchers should use corrections such as MI to make use of valuable multigenerational data.

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Appendix

Table A 1
Descriptive statistics (NFRJ)

	N	Mean	S.E.	Missing rate	Range
Grandparent's years of schooling					
Paternal grandfather	554	10.53	2.7	91.01%	0-16
Paternal grandmother	1,586	9.87	2.35	74.26%	0-18
Maternal grandfather	777	10.36	2.52	87.39%	0-16
Maternal grandmother	1,983	9.77	2.4	67.82%	0-16
Parent's years of schooling					
Father	5,453	12.03	2.24	11.51%	9-18
Mother	5,929	11.48	1.42	3.78%	9-16
Children					
Children's years of schooling	6,123	13.53	1.94	0.63%	9-18
Gender of children (males = 1)	6,162	0.52	0.5	0.00%	0-1
Year of birth	6,162	1969.11	3.96	0.00%	1944-1981
Number of siblings	6,159	2.41	0.77	0.05%	1-7
Birth order	6,162	1.61	0.67	0.00%	1-3

Table A 2
Results of FIML

	Estimate		S.E.
On children's years of schooling			
Father's years of schooling	0.260	***	0.032
Mother's years of schooling	0.156	***	0.030
Paternal grandfather's years of schooling	−0.131	†	0.074
Paternal grandmother's years of schooling	−0.010		0.071
Maternal grandfather's years of schooling	0.138	*	0.066
Maternal grandmother's years of schooling	0.030		0.058
Children's gender	0.028		0.021
Children's year of birth	0.040	†	0.023
Children's birth order	−0.017		0.023
Children's number of siblings	−0.080	**	0.024
On father's years of schooling			
Paternal grandfather's years of schooling	0.396	***	0.066
Paternal grandmother's years of schooling	−0.034		0.067
On mother's years of schooling			
Maternal grandfather's years of schooling	0.218	**	0.067
Maternal grandmother's years of schooling	0.210	***	0.058
Covariances			
Father's years of schooling with			
Mother's years of schooling	0.371	***	0.027
Children's year of birth	0.117	***	0.023
Children's number of siblings	0.002		0.023
Children's birth order	−0.021		0.022
Children's gender	0.046	*	0.022
Mother's years of schooling with			
Children's year of birth	0.166	***	0.022
Children's number of siblings	−0.036		0.024
Children's birth order	−0.043	*	0.022
Children's gender	0.016		0.022
Paternal grandfather's years of schooling with			
Paternal grandmother's years of schooling	0.766	***	0.069
Maternal grandfather's years of schooling	0.630	***	0.079
Maternal grandmother's years of schooling	0.542	***	0.062
Paternal grandmother's years of schooling with			

Maternal grandfather's years of schooling	0.521	***	0.082
Maternal grandmother's years of schooling	0.649	***	0.055
Maternal grandfather's years of schooling with			
Maternal grandmother's years of schooling	0.763	***	0.063
Children's birth order with			
Children's number of siblings	0.269	***	0.023
Children's year of birth with			
Children's number of siblings	0.060	**	0.023
Children's birth order	0.222	***	0.021
Children's gender with			
Children's year of birth	0.010		0.023
Children's number of siblings	−0.032		0.023
Children's birth order	−0.040	†	0.023

Note : †<0.1, *p<0.05, <**p<0.01, ***p<0.001 (two-tailed tests).

Table A 3
Results of SEM(separated by gender)

	SISIT					
	male			female		
	Estimate		S.E.	Estimate		S.E.
On children's years of schooling						
Father's years of schooling	0.226	***	0.062	0.23	***	0.061
Mother's years of schooling	0.168	**	0.062	0.184	**	0.060
Paternal grandfather's years of schooling	0.079		0.074	−0.127	†	0.068
Paternal grandmother's years of schooling	−0.037		0.084	0.055		0.067
Maternal grandfather's years of schooling	0.183	**	0.067	0.094		0.066
Maternal grandmother's years of schooling	−0.001		0.080	0		0.073
Children's year of birth	0.015		0.056	0.095	†	0.054
Children's birth order	−0.007		0.056	−0.043		0.058
Children's number of siblings	−0.025		0.054	−0.105	†	0.064
On father's years of schooling						
Paternal grandfather's years of schooling	0.336	***	0.059	0.252	***	0.056
Paternal grandmother's years of schooling	−0.008		0.066	0.072		0.054
On mother's years of schooling						
Maternal grandfather's years of schooling	0.146	*	0.059	0.202	***	0.056
Maternal grandmother's years of schooling	0.247	***	0.065	0.168	**	0.059
Covariances						
Father's years of schooling with						
Mother's years of schooling	0.323	***	0.051	0.360	***	0.054
Children's year of birth	0.094	†	0.053	0.077		0.054
Children's number of siblings	0.040		0.053	−0.037		0.054
Children's birth order	−0.008		0.053	−0.02		0.054
Mother's years of schooling with						
Children's year of birth	0.139	**	0.051	0.183	***	0.053
Children's number of siblings	−0.015		0.051	−0.042		0.058
Children's birth order	−0.040		0.052	−0.029		0.053
Paternal grandfather's years of schooling with						
Paternal grandmother's years of schooling	0.650	***	0.063	0.647	***	0.069
Maternal grandfather's years of schooling	0.487	***	0.067	0.443	***	0.068
Maternal grandmother's years of schooling	0.402	***	0.062	0.377	***	0.064
Paternal grandmother's years of schooling with						
Maternal grandfather's years of schooling	0.463	***	0.064	0.372	***	0.07
Maternal grandmother's years of schooling	0.633	***	0.068	0.591	***	0.072
Maternal grandfather's years of schooling with						
Maternal grandmother's years of schooling	0.726	***	0.070	0.647	***	0.075
Children's birth order with						
Children's number of siblings	0.254	***	0.061	0.281	***	0.058
Children's year of birth with						
Children's number of siblings	0.061		0.057	0.059		0.057
Children's birth order	0.200	***	0.055	0.246	***	0.054
Observations	1,011			955		

Note : †<0.1, *p<0.05, **p<0.01, ***p<0.001 (two-tailed tests).

TableA 4
Fit indicators

	SISIT(FIML)	SISIT(males)	SISIT(females)	NFRJ(males)	NFRJ(females)
χ^2	76.288***	31.159*	34.816**	28.325*	24.254†
CFI	0.971	0.976	0.965	0.912	0.944
RMSEA	0.038	0.031	0.035	0.032	0.036
SRMR	0.023	0.064	0.062	0.086	0.096

Note : SISIT(FIML)'s df=20, SISIT(males), SISIT(females), NFRJ (males), and NFRJ (females)=16, †<0.1, *p<0.05, **p<0.01, ***p<0.001 (two-tailed tests).

NFRJ					
male			female		
Estimate		S.E.	Estimate		S.E.
0.299	***	0.056	0.264	***	0.048
0.170	**	0.059	0.194	***	0.049
−0.103		0.068	−0.011		0.051
0.101		0.069	0.019		0.048
0.025		0.056	0.133	†	0.074
0.011		0.058	−0.046		0.072
−0.123	*	0.05	0.004		0.043
0.002		0.049	−0.024		0.043
−0.088	†	0.048	−0.083	†	0.043
0.255	***	0.058	0.168	***	0.046
−0.034		0.058	0.032		0.043
0.167	***	0.047	0.359	***	0.061
0.050		0.045	−0.144	*	0.063
0.477	***	0.047	0.452	***	0.042
0.248	***	0.044	0.262	***	0.04
−0.036		0.048	−0.009		0.045
−0.021		0.046	−0.047		0.042
0.350	***	0.046	0.328	***	0.041
0.001		0.051	−0.025		0.043
−0.033		0.047	−0.065		0.043
1.103	***	0.158	0.899	***	0.129
0.379	***	0.092	0.375	***	0.077
0.590	***	0.12	0.396	***	0.083
0.450	***	0.097	0.362	***	0.081
0.654	***	0.128	0.383	***	0.089
0.776	***	0.125	0.921	***	0.137
0.354	***	0.054	0.350	***	0.049
−0.031		0.055	−0.055		0.051
0.110	*	0.049	0.109	*	0.044
3,223			2,939		