Sibship Size and Educational Attainment: Evidence of Cohort Trends from 26 Low-Fertility Countries

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Abstract

Children with many siblings have lower average educational attainment compared to children raised in smaller families. This disadvantage by sibship size has been observed across many different countries. We know remarkable little, however, about how sibship size disadvantage has changed over time within countries and how such trends vary between countries. Using comparative data from 114 surveys from 26 low-fertility countries, we find an increase of the sibsize disadvantage over time in the majority of countries: between the 1931-40 birth cohort and the 1971-80 birth cohort, 16 out of 26 countries showed a statistically significant increase in the sibship size disadvantage in education, while only two countries – Australia and the UK – showed a statistically measurable reduction in the sibship size disadvantage. In many countries, growing differential fertility by parental education played a substantial role in the increasing disadvantage. We discuss possible explanations and implications of the increased disadvantages and the variation in trends and levels between regions and specific countries.

Key words [4]: siblings; family size; educational attainment; cross-national comparisons

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Introduction

The negative relationship between family size and children's educational outcomes in developed countries is one of the most frequently confirmed empirical patterns in the fields of social demography and social stratification (Steelman et al. 2002). Already in the 1960s, Blau and Duncan (1967), in their chapter on kinship and careers, reported that men from smaller families had higher educational attainment compared to men from larger families, and commented that "a man's career chances" are highly impacted by the "size of his parental family". Negative associations between various educational outcomes and number of siblings have been reported for many developed countries. Mechanisms underlying these negative associations also have been studied; especially resource dilution (Blake 1989; Downey 1995, 2001) and differential fertility (Dalla-Zuanna 2007; Kasarda and Billy 1985) have received much attention.

Crucially, however, the shape and strength of the inverse relationship between sibship size and educational attainment – or whether there is in fact an inverse relationship at all – may depend on the context in which the relationship is being studied. The general trends towards smaller family sizes and educational expansion over the past century across most societies in Europe and East Asia suggests the presence of temporal variations. However, the pace, nature, and impetus of these changes have been far from uniform across different national populations and sub-populations. We cannot draw conclusions from any one single context; or, at least, we do not know whether we can. In a similar spirit, Lu and Treiman, in their study on the Chinese case (2008), maintained that "the negative effect from the number of siblings is neither universal nor inevitable" and that it is "contingent on demographic, socioeconomic, and political factors external to the family that influence both the availability of resources and their internal allocation

within a family.” (Lu and Treiman 2008:813). Indeed, some studies documented evidence of positive or non-negative associations (Lu and Treiman 2008; Maralani 2008; Parish and Willis 1993; Pong 1997) and others reported remarkable temporal variations within societies (Gibbs, Workman, and Downey 2016; Lu and Treiman 2008). These studies suggest that a negative relationship between sibship size and educational outcomes is not a universal phenomenon but a topic that should be examined through a comparative lens. However, our understanding of how the relationship between sibship size and education varies over time and across societies has remained limited. There has been little systematic comparative research on this issue, presumable largely due to a lack of readily available data.

We aim to fill this void by analysing sibship size data from 114 surveys collected in 26 countries over the course of the twentieth century. Taking a cohort perspective, we first show how average sibship size changed across the cohorts, from those born in the early twentieth century to those born in 1980s. We, then, examine how the disadvantage in educational attainment associated with an additional sibling has changed across birth cohorts in our 26 low fertility countries. Next, we analyse the role of parental education to assess how much of the association between sibship size and child’s educational attainment is explained by selection on parental socioeconomic status into family size. Alongside our analyses, we put forward several theoretical accounts to explain systematically the empirical pattern we find from our comparative data.

Our study shows three major findings. First, the 16 out of 26 countries in our study experienced an increase in the association between sibship size and educational attainment. Second, despite a common general trend in most countries, there was substantial variation, both between and within regions. By and large, we found a trend towards a stronger sibship size

penalty in post-communist countries and East Asian countries and stable or even decreasing sibship disadvantages among Anglo-Saxon countries such as Australia, Canada, the United Kingdom, and the United States.

Temporal and Societal Variations in the Relationship between Sibship Size and Educational Attainment

Evidence from Prior Research

Despite abundant evidence on the sibship size disadvantages in education and theoretical sources explaining the empirical patterns, we have incomplete evidence of historical variations in how sibship size matters for educational outcomes from studies on a few individual country cases, such as the United States. For example, using data from multiple US surveys, Blake (1989) assessed the relationship between sibship size and years of education and how it varies over time. Gibbs et al. (2016) also addressed the same issue with more consistent and recent data, General Social Surveys from 1972 and 2010. Both studies commonly found increasingly weaker negative associations between sibship size and education. For instance, the educational disadvantage associated with sibship size in the US nearly halved when comparing individuals born in the 1900s with those in the 1960s (Gibbs et al. 2016). In line with this finding, Fahey (2017) also reported a steady decline in sibship size during the latter half of the twentieth century, particularly in the 1970s and 1980s, highlighting that the decline was most prominent among child with lower socioeconomic status, especially black children. He noted that the convergence

in sibship size between high- and low-SES groups may be exerting an equalizing influence on family resources – and thus life chances – available to children from low-SES backgrounds.

An important question, then, is whether we can apply the US experience to other country contexts. Evidence from other countries suggests that the decline in the sibship size penalty found in the US may not be easily generalizable to other contexts. For example, Marteleto (2010) shows that in Brazil, an adolescent's schooling decreases as sibling size increases and that this negative monotonicity strengthens after the reduction in fertility later in the second-half of the past century. A Chinese case has a slightly more ambiguous but similar implication. Lu and Treiman (2008) report that the sibship size penalty in educational attainment was larger in periods dominated by equalization policies and smaller when policies enhancing market competition and inequality were dominant, thereby suggesting an increasingly stronger negative association between sibship size and educational attainment as the country embraced a more market-based economy. Maralani (2008) also documents that, in the urban areas of Indonesia, the association between family size and educational attainment was positive for older cohorts but became more negative for recent cohorts, suggesting that the context of socioeconomic development in a society matters for sibship size penalty in educational attainment. She also finds that there is no significant sibship size penalty across cohorts in rural areas, which gives further evidence that the negative sibsize-education association may not necessarily hold in less developed contexts. Similar results are also found for Malaysia (Pong 1997) and Taiwan (Parish and Willis 1993).

Such inconsistency from prior studies begs two questions. First, is the difference in the trend of sibsize disadvantage in education between the US and the other countries, such as Brazil, China, Indonesia, Malaysia, and Taiwan, due to their different stages of economic

development as Maralani (2008) suggests? Can we see the trend reverse and bound up if those developing countries successfully reach a mature stage of economic development? Or, does the difference between the US and non-US countries reflect other characteristics of countries including simply the possibility of noisy variation? Second, what should we expect to observe in countries not yet studied? What kind of trends in sibship size disadvantage in education can be found in other advanced countries or countries that have reached a mature stage of the demographic transition? Should we expect decreases in the negative sibsize effect on educational attainment relying on the US evidence, or an increasingly more detrimental effect drawing inferences from Brazil, China or Taiwan?

Explanations for Variations over Time and Societies

Previous studies suggest a few important factors that might be responsible for temporal changes in the observed sibship size penalty. First, researchers point to the importance of public policies (Steelman et al. 2002) especially as a moderator of resource allocation within families. Children from a large family suffer from resource dilution, but stronger public policies and supports in education and family are likely to compensate such disadvantages that stem from families. For example, Gibbs et al. (2016) show that the negative effect of sibship size on educational attainment in the US was largest in states where per capita spending on higher education was lowest, which suggests that state resources and policies can offset the impact of the RD mechanism. They frame this as conditional resource dilution (CRD) and suggest that “the expanding size of state-sponsored investments in education and related programs that unlink family background from educational opportunities” explain “the decline in the relationship between sibship size and educational attainment over time” (Gibbs et al. 2016:738). Cross-sectional evidence based on cross-country variations in sibship size and student performance

using PISA data also lends support for the role of public policies in compensating cognitive disadvantages associated with a large number of siblings, revealing a tendency of weaker sibship size penalties among countries with more inclusive public policies such as Nordic countries (Park 2008; Xu 2008). This perspective, therefore, predicts that the sibship size penalty is stronger where public policies are weak and weaker where public policies are more inclusive. Within countries, it is expected that the development of the welfare state and mass public education, regardless of its kind, over the past century weakened the disadvantage associated with large family size.

A second explanation highlights the role of structural changes in schooling systems and labour markets. Many researchers use economies of scale as a major candidate that explains why a larger sibship size is less harmful for children's education (Deaton and Paxson 1998; Qian 2009), but the effectiveness of economies of scale depends on the structures of educational system and labour markets in which parents and children are embedded. For example, Maralani (2008) maintains that, in a less developed context, more siblings can share domestic and labour market work and this can help remove barriers to education for a larger family, while such a mechanism may not be present in a more developed society. Parish and Willis (1993) also argue that, as a society develops, children from large families tend to have more difficulties handling education and work due to rising opportunity costs, which translates to increasingly larger disadvantage in education for those with a high number of siblings. This explanation is closely related to institutional incentives for quantity-quality trade-off (Angrist, Lavy, and Schlosser 2010; Becker and Lewis 1973). As a society moves in a direction where success in the labour market is more tightly coupled with success in school, the merits from a large pool of siblings wane and those from fewer siblings grow. This explains why parents come to value the quality of

children more than the quantity of children. And such a change in preference may come with the transition to smaller families.

The third explanation suggests that the widening of differential fertility based on parental socioeconomic status during the fertility transition can be a driving force of any change in sibsize disadvantage in children's educational outcomes (Van Bavel 2006). It has been argued that observed negative associations between sibship size and child outcomes could be merely capturing the effects of unmeasured parental traits that are confounded with parents' own or children's socioeconomic outcomes (Black, Devereux, and Salvanes 2005), such as parents' cognitive ability (Rodgers et al. 2000). Families that choose to have more children tend to be different from those who opt for lower parities especially in terms of their socioeconomic status (SES) and, therefore, the children within those large households would have achieved lower levels of education independent of the effect of sibship size *per se*. This discussion suggests that more remarkable fertility limitation by high-SES families, compared with low-SES families (Dalla-Zuanna 2007), is an important source of sibship size gap in education, and growing differential fertility by SES that drives fertility decline can widen sibsize-based gap in education. For example, Wood, Neels, and Kil (2014) show that among 14 low-fertility countries, negative educational gradients of fertility are a crucial indicator that explains an observed cross-national variation in fertility, especially between a group of countries with very low fertility, mostly Eastern European countries, and a group of countries with relatively high fertility, mostly Western countries. Choi and Monden (2017) show that such variation in the demographic context of fertility change is important to an understanding of cross-country variation in the sibship size gradients in children's development outcomes. According to the differential fertility explanation,

we can expect that the disadvantage in education associated with additional siblings becomes larger where fertility or family size decreased more.

Finally, it needs to be noted that any change in the association between sibship size and educational attainment discussed above represents only part of the full picture; when we estimate the coefficient of sibship size, x , in the regression of educational attainment, y , the coefficient, $\hat{\beta}$, is the product of the standardized correlation between sibship size and educational attainment and the ratio of the standard deviation (SD) of educational attainment and the SD of sibship size:

$$\hat{\beta} = \frac{Cov(x, y)}{Var(x)} = Corr(x, y) \frac{SD(y)}{SD(x)} \quad \text{Eq. 1}$$

In other words, the three explanations discussed earlier provide plausible theoretical mechanisms explicating a change in $Corr(x, y)$ on the right-hand side, being ignorant of how a change in $\frac{SD(y)}{SD(x)}$ makes any difference in $\hat{\beta}$. However, the distributional change in sibship size, especially, the variance of x , contributes to the coefficient $\hat{\beta}$ as an estimated disadvantage in educational attainment associated with a larger sibsize holding the change in the variance of educational attainment constant between two time-points. Since sibship size is a count variable, the mean of which is linked to its variance proportionally (e.g., negative binomial distributions), any change, very likely a decline, in mean sibship size comes with a reduction in its variance. Since this compression of the distribution occurs by a factor of the reduction in average sibship size, the reduction in $SD(x)$ leads to a larger size of the coefficient. This means that, even without any change in the relationship between sibship size and educational attainment, a simple reduction in average sibship size can cause a stronger negative coefficient of sibship size on educational

attainment.¹ Put differently, a reduction in average sibsize can strengthen any sibsize gap in education captured by $Corr(x, y)$. Of course, an increase (or a decrease) in $SD(Y)$ also is a factor that can come into play. For example, increasing inequality in educational attainment gives more weight on disadvantage in education from having more siblings, all else being equal.

To summarize, a reduction in average sibship size has a tendency of strengthening the educational penalty associated with an additional sibling, being everything else constant. On top of such tendency, a few substantive mechanisms that explain variation in the relationship between sibship size and child's education and expectations based on them also can be considered. However, those mechanisms are not mutually exclusive. Actual changes in government policies, the structures of schooling and labor markets, and the SES gradients of fertility during a fertility transition work together in complicated ways and, therefore, it would be very difficult to make a single prediction about how one countries would do. For this reason, we carefully suggest that the experience of US or any other single countries cannot represent a general expectation.

Data and Variables

Data

We compiled a new database (International Sibsize and Educational Attainment Database; ISEAD) that includes 114 national surveys from 26 countries. Countries and surveys were selected based on the following criteria. First, we consider countries broadly defined as having

¹ We provide a formal account in Appendix A.

low fertility. Regionally, our pool of countries covers Europe (Western and Eastern, including the former Soviet Union), North America and Australia, and East Asia. Second, surveys had to be nationally representative of the adult population. Surveys among exclusively young children and adolescents were excluded because subjects were too young to have completed their formal education. Third, surveys had to contain all the information on a respondent necessary for our analysis, which included the number of siblings,² educational attainment, parental educational attainment (the highest of father's and mother's education, or father's if mother's education is unavailable) as well as basic demographic characteristics (e.g., age at the time of survey or year of birth, and sex). Finally, we limited our time window to data collected from 1950 onwards. Finally, for pragmatic reasons and reproducibility, surveys had to be accessible for free for academic use without restrictions on nationality, or institutional affiliation. This means we had to exclude registry data and secure access data.

We aimed to identify all relevant surveys by following four steps. First, we searched the following data archives for relevant surveys: ICPSR (<https://www.icpsr.umich.edu/icpsrweb/ICPSR/>), CESSDA (<http://cessda.net/>), and GESIS (<http://www.gesis.org/en/services/data-analysis/data-archive-service/>). Next, for each survey in the International Stratification and Mobility File (a collection by Harry Ganzeboom, Donald Treiman, and Elizabeth Stephenson, see <http://www.harryganzeboom.nl/ismf/index.htm>) we checked whether the survey included information on sibling size. Third, we checked large international survey programmes such as ISSP, ESS, SHARE, FFS, GGP, EASS. Fourth, we tracked references in cross-nationally comparative social mobility studies, in particular Breen's

² ISEAD excluded surveys containing incomplete information on sibship size. For example, several household-based surveys that only provided information on siblings living in the same household are not included.

2004 Social Mobility in Europe (Breen, 2004). Fifth, for countries where we could not identify surveys in the first four steps we searched national data archive, if available.

Table 1 lists 26 countries with surveys that satisfied our criteria. A full list of surveys, links to the relevant archives and code to reproduce the data and analysis will be provided at publication. More information on the sample specification is provided in online appendix B.

In our analysis, we limited our samples to individuals who were 27 years or older at the time of the survey to make sure that respondents had completed formal education. To take a cohort-based approach, we pooled all national surveys of each country and broke each pooled national sample into 9 ten-year-wide birth cohorts that covered the 20th century: from those born between 1901 and 1910 to those born between 1981 and 1990. For a robust estimation, we used country-cohort samples with at least 500 observations.³ The final data we used included 541,289 adult individuals from 166 country-cohort samples. For each country, we covered at least 5 birth cohorts, from the cohort of 1931-40 to the cohort of 1971-80. We limited our analyses to this subset of birth cohorts whenever we intended to make direct cross-national comparisons.

³ We exceptionally included one country-cohort group with 495 observations, the 1931-40 cohort of Spain.

Table 1: List of Countries and Cohorts from the International Sibsize and Educational Attainment Database (ISEAD)

	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80	1981-90	No. Cohorts	Region
Australia			0	0	0	0	0	0		6	AS
Belgium				0	0	0	0	0		5	WE
Bulgaria			0	0	0	0	0	0		6	EE
Canada		0	0	0	0	0	0	0		7	AS
China	0	0	0	0	0	0	0	0	0	9	EA
Taiwan			0	0	0	0	0	0	0	7	EA
Czech Republic			0	0	0	0	0	0		6	CE
Estonia			0	0	0	0	0	0		6	SU
France		0	0	0	0	0	0	0		7	WE
Georgia				0	0	0	0	0		5	SU
East Germany				0	0	0	0	0		5	EE
West Germany		0	0	0	0	0	0	0	0	8	WE
Hungary			0	0	0	0	0	0		6	EE
Italy				0	0	0	0	0		5	SE
Japan			0	0	0	0	0	0	0	7	EA
South Korea				0	0	0	0	0	0	6	EA
Lithuania				0	0	0	0	0		5	SU
Netherlands			0	0	0	0	0	0		6	WE
Norway				0	0	0	0	0		5	NE
Poland			0	0	0	0	0	0	0	7	CE
Romania			0	0	0	0	0	0		6	EE
Russia			0	0	0	0	0	0		6	SU
Spain				0	0	0	0	0	0	6	SE
Sweden				0	0	0	0	0	0	6	NE
United Kingdom	0	0	0	0	0	0	0	0	0	9	AS
United States	0	0	0	0	0	0	0	0	0	9	AS
No. Countries	3	6	17	26	26	26	26	26	10	166	

Notes: WE=Western Europe; NE=Northern Europe; SE=Southern Europe; CE=Central-Eastern Europe; EE=Eastern Europe; SU=Former Soviet Union; AS=Anglo-Saxon; EA=East Asian

Variables

Sibship Size

Sibship size is the total number of brothers and sisters a respondent has ever had, not including the respondent herself. Since many surveys did not specify whether respondents should count half- or non-biological siblings such as step-siblings and adopted siblings, we assumed that all values of the number of siblings represent sibship size inclusive of all types of siblings. To minimize an arbitrary variation in the upper bound of sibship size across surveys, we use the value 10 for all sibship size values higher than 10.¹

Educational Attainment

We measure educational attainment as the number of years a person had stayed in school as a full-time student. We chose this measure as it provides a measure of educational attainment comparable across countries with wide variations in the structure and characteristics of educational system. It also has the benefit that a continuous measure is much simpler to use in statistical analyses than would be an ordinal or categorical specification. A major challenge in constructing years of schooling was that only a few surveys asked respondents about the actual number of years of school he or she had completed. For parental education, such a case was even rarer. Most surveys instead measured education categorically, asking, for example, what the highest level of educational level a respondent (or her parent) had completed or what the highest level of qualification in education a respondent (or her parent) had attained. While some surveys employed internationally standardized schemes such as the ISCED, most surveys used country-specific schemes that were not easily comparable with those from other countries.

¹ Our results are not sensitive to this cutoff value. Results from the analyses applying alternative cutoff values are available upon request.

To construct the measure as precisely and consistently as possible across our 26 countries, we referred to mapping schemes provided by the Institute of Statistics at UNESCO (<http://uis.unesco.org/en/iscled-mappings>). These guides allowed us to harmonize country-specific educational schemes by providing the theoretical number of cumulative years corresponding to each level of schooling or qualification within a given country. We used these mappings to build a measure of educational attainment capturing the theoretical years of schooling for a person with a certain level of schooling or qualification, rather than a measure of the actual length of a person's schooling.² The cohort trends of educational attainment all 26 countries are illustrated in Table C1 of the online appendix C.

Analytical Strategy

Our central interest is to describe how sibship size and educational disadvantage associated with an additional sibling have changed across birth cohorts for each of the 26 countries. For both, we consider statistics conditional on gender, age, and survey effects for each country-cohort sample. In other words, we estimate the mean sibship size for each cohort and country sample conditional on gender, age, and survey effects. Likewise, we estimate the OLS coefficient of sibship size on education using the following model specification:

$$\begin{aligned} education_i = & \beta_0 + \beta_1(number\ of\ siblings)_i + \beta_2(female)_i + \beta_3(age)_i \\ & + \beta_4(age^2)_i + \beta_5(age^3)_i + \sum_k \gamma_k(survey_k)_i + \varepsilon_i \end{aligned} \quad \text{Eq. 2}$$

² An important limitation of our measurement strategy is that qualitative differences between educational systems are ignored. For example, many European countries have strict divisions even at the same secondary level in terms of how much a track is vocationally-oriented. Years of schooling, however, cannot accommodate such differences.

where k denotes a survey marker that identifies different surveys in a country-cohort sample. The parameter β_1 is our central interest. The general aim of this approach is to examine whether and how β_1 has changed across birth cohorts and how this cohort change varies across countries.

Results

Cohort Trends in Sibship Size

Figure 1 shows the cohort trends of average sibship size over the past century in 26 countries. A common notable trend is that almost all countries experienced a decline in sibship size. However, there are a few notable patterns of variation by region as well as across countries within the same region.

First, the changes are most dramatic in East Asian countries. For the cohort born between 1951 and 1960, South Koreans have about four siblings on average, but for the most recent two cohorts, 1971-80 and 1981-1990, the mean number of siblings is around two. A similarly sharp fall is observed for China. Chinese adults who were born after 1980 have on average just above 1.5 siblings, a level substantially lower than the average sibship size of three observed for previous cohorts. Despite an absence of data for the two youngest cohorts, Taiwan also started a sharp decline from the birth cohort of 1951-1960 onwards. While Japan shows a similarly rapid decline in sibship size, the decline differed in timing from other East Asian countries. Sibship size in Japan had begun to fall already among those born in the 1940s and reached levels below two from those born in the 1960s onwards with little change since.

Figure 1: Cohort Trends in Average Sibship Size

A second notable observation is that Anglo-Saxon countries show relatively high average sibship sizes persisting in the latest cohorts. The United States, United Kingdom, and Australia all show average numbers of siblings significantly higher than two in the 1981-1990 birth cohort, unlike countries in other regions which typically dropped to average sibship sizes of 2 or below by this time. An exception is the two most recent birth cohorts of Canada; young Canadian adults, especially those born after 1960, tend to have considerably smaller numbers of siblings than their older counterparts. Those born in the 1970s tend to have just about two siblings on average, unlike the youngest cohorts of other English-speaking countries. The United States, on the other hand, shows the highest levels of sibship size with about three siblings on average. Canada was very similar to the US in sibship size trends until the 1951-1960 cohort, but the two North American countries began to diverge in subsequent cohorts. Another interesting pattern is a short-term increase that corresponds to the baby-boomer cohort, which is only observed in Anglo-Saxon countries.

European countries, despite their varying starting levels and rates of decline, all appear to converge to around two siblings or just below in the most recent birth cohorts. The Netherlands and Spain show a notably sharp fall, especially among recent birth cohorts. Other countries in the same regions show a gradual downward or even flat trend. One particularly interesting pattern is the flatness of the sibship size trend across birth cohorts in West Germany, which indicates that individuals in this area appear to have always had only two siblings on average over the last century. Relative to Western European countries, Central and Eastern European countries appear to show generally low sibship sizes in the most recent cohorts, with average sizes of around 1.5 siblings rather than two siblings.

Cohort Trends of Sibsize Penalty in Educational Attainment

Now we turn to another main question, temporal (cohort) variations in the relationship between sibship size and educational attainment and how they differ by country. Figure 2 shows the estimates of the coefficient of the number of siblings on the highest years of education attained, net of gender, age, and survey effects. Negative values, therefore, indicate penalties in educational attainment that are associated with having an additional sibling.

First of all, in all countries and for most birth cohorts, an additional sibling is statistically significantly associated with fewer years of schooling. This pattern is consistent with existing evidence of a negative effect of the number of siblings in developed countries. For East Asians born before 1950, however, such a sibling penalty was not evident at all. It was either substantively small (Japan and Taiwan) or failed to be significantly different from zero (China and South Korea). This finding is in line with the argument that the effect of sibship size is sensitive to the context of economic development, even being positive where preferences for large families are aligned with better family resources and where the cost of schooling is low (Maralani, 2008). As the East Asian societies developed, however, the coefficients became more negative and began to align with estimates derived from Western counterparts.

When it comes to cohort trends, we do not find any evidence of consistent upward cohort trends in most countries, which does not support the prediction based on the importance of expanding public policies for moderating sibship size influence during the development of the modern welfare state. In this regard, Anglo-Saxon countries seem to be exceptional. The UK and Canada are the two countries showing steady reductions in the educational attainment penalty

Figure 2: Cohort Trends in Disadvantage in Educational Attainment from Having Every Additional Sibling

Notes: Whiskers show 95 confident intervals of the coefficient. Note that the scale of y-axis is different for Eastern Europe and East Asia due to Bulgaria and China.

associated with an additional sibling since the 1931-40 birth cohort. Australia also experienced a remarkable decrease in the sibsize disadvantage in educational attainment mostly due to the most recent birth cohort (born in the 1970s). The trend in the US is also stable, suggesting no increasing sibship size gaps in education. For most regions, however, sibsize disadvantage in education appears to have increased, although the magnitude of the increase varies across countries and the trends involves volatile fluctuations in some countries. The trend of increasingly larger educational disadvantage from having more siblings is a generally notable descriptive pattern for Western European, Post-communist, and East Asian countries. There is considerable variation and exceptions within these regional categories.

In Western Europe (the top right panel of Figure 2), we see that all four countries show notable and significant increases after the birth cohort of 1931-1940. For example, for those born in 1930s in all those four countries, having an additional sibling came with about a 2.4-month reduction in the length of schooling, but for those born in the 1970s this penalty had increased to around 3.6 months in the Netherlands and to about 5 months in France, West Germany, and Belgium. We found a similar trend for Spain (top-left panel), where the coefficient of an additional sibling decreased from -0.25 to -0.5 years of schooling. For the two Nordic countries (Norway and Sweden, top-central panel) and Italy (top-left panel), the trends are not as directional as those observed in their Western European counterparts. Trends in these countries seem to fluctuate unpredictably around -0.2 and -0.3, as in Norway and Sweden, or around -0.4, as was the case in Italy.¹

¹ The trend of France in Figure 2 differs from the finding from Ferrari and Dalla-Zuanna (2010), which reports no notable trend in the sibship size effect for the country. They also report a similarly stable trend in Italy, which is consistent with our findings in Figure 2. This difference, we speculate, comes from differences in the measurement of educational outcomes (dummies indicating attaining a high school degree and a college qualification rather than years of schooling), differences in statistical modeling (logistic rather than OLS), and different data sources.

Countries with Post-communist legacies (see three panels in the middle row of Figure 2) show growing sibship size penalties associated with sibship size with considerable variation. East Germany, Bulgaria, Hungary and Romania show consistent and significant downward trends. For example, having an additional sibling was associated with a 0.2-year reduction in educational attainment in East Germany for the 1930-1940 birth cohort, but this penalty increased to about 0.35 years for the 1960-1970 birth cohort. Steeper and more consistent increases in the sibship size penalty are observed in Romania and Hungary; the gap in educational attainment shifted from between -0.2~ -0.3 years for the 1920-1930 birth cohort to about -0.6~-0.7 years for those born in 1970s. More outstanding still is Bulgaria, where the sibship size disadvantage went from about 6 months of schooling for the 1921-1930 birth cohort to 1 year for those born in the 1960s and ultimately reached levels of about 1.5 years for the 1971-80 cohort.

The widening disadvantage from having more siblings is also generally common in the four former Soviet Union republics (middle-left panel), but the patterns are nonlinear. Lithuania and Georgia show a substantial decline in the coefficient for recent birth cohorts, especially those born in the 1970s, where having one more sibling is associated with more than half a year shorter schooling. Estonia shows only a slight decline starting from -0.3 for the 1931-40 cohort to -0.4 for the 1971-80 cohort. Russia looks trickier to draw any directional inference as the coefficient shows a secular decline starting with the 1941-50 birth cohort, but the rate of the decline is in general slow and statistically insignificant. In consequence, Russia has the smallest sibsize penalty in education amongst the four former Soviet Union countries in the most recent birth cohort.

As discussed earlier, Anglo-Saxon countries (Bottom-right panel) present an exceptional case where no countries show a declining trend in the coefficient of sibship size on years of education. The United States shows a generally stable trend with minor vicissitudes amongst recent cohorts, which is in line with Gibbs and colleagues' study on the US experience (Gibbs et al. 2016). The other three countries show increasingly smaller disadvantages among recent birth cohorts, suggesting that the educational price of an additional sibling has become lower. For example, for those born in the 1930s, an additional sibling comes with about a 0.3-year loss in schooling years in Australia, Canada, and the UK. The loss for those born in the 1970s, however, reduces to about 0.1 years in Australia and the UK and to about 0.25 years in Canada.

All East Asian countries show significant downward secular trends. These four countries shared a common trend of gradual decline from near zero values of the coefficient, but, interestingly, they began to diverge after the birth cohort of 1961-1970. China and Japan experienced more dramatic increases in educational disadvantage, from 0.3 to 0.6 years in Japan and from 0.3 to 1.3 years in China. South Korea, on the other hand, shows a flat curve after the divergence without any substantive changes, moving around 0.15~0.2-years of sibsize penalty in education. Taiwan shows slightly larger negative coefficients than Korea in general, ending up with about 0.4 years of sibship size disadvantage in education in the most recent cohort. The trends of China and Taiwan are generally consistent with the patterns documented by previous studies (Lu and Treiman 2008; Parish and Willis 1993).

To separate out the changes due to the compressed distribution of sibship size as a consequence of the transition to small sibship size from the trends in Figure 2, we plot the equivalent cohort trends of the correlation coefficients between sibship size and educational attainment (see Eq. 2) in Figure 3. The trends in Figure 3 are generally consistent with those in

Figure 2. Several countries, such as France, Spain, East Germany, Poland, and Japan, show much flatter trends unlike notably falling trends in Figure 2 when the standardized correlation coefficient is teased out, which is free from the distributional changes in sibship size and/or educational attainment. More remarkable is the case of Bulgaria and China; their outstanding plummets show much moderate downhill curves that are now comparable with neighboring countries. This difference suggests that the outstandingly sharp increase in educational disadvantage by sibship size in these two countries are largely due to either widening dispersion of educational attainment or more compression of sibsize rather than due to changing relationship between sibsize and education. Norway and Czech Republic are two countries whose weakening negative correlations have been offset by distributional changes in education and sibsize.

Figure 3 about here

Figure 4 shows whether the cohort changes between the 1931-40 and 1971-1980 birth cohorts in those two statistics estimating the association between sibship size and educational attainment were positive or negative and statistically significant or not. The figure also shows whether there is any relationship between the change in average sibship size and the change in the association between sibship size and educational attainment. When it comes to the regression coefficient of sibship size on education (the left panel), only two out of 26 countries, UK and Australia, became significantly more positive. 8 countries show either positive or negative changes but failed reach statistical significance. We found evidence of increasing educational disadvantages associated with larger sibsize (or increasingly negative changes in the regression coefficient) from 16 countries. The right panel shows that most of countries moved up towards or over the line indicating zero association when the correlation coefficient is considered. Out of 26

Figure 3: Correlation Coefficients between Sibship Size and Educational Attainment

Notes: Correlations are semi-partial correlations between sibsize net of gender, age, and survey effects and educational attainment; whiskers show 95 confident intervals of the coefficient that are constructed from bootstrap standard errors

countries, four countries (Australia, UK, Canada and Norway) became significantly more positive, and 13 countries show significantly negative changes. 9 countries failed to reject the hypothesis of null change. The fitted lines in Figure 4 show that there is no evidence of a meaningful relationship between reduction in mean sibship size and change in the association between sibship size and educational attainment. We found a notable upward slope in the left panel when two outliers, China and Bulgaria, are ruled out (red dashed line), but the estimate is still small and statistically insignificant. This suggests a potentially important role of changing dispersion of educational attainment in determining sibship size disadvantage in education. In other words, widening educational inequality leads to greater penalty in education from larger sibsize.

To conclude, Figure 4 shows that only a minority of countries experienced weakening associations between sibship size and educational attainment. Majority of 26 countries underwent growing negative associations and most of their changes are statistically significant.

Figure 4: Changes in the Association between Educational Attainment and Sibship Size by Change in Average Sibship Size

Notes: In the left panel, the blue fitted line comes from the whole country sample and the red (dashed) fitted line comes from the country sample excluding China and Bulgaria as outliers. The whiskers show the 95 percent confidence intervals

Explaining cross-national variation in the cohort trend of sibship size penalty

How can we understand our findings in light of the theoretical explanations discussed earlier? As we have highlighted, our finding of the dominance of declining trends in the coefficient of sibship size on educational attainment in most countries is not unexpected, considering the increasingly compressed variance in sibship size. A more surprising finding was the substantial variation in the extent to which this coefficient declined across countries. Figures 3 and 4 strongly suggest that there are important regional factors at play. For example, no Anglo-Saxon countries show significant downward shifts in the coefficient of sibship size on schooling between birth cohorts, with three of them (Australia, Canada, and the UK) in fact showing an upward shift. Both Nordic countries, Norway and Sweden, also show no changes in the sibship size gap in education. As we have only two Nordic countries, it may be premature to attribute this trend to the unique institutional characteristics shared by these countries. However, our findings suggest that Anglo Saxon and Nordic countries may deviate from a more general trend of increasingly strengthened sibship size disadvantage in education throughout the rest of Europe and East Asia.

Changes in public policies may explain part of this cross-national variation. For example, the absence of notable changes in Sweden and Norway across cohorts, as well as their comparatively small sibship size disadvantages from the outset, may be indicative of the strong buffering effects of their exceptionally inclusive social policies (Park 2008; Xu 2008). Similarly, the increasing sibship size disadvantages in post-communist countries, especially amongst the most recent cohorts who experienced the post-communism period as adolescents, also provide support for the role of changing public policies. As Lu and Treiman (2008) suggested, a shift in policy orientation between egalitarian and competitive market economies can mitigate or amplify

the effect sibship size can have on a child's life chances. In the case of post-communist countries, the rapid transition to a market-based economy after the collapse of state communism may have contributed to the strengthened negative associations between sibship size and educational attainment observed over time.

The importance of education and labor market institutions is another structural explanation which may explain the remarkable trends of increasing sibship size disadvantages observed in East Asian countries. Over the past century, East Asian countries experienced the most radical structural changes in education and industry compared with other Western and European counterparts. Within these countries, children's longer stays in school became increasingly normative and compulsory by law. Along with this, labor markets valuing human capital replaced more traditional markets where parents expected higher financial payoffs from having many children with minimum skills (Montgomery, Arends-Kuenning, and Mete 2000). These radical structural and institutional changes may have been responsible for the growing disadvantages in educational attainment from having larger family sizes and, by extension, the observed sibship size payoffs to education by reinforcing a quantity-quality tradeoff in children (Parish and Willis 1993).

Role of Parental Education

Another explanation for the trends of educational disadvantage associated with large sibsize is the dynamics of differential fertility; a growing gap in children's educational attainment between small families and large families results from parental SES becoming an increasingly stronger predictor of family size. We examine whether and how this account fits our data, using parental

education as a primary indicator of family SES. We do this by quantifying how much of the educational disadvantage associated with sibship size is explained away by parental education and how much of it remains net of parental education. This analysis is one way to gauge how intergenerational mobility in educational attainment operates through sibship size.¹

In Figure 5, we plot how much of the coefficients of sibship size on years of education is explained by parental education and vary across cohorts by presenting the difference in the coefficient of sibsize without controlling for parental education and the coefficient with controlling for parental education. The dots and lines, therefore, show how the role of parental education as confounder has changed over time in gaps in educational attainment by sibship size. The result shows that the size of the coefficients shrinks for all birth cohorts in all countries, suggesting the role of differential fertility by parental education in sibship size gaps in educational attainment. Our calculation shows about on average 40% reduction in sibship size coefficient when parental education is controlled for (see Figure C3 in the online appendix). Substantial regional and country variations are, however, observed. In many countries, especially those in Central-Eastern and Eastern Europe, some in Western Europe (Belgium and France), US for the most recent cohort and those in East Asia (except Japan), differential fertility by parental education explains sibship size penalty in education increasingly more in recent birth cohorts. Other countries show generally flat or trendlessly fluctuating changes with some cross-national

¹ Parental education matters either because of differential fertility or because of its impact on the pool of family resources – whether material or not – available to children (or a child and his or her siblings). The former explanation infers the causal effect of parental education on family size, while the latter suggests parental education acts as a confounder influencing both one's educational attainment and unmeasured family resources. In the present analysis, we are unable to disentangle these two mechanisms due to data limitations. Therefore, our evidence is associational rather than causal.

Figure 5: Sibship Size Penalty in Educational Attainment Explained by Parental Education

Notes: Note that the scale of y-axis is different for Eastern Europe due to Bulgaria.

variation in the magnitude (ie intercepts); Germanys, the Netherlands, Norway, Sweden, Australia and UK show the estimate of parental role below 0.1 years and others like Italy, Spain and former USSR republics show relative high estimates. There are two exceptional countries with weakening trends such as Canada (the most recent cohort) and Japan. One inference we can draw, therefore, is the absence of the weakening role of differential fertility by parental SES.

Figure 6 corroborates this inference. The figure shows the cohort trends of the gap in parental education between children with small sibsize (0 or 1) and those with large sibsize (3 or more). The pattern of the trends largely mirrors that in Figure 5. The countries with increasing gap in parental SES by sibship size are those with the increasing role of parental SES in sibship size penalty in child's education and *vice versa*. For example, Belgium and France, where sibsize gap in parental education has been widening, are the two countries in the region where the role of parental education in explaining sibsize penalty. Japan is the only country in East Asia that achieved reductions in sibsize gap by parental education and the role of parental education in sibsize penalty. This remarkable similarity between Figure 5 and Figure 6 suggests the importance of differential fertility during the demographic transition as a key nexus in the intergenerational transfer of educational attainment (Choi and Monden 2017; Mare and Maralani 2006).

Figure 6: Gap in Parental Education between Children with Small Sibsize (0-1) and Children with Large Sibsize (3+)

Notes: Note that the scale of y-axis is different for Eastern Europe due to Bulgaria.

Discussion

We presented comparative evidence of how sibship size and the educational disadvantage associated with larger sibship sizes have changed across birth cohorts over the past century using a new internationally comparable database. Our findings include three major patterns. First, the majority of countries studied experienced a strengthened penalty in educational attainment associated with larger sibship sizes. Between the 1931-40 birth cohort and the 1971-80 birth cohort, 16 out of 26 countries showed a statistically significant increase in the sibship size disadvantage in education, and only 2 countries showed a statistically measurable reduction in the sibship size disadvantage. Second, despite a common negative direction of the trend shared by most regions, we observed substantial variation between and within regions. While the trend towards a stronger sibship size penalty was pronounced in countries with post-communist legacies, countries in East Asia, and some countries in Western Europe, such a pattern was not observed in the two Nordic countries sampled. More remarkable still were the Anglo-Saxon countries, all of which showed either an ignorable change in the sibship size penalty over time or even a decreasing penalty in education associated with a larger sibship size. Lastly, we found that growing differential fertility – or the growing SES gradient of family size – is likely the key factor explaining why the gap in educational attainment between children from large families and those from small families has widened. Indeed, our analysis revealed growing sibship size disadvantages largely from countries with expanding gaps in parental education between sibship size groups.¹

¹ We carried out the same analyses with the relative measures of child's education and parental education and found substantively same results. The results are summarized in Figures C4 to C6 in the online appendix C.

On top of differential fertility, the revealed patterns largely support the role of public policies and structural changes in the institutions of education and labor markets. The strengthened sibsize penalties in countries that underwent the transition from a state communist regime to a market-based economy and constantly inclusive social and welfare policies in Nordic countries fit well the trend patterns we found from our comparative data. Remarkable increases in sibsize disadvantage in East Asian countries, especially during the mid to late 20th century, are also consistent with their experiences of rapid industrialization. Table 2 summarizes these macro-level factors explaining the country-level variation in the trend of sibship size disadvantage in educational attainment.

Table 2: Factors Driving the Cohort Change in Sibship Size Disadvantage in Educational Attainment

	Public policies		Rapid restructuring in markets and education	Growing differential fertility
	Policy changes (from egalitarian to market competition)	Inclusive social & welfare policies		
Western Europe		Δ		O
Northern Europe		O		
Southern Europe			Δ	
Central-Eastern E	O			O
Eastern Europe	O			O
Former USSR	O			
Anglo-Saxon				
East Asia	China		O	O (except Japan)

A question that remains largely unanswered, however, is how we understand the deviating pattern of stagnant or weakening sibship size penalty amongst the Anglo-Saxon countries. Table 2 may provide a clue here, as Anglo-Saxon countries have not undergone any listed macro-level changes substantively, which might have enhanced sibship size penalty in educational attainment, unlike countries belonging to other regional groups. If this is indeed an

appropriate explanation about Anglo-Saxon trajectories during the past century, it is reasonable to expect no trend of growing sibsize-based inequality in educational attainment. However, this answer appears to be only insufficiently satisfactory considering the experiences of the Nordic countries. While the Nordic countries also did not undergo the specified macro-level changes theorized to enhance sibship size gaps in education, they did maintain or even enhance inclusive social welfare systems that should have suppressed sibship size disadvantages. Table 2 then suggests that we expect a more weakened negative trend (or even a more strengthened positive trend) for Nordic countries than for Anglo-Saxon countries. Our finding, however, is opposite. And the finding in Figure 4 rules out a possibility that distributional changes in sibship size and educational attainment explain the unique Anglo-Saxon pattern. This seems to lead to a need for alternative explanations. While a recent study also reporting a weakening negative sibsize effect on educational attainment in the US indicated that such a trend “may be the result of the expanding size of state-sponsored investments in education and related programs that unlink family background from educational opportunities” (Gibbs et al. 2016:738), our cross-national comparison suggests that an interpretation focusing exclusively on the role of state policies may be too general to explain why the US shows such an exceptional trajectory. Moreover, as our evidence highlights that this trend of weakening sibship size-education penalties is not specific to the US but instead extends to all Anglo-Saxon countries, effective explanations cannot be too country-specific and should incorporate other cultural and institutional factors shared by Anglo-Saxon countries.

We believe that our study makes an important contribution to research on the intergenerational reproduction of educational attainment or, more generally, the attainment of SES, by providing cross-national evidence, which has been relatively rare in intergenerational

research largely due to data limitations. Our findings suggest that the universal demographic trend of reducing family sizes engenders two offsetting consequences on children. On one hand, such a compositional change makes fewer children suffer the penalties related to large family sizes, thereby reducing the importance of differential fertility as a route to intergenerational transmission of SES (Fahey 2017; Präg, Choi, and Monden 2018). On the other hand, an increase in the negative coefficient of sibsize on education suggests a growing penalty from growing up in large families, thereby strengthening the importance of being born in a small family for achieving high educational attainment. Which one of these two forces is stronger than the other remains an empirically open question, but our study suggests that several macro-level changes in social and economic institutions and policies may moderate or mediate such intergenerational processes, thereby producing substantial cross-country variation. Again, Table 2 provides a meaningful presentation of some such macro-level changes that may be linked to the evolving role of family size in children's educational attainment. In addition, growing levels of differential fertility in terms of parental education in many, but not all, countries (see Figure 6) imply that changes in family size can be an important route for intergenerational reproduction of education.

Our study calls for more comparative research on the role of demographic changes in intergenerational transmission of socioeconomic (dis)advantages. Recently, researchers have developed sophisticated analytical approaches to study the significance of differentials in marriage and fertility in intergenerational mobility (Lawrence and Breen 2016; Maralani 2013; Mare and Maralani 2006; Song and Mare 2015). However, none of these studies are cross-societal. The absence of the comparative perspective suggests that the macro-historical context of demographic changes cannot be incorporated in the consideration of demography. This can be problematic for two reasons. First, at least among low-fertility societies, new patterns of social

stratification in marriage and fertility have been emerging over the past couple decades. For instance, the empowerment of women has turned positive for promoting fertility and the positive relationship matters increasingly more, while an opposite was the case before this turn (Myrskylä, Kohler, and Billari 2009). In the US, marriage is now more widely accepted as a norm for more highly educated and economically affluent women than low-income, low-educated counterparts (Carbone and Cahn 2015; McLanahan 2004). Second, such new stratifying patterns of family formation in low-fertility societies emerged heterogeneously across societies and, more importantly, large part of such variation depends on country-specific institutions and policies. Getting out of the very low fertility trap and boosting the fertility rate have been a crucial social policy object in many of these countries (Goldstein, Sobotka, and Jasilioniene 2009; McDonald 2006). The effectiveness of such policy efforts largely depends on the country's institutional characteristics (McDonald 2006). For example, women's empowerment is a complex concept that captures women's relative well-being and life chances across multiple life domains particularly education, the family and the career in the labor market. Some countries are successful to assemble the structural conditions empowering women beyond their school success, while others fail to overcome conventional traps that make women choose one at the expense of another due to insufficiently supportive policies and institutions. This suggests that the role of demographic factors in the intergenerational transmission of resources and statuses vary highly across societies but predictably rather than randomly. Our comparative study illustrates one way of such complex processes.

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Appendix A: A Formal Demonstration of How a Change in Sibship Size leads to a Change in the Coefficient of Sibship Size on Educational Attainment

The educational disadvantage of an additional sibling as the regression coefficients of sibship size on educational attainment of the first cohort $c1$ and the second cohort, $c2$, can be written with regard to the covariance and variance as:

$$\hat{\beta}_{c1} = \frac{\text{Cov}(x_{c1}, y_{c1})}{\text{Var}(x_{c1})}$$

$$\hat{\beta}_{c2} = \frac{\text{Cov}(x_{c2}, y_{c2})}{\text{Var}(x_{c2})}$$

where x denotes the number of siblings and y denotes years of education. Since the number of siblings is a count variable and usually follows a negative binomial distribution, a decline in the average sibship size between two cohorts can infer a decline in the variance of sibship size and a possible extra reduction in variance due to a corresponding reduction in the over-dispersion parameter.

Therefore, we make three assumptions:

- (1) Sibship size follows the negative binomial distribution with the over-dispersion parameter α , so that sibship size has mean μ and variance $\mu(1 + \alpha\mu)$. When $\alpha = 0$, the distribution reduces to the Poisson distribution, where mean and variance are identical. As α gets larger, the variance becomes larger than the mean, meaning over-dispersion.
- (2) There is no changes in the association between sibship size and educational attainment, and also in the association between sibship size and an unobserved confounder (say z),

which is associated with both sibship size and educational attainment, between c1 and c2.

That is, the change in average sibship size by a factor of θ ($0 < \theta < 1$) equally applies to all individuals such that:

$$\mu_{x_{c2}} = \theta \mu_{x_{c1}},$$

$$x_{c2} = \theta x_{c1}$$

and

$$\text{Corr}(x_{c1}, y_{c1}) = \text{Corr}(x_{c2}, y_{c2})$$

(3) There is no change in the distribution of educational attainment between c1 and c2.

That is, y_{c1} and y_{c2} are largely exchangeable in our derivation in the following.

Then, we can write $\hat{\beta}_{c2}$:

$$\hat{\beta}_{c2} = \frac{1}{\theta} \hat{\beta}_{c1}$$

because the numerator $\text{cov}(x_{c1}, y_{c1})$ changes by a factor of θ and the denominator $\text{var}(x_{c1})$ reduces by a factor θ^2 as the mean and the over-dispersion parameter reduces accordingly:

$$\mu_{x_{c2}} = \theta \mu_{x_{c1}},$$

$$\alpha_{x_{c2}} = \theta^2 \alpha_{x_{c1}}$$

Assumption (1) is largely supported empirically by data. Assumption (2) is a very strong assumption that hardly fits the reality. But this extreme hypothetical scenario provides a

good reference situation where we consider endogenous change between sibship size and the coefficient only, ruling out any possible involvement of exogenous sources of changes. Assumption (3) can be easily achieved by using the standardized measure of educational attainment.

By assuming (1), (2), and (3), then, we can come to a conclusion that a simple reduction in sibship size by a factor of θ induces a change in the coefficient by a factor $1/\theta$.

Appendix B: Issues in Sample Specification

1. Age Restriction

As described in the manuscript, we limited our samples to individuals who were at least 27 years old at the time of the survey to make sure that respondents had completed formal education. The results of our analyses are robust to a change in this age cutoff (e.g., 25 and 30). For several surveys that only asked about respondent's siblings who were older than age 18, we used a higher age cutoff (age > 35) assuming no respondents had a sibling younger by more than 18 years. In one survey (UK Household Longitudinal Study), respondents are asked to report the number of siblings alive. We include only young adults from this survey assuming young adults do not have siblings who are deceased since it is the only available survey with the information on parental education for the young cohorts of UK.

2. Observations Missing on Parental Education

Out of total 541,289 individuals with sibship size and other required information from 26 countries and 166 country-cohort samples, 82,654 individuals are missing information on their parent's education. This is about 15.3% of the total sample.

Out of the 15.3%, about 4% of missing observations (21,381 individuals) are from China, 1.6% (8,750 individuals) are from Japan, and 4.4% (23,856 individuals) are from the UK. Missingness in these three countries is mostly due to their survey designs (e.g., parental education was not asked) rather than due to potentially bias-inducing non-response. For example, Chinese surveys covering old birth cohorts (from 1901-10 to 1931-40) did not

ask parental education. Similarly, some UK surveys covering recent cohorts (from the 1941-50 cohort on) did not contain information about parental education by design.

Only about 5.3% of total missing observations are from the remaining 23 countries. They are mostly conventional missing cases (e.g., non-responses, don't know, etc.). Two country-cohort cells become missing as a whole because they fail to keep the minimum 500 observations after dropping observations missing on parental education. These are the oldest cohorts in West Germany and Spain. We, however, find that this 5.3 % of total missing cases does not induce bias. See Figure 2 and Figure B1 in this appendix.

Table B1 shows the numbers of observations for individual country-cohort cells without and with parental education

Table B1: Numbers of Observations for Country-cohort Cells and Information of Missing Observations

	Model	1901 -1910	1911 -1920	1921 -1930	1931 -1940	1941 -1950	1951 -1960	1961 -1970	1971 -1980	1981 -1990	Total	Missing (%)	Missing % Total
Australia	(1)			872	1,042	1,443	1,375	1,510	964		7,206	2,314	
	(2)				582	855	1,164	1,380	911		4,892	(32.1)	0.4
Belgium	(1)				754	1,064	1,396	1,503	1,222		5,939	439	
	(2)				704	973	1,292	1,382	1,149		5,500	(0.5)	0.1
Bulgaria	(1)			1,005	2,158	2,641	2,642	3,393	2,010		13,849	462	
	(2)			946	2,075	2,557	2,571	3,294	1,944		13,387	(0.6)	0.1
Canada	(1)		1,726	3,381	4,110	6,063	7,395	7,024	1,200		30,899	1,234	
	(2)		1,649	3,151	3,826	5,674	7,171	6,999	1,195		29,665	(1.5)	0.2
China	(1)	3,051	2,806	565	2,641	5,370	7,395	8,832	6,406	1,370	38,436	21,381	
	(2)					1,233	3,015	5,989	5,572	1,246	17,055	(55.6)	4.0
Taiwan	(1)			799	2,066	2,982	5,520	4,475	1,640	733	18,215	446	
	(2)			760	1,979	2,872	5,392	4,436	1,612	718	17,769	(2.4)	0.1
Czech Republic	(1)			1,499	2,101	2,847	2,892	2,260	1,466		13,065	607	
	(2)			1,425	1,986	2,734	2,782	2,139	1,392		12,458	(4.6)	0.1
Estonia	(1)			549	1,184	1,252	1,465	1,403	1,080		6,933	11	
	(2)			547	1,179	1,251	1,463	1,402	1,080		6,922	(0.0)	0.0
France	(1)		1,399	5,877	13,074	22,401	24,112	14,554	6,193		87,610	1,676	
	(2)		1,383	5,731	12,773	22,042	23,702	14,260	6,043		85,934	(1.9)	0.3
Georgia	(1)				1,280	1,200	1,903	2,022	1,504		7,909	420	
	(2)				1,078	1,111	1,842	1,978	1,480		7,489	(5.3)	0.1
East Germany	(1)				1,181	1,250	1,733	1,609	1,223		6,996	570	
	(2)				1,091	1,139	1,582	1,491	1,123		6,426	(8.1)	0.1
West Germany	(1)		532	1,921	3,907	4,962	5,483	7,436	6,136	2,134	32,511	4,192	
	(2)			1,455	3,314	4,205	2,056	6,780	5,592	1,917	28,319	(12.9)	0.8
Hungary	(1)			1,519	2,741	3,604	3,702	2,549	2,034		16,149	825	
	(2)			1,362	2,545	3,241	3,627	2,527	2,022		15,324	(5.1)	0.2
Italy	(1)				595	2,221	2,199	2,467	1,036		8,518	200	
	(2)				556	2,146	2,151	2,434	1,031		8,318	(2.3)	0.0
Japan	(1)			2,280	6,150	9,336	8,555	8,625	6,572	548	42,066	8,750	
	(2)			1,753	4,961	7,519	6,564	6,476	5,537	506	33,316	(20.8)	1.6

Table B1: Numbers of Observations for Country-cohort Cells and Information of Missing Observations (continued)

	Model	1901 -1910	1911 -1920	1921 -1930	1931 -1940	1941 -1950	1951 -1960	1961 -1970	1971 -1980	1981 -1990	Total	Missing (%)	Missing % out of Total
South Korea	(1)				826	1,808	3,003	3,566	2,428	654	12,285	379	
	(2)				761	1,708	2,908	3,477	2,404	648	11,906	(3.1)	0.1
Lithuania	(1)				1,547	1,413	1,712	1,798	1,362		7,832	885	
	(2)				1,252	1,234	1,551	1,653	1,257		6,947	(11.3)	0.2
Netherlands	(1)			1,288	2,889	4,430	5,430	5,752	1,970		21,759	975	
	(2)			1,209	2,718	4,222	5,249	5,518	1,868		20,784	(4.5)	0.2
Norway	(1)				1,556	2,489	2,506	2,940	2,476		11,967	199	
	(2)				1,507	2,452	2,469	2,895	2,445		11,768	(1.7)	0.0
Poland	(1)			1,233	4,286	5,464	6,766	4,111	3,437	907	26,204	1,203	
	(2)			1,176	3,921	5,186	6,526	3,983	3,322	887	25,001	(4.6)	0.2
Romania	(1)			695	1,946	2,085	2,368	2,264	1,520		10,878	201	
	(2)			675	1,909	2,043	2,335	2,228	1,487		10,677	(1.8)	0.0
Russia	(1)			1,526	2,643	2,492	3,648	2,584	1,181		14,074	2,881	
	(2)			1,024	1,973	1,935	2,965	2,209	1,087		11,193	(20.5)	0.5
Spain	(1)				501	739	814	1,051	1,184	600	4,889	553	
	(2)					726	803	1,042	1,170	595	4,336	(11.3)	0.1
Sweden	(1)				763	1,726	1,631	1,782	1,591	660	8,153	573	
	(2)				713	1,622	1,515	1,648	1,466	616	7,580	(7.0)	0.1
United Kingdom	(1)	773	2,280	2,521	3,769	4,102	6,639	7,221	5,537	1,848	36,690	23,856	
	(2)	662	2,023	2,193	2,076	1,019	1,295	1,797	1,769		12,834	(65.0)	4.4
United States	(1)	2,325	5,348	7,064	6,699	9,663	9,406	6,184	2,901	667	50,257	7,422	
	(2)	1,542	3,380	4,960	5,945	8,985	8,808	5,799	2,774	642	42,835	(14.8)	1.4
Total	(1)	6,149	14,091	34,594	72,409	105,047	121,690	110,915	66,273	10,121	541,289	82,654	
	(2)	2,204	8,435	28,367	61,424	90,684	105,798	95,216	58,732	7,775	458,635	(15.3)	15.3

Notes: Model (1) shows the numbers of all observations with the information of sibship size and other required variables but not necessarily parental education. Model (2) shows the numbers of all observations with the information of sibship size, other required variables AND parental education.

Figure B1: Cohort Trends in Disadvantage in Educational Attainment from Having Every Additional Sibling (Nested Samples)

Notes: Whiskers show 95 confident intervals of the coefficient. Note that the scale of y-axis is different for Eastern Europe and East Asia due to Bulgaria and China.

Appendix C

Figure C1: Cohort Trends of Educational Attainment

Figure C2: Cohort Trends in Disadvantage in Educational Attainment from Having Every Additional Sibling Net of Parental Education

Notes: Whiskers show 95 confident intervals of the coefficient. Note that the scale of y-axis is different for Eastern Europe and East Asia due to Bulgaria and China.

Figure C3: Percentage Reduction in Educational Attainment Associated with Every Additional Sibling by Conditioning on Parental Education

Figure C4: Relative Education by an Additional Sibling with and without Conditioning on Parental Education

Notes: Grey areas show 95 confident intervals of fitted curves. Note that the scale of y-axis is different for Eastern Europe due to Bulgaria.

Figure C5: Cross-national Association between Change in Average Sibship Size and Change in Disadvantage in Relative Education Associated with an Additional Sibling

Figure C6: Average Parental Relative Education Completed by Sibship Size

Notes: Note that the scale of y-axis is different for Eastern Europe due to Bulgaria.