Transmission of Human Capital across Four Generations: Intergenerational Correlations and a Test of the Becker-Tomes Model*

by

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Abstract

Most previous studies on intergenerational transmission of human capital are restricted to two generations - between the parent and the child generation. In this paper we investigate if there is an independent effect of the grandparent and the great grandparent generations in this process. We use a dataset where we are able to link individual measures of life time earnings for three generation and data on educational attainments of four generations. We first do conventional regressions and transition matrices for life time earnings measures and educational attainments adding variables for the grandparent and great grandparent generations, respectively. We find that grandparents and even great grandparents significantly influence earnings and education. We then estimate the so called Becker-Tomes model using the educational attainment of the great grandparent generation as an instrumental variable. We fail to find support for the model's predictions.

Keywords: Intergenerational income mobility, earnings distribution, income inequality
JEL-Codes: D31; J62

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1 Introduction

Although most families have close connections with their grandparent or even great grandparent generations and most people would admit strong influences and transmission of different resources beyond their parent generation, economic analysis of intergenerational links is almost exclusively concerned with the relation between the parent and child generations. Dynamic macroeconomic models e.g. of human and physical capital investments, fertility and inequality as well as and models of cultural transmission and models of how parents can affect various aspects of their children's lives focus on the link between two consecutive generations (Diamond, 1965, Becker and Tomes, 1979, 1986, Becker, Murphy and Tamura, 1990, Galore and Zeira, 1993, Bisin and Verdier, 2000, Mulligan, 1995, and Saez Marti and Sjögren, 2008). Also empirical studies on intergenerational income mobility, surveyed in Solon (1999) and Black and Devereux (2010), are with a few exceptions restricted to two generations,[3] and the by far most important model for intergenerational transmission of human capital – the Becker-Tomes model – relates financial and other parental resources of the parent generation to the outcome of the child generation.

The possible independent effects of generations beyond the parent generation have important implications for how we view income inequality in a given point of time as well as how we interpret intergenerational transmission of human capital. Income inequality in a mobile society is seen as more justifiable since the individual's relative economic position to a larger extent is linked to the individual's own choices and economic performance, rather than inheritance from previous generations. An often used example (see e.g. Borjas, 2009), departs from an initial income difference on 20 percent between two families. If there is an intergenerational correlation on 0.3 we expect only 30 percent of this difference, or 6 percentage points, remains in the second generation. In the third generation difference is almost entirely eliminated, since only 1.8 percent is expected to remain. This example relies, however, critically on the assumption that the intergenerational transmission process of human capital has a memory of only one period. If this is not the case, the income convergence will take longer.

In this paper we investigate if there is an independent effect of the grandparent and the great grandparent generation in the intergenerational transmission of human capital. Is the

[3] Examples of some studies that focus on estimating relationship between outcomes (education or occupation) for grandparents and grandchildren are Behrman and Taubman (1985), Maurin (2002), Sacerdote (2004), Sauder (2006) and Warren and Hauser (1997).

AR(1) process used in most studies on intergenerational income mobility sufficient for describing the income process across generations and to predict the income distribution for future generations? To answer this question we use an exceptional data set containing measures of life time earnings for three consecutive generations and data on educational attainments for four generations. The data set is based on a survey of all third graders in Sweden's third largest city, Malmö, and its suburbs, in 1938. This *index* generation has been followed until retirement and the identity and information on parents, spouses, children and grandchildren have been added. The first generation is, on average, born late in the nineteenth century and the fourth generation is typically finishing their education in the early twenty-first century. Altogether there are 901 complete families, i.e. families with education data available on at least one individual in each of four consecutive generations.

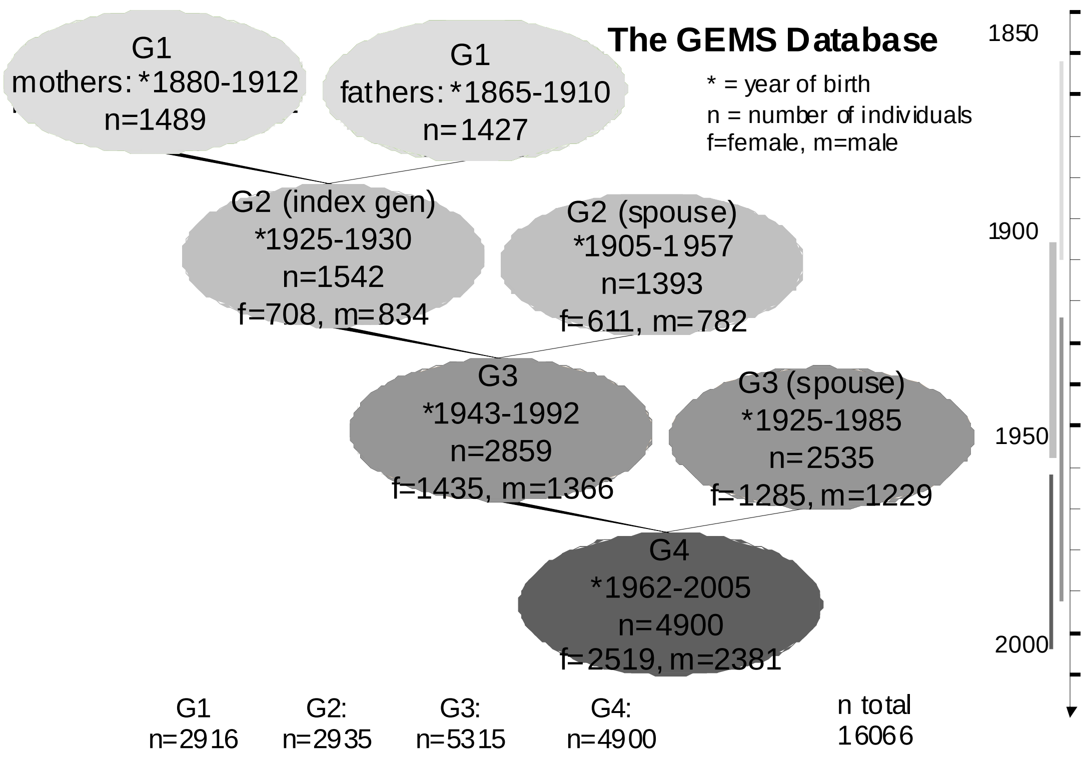
The empirical analysis is carried out in two steps. First, we estimate AR(1) models using OLS to investigate whether or not the analysis built on data from two consecutive generations can predict the correlations between the incomes of the child and grandparent generations for life time income and between the child and the great grandparent generations for educational attainments. We explore heterogeneity in the intergenerational links in different parts of the income and educational distribution using an analysis built on transition matrices. We conclude that grandparents and even great grandparents influence child earnings and education more than predicted by the correlation between two consecutive generations. As a second step we test implications of the Becker-Tomes model for educational attainments using instrumental variables techniques. This is feasible since we have data on educational attainments of the great grandparent generation, which is used as an instrumental variable for the educational attainments of the grandparent generation. This approach was suggested already in Becker and Tomes (1986), but because of lack of data on four generations, has never been implemented. We fail to find support for the model's prediction.

The paper proceeds as follows. Section 2 presents the data set, discusses the construction of variables and provides some descriptive statistics of the variables used in this study. In section 3 we present descriptive estimations from associating outcomes of children with those of parents, grandparents (income and education) and great grandparents (education). In section 4 we present the simple Becker-Tomes model of intergenerational transmission and test it using data on education spanning four generations. Section 5 concludes.

2 Data and Descriptive Statistics

Figure 1 shows a schematic overview of the dataset consisting of information for individuals from four generations of the same family. The data originally stems from the so called Malmö Study, a survey initiated in 1938 by a team of educational researchers.[4] All pupils attending third grade (at age 10) in any school in city of Malmö with suburbs (n=1,542) were part of the original survey and constitute the *index*, or second, generation. The original purpose was to analyze the correlation between social surroundings and cognitive ability. Hence a host of family background information was collected, including parental earnings for several years and father's education. The Malmö Study has since been extended with information from both several rounds of follow up surveys and register data over the years. The last collection of data using questionnaires to the initially sampled children was conducted 55 years after the first survey, i.e. in 1993.[5] By that time, most of the individuals had reached retirement age.

Figure 1 Schematic picture of the GEMS database.



[4] The material was originally collected by Siver Hallgren and developed by Torsten Husén.
[5] In 1993 69% of the third and fourth generations lived in the county of Skåne, 8% lived in the county of Stockholm, and the rest were quite evenly spread out. 38 % lived in Malmö.

We have extended the data in several ways. We have manually added church book information on date of birth and death of the parents of the index generation. These parents constitute the first generation and were born between 1865 and 1912. We have also added register information on the second generation's children and grandchildren, as well as information on the spouses of the index generation, i.e., the second parent of these children and also of the grandchildren. The resulting dataset consists of information on four generations of the same families. The average birth year of the first generation (G1) is 1898; the second, the index generation (G2) is 1928; the third generation's, the children of the index generation (G3), average birth year is 1956; and, finally, the average birth year of the grand children of the index generation (G4) is 1994.

In the appendix we give a short historical overview related to Malmö and Sweden, focusing on the evolvement of institutions of likely importance to intergenerational mobility and the welfare state in Sweden during the relevant time period.

2.1 Data on Educational Attainment

The measure of educational attainments for the first generation is based on occupational classification for fathers from a survey in 1938. This variable was constructed by educational researchers at that time so it should be reliable at least regarding the educational requirements for different occupations at that time. However, some of these fathers may of course have been over- or undereducated for their positions.

For the second to fourth generations we have added high quality educational level data from national education registers. For the second generation we mainly use data from 1985, for the third and fourth generations from 2009. For all generations we transform the educational level measure into years of schooling based on the required number of years that has to be completed for each level.[6] To avoid the problem that some children in the youngest generation may still be in school at the time of data collection, we restrict the analysis of years of education to individuals that are at least 25 years of age in 2009, hence excluding those born after 1984.

[6] The main variable years of schooling is created using information taken from either the education register or the census. With detailed information on completed level of education, we construct years of schooling in the following way: 7 for (old) primary school, 9 for (new) compulsory schooling, 9.5 for (old) post-primary school (*realskola*), 11 for short high school, 12 for long high school, 14 for short university, 15.5 for long university, and 19 for a PhD. For those few individuals in the second generation where registry information for 1985 is missing, we use survey information from 1964. The education information from 1964 is in 6 levels, and probably of less quality than for 1985 or 2009. The conversion is one by imputing years of schooling by regressing the years of schooling variable in 1985 on indicators for the 1964 using all individuals for which educational info is available in both years. For individuals in the third generation with missing education data, we instead draw on registry information from 2005 and 1985.

To further increase the amount of available observations for the analysis of education transmission, we also construct a measure of whether or not the individual has completed an academic track in high school. This is a strong predictor of whether or not the individual continues to higher education. We are then able to include children born until 1990. This increases the sample by about 35 percent and hence makes any sample selection bias less problematic.

2.2 Measures of Life Time Earnings

The amount of earnings information available differs across generations. For the first generation, i.e. the parents of the men and women from the original survey, we have annual earnings for the years 1929, 1933, 1937, 1938 and 1942 for fathers. For the second generation (most of them born in 1928) we have earnings information already from 1948 if the individual belongs to the original Malmö sample. From 1985 and onwards we have earnings information for every single year, and before that for every third, fourth or fifth year. For the other parent of the third generation individuals, we have earnings information from 1948 if they cohabited with the Malmö-parent and from 1968 if they did not. For the third generation we have earnings information from 1968 and onwards. The fourth generation is excluded from the analysis of earnings transmission. Although there is earnings information available from 1968, too large a fraction of the fourth generation is too young to construct meaningful measures of life time earnings. The earnings data for the first generation, and for the second generation up to 1968, are manually collected from the local tax authorities. Earnings data from 1968 and onwards are based on register information. The earnings measure for the first generation is calculated as the sum of work and capital income, whereas capital income is not included in the earnings measure for the later generations.

Although the quality and amount of earnings information both differ across generations, we typically cover the most important years in the working life of parents belonging to the first three generations. For the first generation we observe father's earnings when their children surveyed in the Malmö study were age one to fourteen. The typical father in our earnings estimation sample is born in 1896, and hence have earnings observed between age 33 and 46. For the second generation, the men and women are typically born in 1928 (as is the case for the children in the Malmö study) or around these years (as is the case for the "other" parent of the Malmö study children). These men and women were born between 1888 and 1957, our coverage of their lifetime earnings depends partly on if they are cohabiting with someone from the Malmö cohort, and partly when they are born. For the third generation, typically born in the mid 1950s, we observe earnings from 1968 to 2008, hence covering most of their working life (They are born between 1943 and 1981, and more than 80 percent are born between 1950 and 1965). For the first generation, we typically observe earnings at 5 occasions over 14 years, for the second generation typically 15 observations over more than 40 years, and for the third generation, typically 20 observations over 40 years.

Because of the detailed earnings information, we can construct very good measures of lifetime earnings for the men in the first three generations. We compute our earnings measure in the following way: Utilizing all earnings data available (as long as we observed positive earnings a given year and excluding the observations when the individuals are very young: 19 years of age for the first generation, 23 for the second and 27 for the third) for each individual, we regressed log-earnings on a cubic in birth year as well as year dummies.[7]

$$\log(earnings)_{it} = \alpha + \gamma_1 birthyear_i + \gamma_2 birthyear_i^2 + \gamma_3 birthyear_i^3 + year_t + \varepsilon_{it}$$

We obtain the residual for each individual-year cell *it*, and then compute the mean residual for each individual. We use the individual specific mean of the residual, i.e. the stable part of individual earnings, as our measure of life time earnings used as the dependent variable in the earnings regressions.

2.3 Descriptive Statistics

For education there are 901 complete families, i.e. with data available on at least one individual in each generation, for four consecutive generations.[8] For earnings there are 730 families with earnings information available for one male member of the family in three consecutive generations. The main reason for attrition of families is lack of off-spring, and to a lesser extent missing information on earnings or education. Since earnings are less informative for women in the earlier years, we restrict the analysis of earnings associations to sons, fathers and grandfathers. Note that for roughly half of the earnings sample, the male family member in the second generation (the father) is not the biological son of the male

[7] This is the approach taken in e.g. Haider and Solon, 2006 and Böhlmark and Lindquist, 2006. Life cycle bias should hence not be an issue here, as we have access to reasonable lifetime income measures for both parents and children. See also Lee and Solon, 2009.

[8] We have 901 complete families with four generations when we include 4 generation children born through 1990. For this sample the education measure for the fourth generation is used is academic high school track. In order to obtain a meaningful measure of years of education for the fourth generation we restrict the analysis to children born before 1986, resulting in 673 complete families.

member of the family in the first generation (the grandfather), but instead is the son in law. This almost doubles the earnings sample.[9]

Table 1 reports descriptive statistics by generation and gender for the samples used in this study. We show statistics corresponding to the individuals in our estimation sample for education (four generations separated by gender) and earnings (three generations of men).

The first column shows means and standard deviations for the fathers of the children in the index generation (generation 2). These 905 fathers were on average born in 1896 and had 7.3 years of schooling. The next two columns show descriptive statistics for those in the index generation (first interviewed in 1938 and typically born in 1928) as well as mothers and fathers of the children in the third generation. For this second generation typically born in 1928, there are 470 men that acquired 10.2 years of schooling and 435 women that acquired 9.5 years, on average.[10] Note that earnings figures for men in the second and third generation pertain to sons and grandsons of the first generation of men as well as the male spouse of the daughters and granddaughters belonging to the index and the next generation. Hence, the dispersion in the year-of-birth variable is much higher for the men in the index generation. The last two columns show descriptive statistics for the descendants of the earlier three generations that are old enough to be included in the regressions (27 years in 2008 for earnings regressions and 25 (19) years in 2009 for education (academic high school track) regressions). The average residual of log earnings, with means and standard deviations reported in the third row, summarizes the earnings measure actually used the in estimations.[11]

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[9] As a check, we also estimated transmission coefficients for education using these sample restrictions. The estimates are then very similar to the ones using only individuals that are biologically related across the four generations (which are the estimates reported in Table 2).

[10] Although not shown, earnings increased from about 86,000 SEK (calculated in 1933) for the men in the first generation to 311,000 SEK (in 2000) for the men in the third generation, all expressed in 2010 year prizes.

[11] Note that they are based on averages (and hence standard deviation<1) and are negative because those with fewer years of earnings data have lower earnings.

Table 1 Descriptive statistics

	Generation 1 (great grandparents)	Generation 2 (grandparents)		Generation 3 (parents)		Generation 4 (children)	
Variable	Great grandfather (1)	Grandmother (3)	Grandfather (4)	Mother (5)	Father (6)	Daughter (7)	Son (8)
Years of schooling	7.30 (1.60) [5,14]	9.53 (2.67) [7,19]	10.15 (2.96) [7,20]	12.05 (2.47) [7,20]	12.11 (2.59) [7,20]	12.95 (1.98) [7,20]	12.42 (2.13) [7,20]
Academic high school track						0.55 (0.50) [0,1]	0.44 (0.50) [0,1]
Average residual log earnings	-0.047 (0.529) [-1.74,2.76]		-0.018 (0.637) [-2.71,2.26]		-0.121 (0.763) [-4.11,1.90]		
Year of birth (Education)	1896.12 (7.20) [1859,1910]	1927.91 (0.40) [1925,1930]	1927.87 (0.40) [1926,1929]	1954.67 (4.90) [1944,1970]	1954.53 (4.46) [1943,1969]	1981.45 (6.30) [1962,1990]	1981.49 (6.35) [1962,1990]
Year of birth (Earnings)	1895.70 (7.48) [1865,1910]		1926.73 (3.27) [1888,1947]		1956.69 (5.54) [1943,1981]		
Number of observations (Education)	905	435	470	831	722	1,451	1,548
Number of observations (Earnings)	803		1,174		1,174		

Notes: The education numbers are calculated for the observations used in table 2 (column 1) and table 3 (columns 1-2) and the earnings numbers are calculated for the observations used in Table 5. The statistics for year of schooling for generation 4 is calculated for those born before 1985 (887 daughters and 936 sons).

3 Results

3.1 Intergenerational persistence in educational attainments

Table 2 shows the first set of results: the estimated transmission coefficients for education across the four generations under study. All estimates are results from estimation of bivariate regression models such as

$$y_t = a + by_{t-j} + u_t, \text{ where } j \geq 1 \qquad (2)$$

and where y_t is the outcome of the child and y_{t-j} is outcome of the parent (j=1), grandparent (j=2) or great grandparent (j=3). Since the last generation in many cases has not yet completed their education at the date of the data collection, the last row in Table 2 reports linear probability model estimates of the association between the probability of having completed an academic oriented high school track and earlier generations' educational attainments measured in years of education. The estimates (standard errors) are outcomes from regressions using unstandardized variables. We report standardized estimates in brackets.

Table 2 shows two interesting outcomes. First, the statistically significant 0.137 estimate for the association between the great grandfather's educational attainment and that of the great grandchild shows that there is a persistent correlation despite the fact that there are two generations, or on average 75 years, between the two studied generations. Second, the association between educational outcomes of the great grandparent generation and the child generation as well as between the great grandparent generation and the parent generation is stronger than what would be expected if we were to predict these correlations based on the correlation between the adjacent generations involved.

The second result is easily obtained by multiplying the diagonal elements in the transition matrix. For example, multiplying the correlation between the first and second generations, 0.607, with that between the second and third, 0.281, yields a prediction for the correlation between the first and the third generation on 0.171. By applying the delta-method we obtain an approximate of bounds for the standard error for this prediction between 0.040 and 0.046.[12] These approximated bounds enable us to formally test and reject that the obtained

[12] The approximation of the variance for the product of β_1 and β_2, where β_1 is the correlation between generation one and two and β_2 is the correlation between generation two and three, is $\beta_1^2\sigma_{\beta_1}^2 + \beta_2^2\sigma_{\beta_2}^2 + 2\beta_1\beta_2\sigma_{\beta_1\beta_2}$. Since we are not able to estimate $\sigma_{\beta_1\beta_2}$, we instead depart from our

prediction is equal to the correlation between the first and the third generation, which was estimated to 0.375.

Table 2 Matrix of estimated transmission coefficients across generations: Education

	Years of Schooling – great grandparent (1)	Years of Schooling – grandparent (2)	Years of Schooling – parent (3)
Years of Schooling - grandparent	0.607*** (0.065) [0.334] N=905		
Years of Schooling – parent	0.375*** (0.043) [0.229] N=1553	0.281*** (0.024) [0.312] N=1553	
Years of Schooling – child	0.145*** (0.046) [0.123] N=1823	0.131*** (0.023) [0.202] N=1823	0.296*** (0.021) [0.412] N=1823
Academic HS studies (=1) – child	0.032*** (0.007) [0.104] N=2999	0.028*** (0.004) [0.163] N=2999	0.066*** (0.004) [0.343] N=2999

Notes: Each reported estimate is from a separate regression of the child's education on education of education of the ancestor. All regressions control for a quadratic in birth year of both generations. The reported standard errors (in parentheses) are clustered on families. Standardized estimates are reported in brackets.

Table 3 reports the results when we have estimated the intergenerational transmission coefficients separately by gender of offspring and ancestor. The most striking feature of these estimates is that the intergenerational correlation in educational attainments seems to be independent of the gender of both ancestor and offspring. For example, the correlation between the first and the third generation is almost the same for males and females in the first generation.

estimates of σ_{β_1}, σ_{β_2} and the fact that the maximum correlation coefficient value is 1 to obtain an upper bound for $\sigma_{\beta_1\beta_2}$. For the lower bound $\sigma_{\beta_1\beta_2}$ is set to 0.

Table 3 Matrix of estimated transmission coefficients across generations: Years of education

	great grandfather	grandmother	grandfather	mother	father
Years of Schooling – grandmother	0.565*** (0.076) [0.311] N=435				
Years of Schooling – grandfather	0.661*** (0.118) [0.364] N=470				
Years of Schooling – mother	0.344*** (0.049) [0.210] N=831	0.287*** (0.047) [0.319] N=415	0.273*** (0.039) [0.303] N=416		
Years of Schooling – father	0.409*** (0.060) [0.250] N=722	0.322*** (0.057) [0.357] N=335	0.249*** (0.048) [0.277] N=387		
Years of Schooling – daughter	0.159*** (0.062) [0.135] N=887	0.135*** (0.043) [0.208] N=461	0.117*** (0.040) [0.181] N=426	0.305*** (0.039) [0.425] N=556	0.228*** (0.041) [0.318] N=331
Years of Schooling – son	0.133** (0.052) [0.113] N=936	0.118*** (0.041) [0.183] N=483	0.146*** (0.042) [0.226] N=453	0.306*** (0.042) [0.426] N=521	0.328*** (0.035) [0.458] N=886
Academic HS track – daughter	0.035*** (0.009) [0.112] N=1451	0.022*** (0.008) [0.129] N=713	0.030*** (0.007) [0.172] N=738	0.069*** (0.007) [0.358] N=815	0.055*** (0.008) [0.289] N=636
Academic HS track – son	0.029*** (0.010) [0.093] N=1548	0.030*** (0.008) [0.176] N=747	0.028*** (0.007) [0.160] N=801	0.066*** (0.007) [0.343] N=829	0.071*** (0.006) [0.368] N=719

Notes: Each reported estimate is from a separate regression of the child's education on education of education of the ancestor. All regressions control for a quadratic in birth year of both generations. The reported standard errors (in parentheses) are clustered on families. Standardized estimates are reported in brackets.

Changes in education distributions and possible changes in the meaning of a particular number of years of education over time and possible non-linearities in the transmission process are not fully captured in the linearly estimated transmission coefficients. We therefore compute intergenerational transmission probabilities across education categories and corresponding odds ratios. The results are reported in Tables 4a through 4d. For each generation we define four levels of education, from compulsory to university education. Transmission probabilities and odds ratios confirm the main result from Table 2, namely that there is substantial persistence in the attained education level across generations. In particular, Table 4c shows that there is a much higher probability that an individual belongs to the same education level as his ancestor even after four generations than to belong to any other education category. In addition, these transition probabilities indicate a presence of non-linearities: There seems to be higher persistence in the upper end of the education distribution. People with more than compulsory education in the first generation are on average between 49 and 67 percent more likely to have great grandchildren with university education, whereas people with only compulsory schooling are 3 percent more likely to have great grandchildren with the same educational attainments.

Table 4a Education of children (generation 2) conditional on education of parents (generation 1), transition probabilities and odds ratios

Education of parents (generation 1)		Education of children (generation 2) Compulsory	Post Compulsory: short or vocational	High school	University	All $P_{i.}$ $Obs_{i.}$
Compulsory	P_{1j}	0.50	0.32	0.14	0.04	0.85
	$P_{1j}/P_{.j}$	1.12	1.01	0.86	0.54	765
Post compulsory:	P_{2j}	0.23	0.31	0.31	0.16	0.08
Some vocational	$P_{2j}/P_{.j}$	0.50	0.99	1.85	2.19	75
Post compulsory:	P_{3j}	0.08	0.32	0.30	0.30	0.04
theoretical (short)	$P_{3j}/P_{.j}$	0.18	1.04	1.79	4.08	37
High School/	P_{4j}	0.11	0.18	0.25	0.46	0.03
University	$P_{4j}/P_{.j}$	0.24	0.58	1.51	6.37	28
All	$P_{.j}$	0.45	0.31	0.17	0.07	
	$Obs_{.j}$	408	281	150	66	905

Notes: Education generation 1: compulsory max 8 yrs, post-compulsory: vocational 9 yrs, post-compulsory: theoretical (Real skola) 10 years, high school or university: min 12 years
Education generation 2: compulsory max 9 yrs, post-compulsory: short theoretical or vocational high school (Real or short high school) 10-11 yrs, Theoretical High school 12-14 yrs, university: min 15 yrs

Table 4b Education of grandchildren (generation 3) conditional on education of grandparents (generation 1), transition probabilities and odds ratios

Education of grandparents (generation 1)		Education of grandchildren (generation 3): Compulsory	Post Compulsory: short or vocational	High school	University	All $P_{i.}$ $Obs_{i.}$
Compulsory	P_{1j}	0.20	0.40	0.26	0.15	0.85
	$P_{1j}/P_{.j}$	1.08	1.09	0.98	0.79	1317
Post compulsory:	P_{2j}	0.13	0.23	0.30	0.34	0.08
Some vocational	$P_{2j}/P_{.j}$	0.69	0.64	1.11	1.84	128
Post compulsory:	P_{3j}	0.10	0.15	0.33	0.42	0.04
theoretical (short)	$P_{3j}/P_{.j}$	0.55	0.41	1.24	2.23	60
High School/	P_{4j}	0.02	0.13	0.29	0.56	0.03
University	$P_{4j}/P_{.j}$	0.12	0.34	1.09	3.01	48
All	$P_{.j}$	0.18	0.37	0.27	0.19	
	$Obs_{.j}$	280	567	416	290	1553

Education generation 1: compulsory max 8 yrs, post-compulsory: vocational 9 yrs, post-compulsory: theoretical (Real skola) 10 years, high school or university: min 12 years
Education generation 3: compulsory max 9 yrs, post-compulsory: short theoretical or vocational high school (Real or short high school) 10-11 yrs, Theoretical High school 12-14 yrs, university: min 15 yrs

Table 4c Education of great grandchildren (generation 4) conditional on education of great grandparents (generation 1), transition probabilities and odds ratios. (families with 4th generation born before 1985)

Education of Gr. Grandparents. (generation 1)		Education of great grandchildren (generation 4): Compulsory	Post Compulsory: short or vocational	High school	University	All Pi. Obsi.
Compulsory	P1j	0.10	0.16	0.50	0.24	0.89
	P1j/P.j	1.03	1.05	1.01	0.93	1620
Post compulsory:	P2j	0.09	0.07	0.46	0.38	0.07
Some vocational	P2j/P.j	0.93	0.43	0.94	1.49	121
Post compulsory:	P3j	0.04	0.13	0.40	0.43	0.03
theoretical (short)	P3j/P.j	0.43	0.82	0.82	1.67	47
High School/	P4j	0.06	0.11	0.43	0.40	0.02
University	P4j/P.j	0.58	0.74	0.87	1.57	35
All	P.j	0.10	0.16	0.49	0.25	
	Obs.j	179	283	897	464	1823

Education generation 1: compulsory max 8 yrs, post-compulsory: vocational 9 yrs, post-compulsory: theoretical (Real skola) 10 years, high school or university: min 12 years
Education generation 4: compulsory max 9 yrs, post-compulsory: short theoretical or vocational high school (Real or short high school) 10-11 yrs, Theoretical High school 12-14 yrs, university: min 15 yrs

Table 4d Education of great grandchildren (generation 4) conditional on education of great grandparents (generation 1), transition probabilities and odds ratios. (families with 4th generation born before 1990)

Education of Gr. grandparents (generation 1)		Education of great grandchildren (generation 4): Compulsory or vocational highschool track	Academic highschool track	All $P_{i.}$ $Obs_{i.}$
Compulsory	P_{1j}	0.53	0.47	0.86
	$P_{1j}/P_{.j}$	1.04	0.95	2567
Post compulsory:	P_{2j}	0.40	0.60	0.08
Some vocational	$P_{2j}/P_{.j}$	0.79	1.22	238
Post compulsory:	P_{3j}	0.38	0.62	0.04
theoretical (short)	$P_{3j}/P_{.j}$	0.75	1.26	111
High School/	P_{4j}	0.29	0.71	0.03
University	$P_{4j}/P_{.j}$	0.57	1.44	83
		0.51	0.49	
All	$P_{.j}$	1521	1478	2999
	$Obs_{.j}$	0.53	0.47	0.86

Education generation 1: compulsory max 8 yrs, post-compulsory: vocational 9 yrs, post-compulsory: theoretical (Real skola) 10 years, high school or university: min 12 years
Education generation 4: Compulsory or vocational highschool track, academic track measured at earliest age 19

3.2 Intergenerational persistence in earnings

Table 5 shows the estimates of intergenerational earnings mobility between the first and second generation, the second and third generations as well as between the first and third generation, respectively. Although Swedish society has undergone fundamental changes between the most active period of the first generation born around 1900 and the third generation mostly born in the 1950s and 60s, the correlation in earnings between consecutive generations seems to be quite stable: 0.356 between the first and the second generation and 0.303 between the second and third. This finding is very much in line with what have been found in previous studies (see e.g. Black and Devereux, 2011, for an overview).

The results in Table 5 allow us to predict the earnings mobility between the first and third generations from the two two-generation mobility measures. This gives us a prediction of 0.108, which is substantially lower than the estimate of 0.184 obtained from data. Again applying the bounding exercise for the delta method as explained in footnote 11 gives an estimate of the standard error between 0.020 and 0.028. A *t*-test of equality between the predicted and the estimated three-generation mobility measure gives a *t*-value between 1.47 and 1.58, i.e., indicating a marginally significant difference.

Table 5 Matrix of estimated transmission coefficients across generations: log earnings of male offspring regressed on log earnings of male ancestor

offspring	Ancestor	
	grandparent	parent
Log(Earnings) – parent .	0.356*** (0.040) [0.307] N=803	
Log(Earnings) – child	0.184*** (0.044) [0.141] N=1174	0.303*** (0.043) [0.268] N=1174

Notes: Each reported estimate is from a separate regression of the son's residual log earnings on residual log earnings of the ancestor. The earnings measures are average residual log-earnings from a regression of log earnings on a cubic in birth year and year dummies (see section 2). The reported standard errors (in parentheses) are clustered on families. Standardized estimates are reported in brackets.

As in the case of education, it is interesting to explore a presence of non-linearities in the transmission of earnings across generations. We do this by means of transmission matrices. Table 6 shows transition matrices for income quintiles across generations. The first panel reports the transition probabilities between the first and the second generation; the second panel the corresponding figures for the second and third generation; finally, the third panel shows the transitions between the first and the third generations.

There is one results of particular interest revealed in Table 6: the persistence, in particular across two consecutive generations, seems to be higher in the higher end of the income distribution. The highest persistence in all three panels is found for the fifth quintile, i.e. the top 20 percent of earnings. As much as 34 percent of the grandchildren of the individuals in the fifth quintile remain in the very top of the income distribution. Interestingly, the persistence in this cell is almost as high when we compare grandfathers and grandsons (first and third generations) as when the grandsons are instead compared to their fathers (second and third generations).

Table 6 Transition matrices: offspring earnings quintile conditional on ancestor's earnings quintile.

Earnings quintile of ancestor	Earnings quintile of offspring				
			Fathers		
Grandfathers	Q1	Q2	Q3	Q4	Q5
Q1	0.30	0.29	0.21	0.11	0.10
Q2	0.25	0.20	0.20	0.23	0.11
Q3	0.16	0.20	0.26	0.22	0.17
Q4	0.16	0.18	0.21	0.27	0.18
Q5	0.14	0.14	0.11	0.18	0.44
			Sons		
Fathers	Q1	Q2	Q3	Q4	Q5
Q1	0.31	0.26	0.17	0.18	0.09
Q2	0.20	0.24	0.19	0.20	0.18
Q3	0.21	0.18	0.28	0.18	0.15
Q4	0.15	0.18	0.22	0.22	0.23
Q5	0.14	0.15	0.14	0.23	0.35
			Sons		
Grandfathers	Q1	Q2	Q3	Q4	Q5
Q1	0.19	0.23	0.21	0.24	0.14
Q2	0.23	0.22	0.23	0.17	0.14
Q3	0.25	0.19	0.20	0.20	0.16
Q4	0.17	0.20	0.21	0.20	0.22
Q5	0.16	0.16	0.16	0.18	0.34

Notes: fathers and sons; 774 families

If we briefly summarize results from our descriptive estimations they point toward a surprisingly strong association between grandparental education /earnings and education/earnings of grandchildren, and between great grandparental education and education of great grandchildren. Hence, regression toward the mean takes longer time in Sweden than suggested by the in comparatively low estimates of intergenerational persistence found for two consecutive generations. In addition, transition matrices reveal that there is higher persistence in the upper end of the education and income distributions. We also find that simply taking the square of the intergenerational elasticity does not give an accurate picture of what we find using children and grandparents, suggesting that the basic assumption that intergenerational transmission follows an AR(1) process does not hold.

4 A test of the Becker-Tomes model of intergenerational transmission of human capital

We proceeds to investigate the predictions of the Becker-Tomes model using the very instrumental variables technique suggested by Becker and Tomes, but that has never been implemented for lack of data on several generations.

4.1 The model and its predictions

Consider the simplest version of the classic Becker-Tomes (BT) model of intergenerational transmission of human capital across generations:

(1) $$y_t = \alpha + \beta y_{t-1} + \rho e_t + u_t$$

(2) $$e_t = a + \lambda e_{t-1} + v_t$$

This simple model assumes; first, that income (y) of the child-generation t is a linear additive function of income in the parental generation t-1 (because of parental investment in children's human capital, where investment is credit constrained), unobserved endowment or ability (e) and an error term, and; second that the unobserved endowment is transmitted across generations through an AR(1) process. The model can be easily modified to i) explicitly describe the relationship for education instead of earnings (as in Plug and Wijverberg, 2005, and Sauder, 2006),[13] and to ii) various functional forms. In the empirical test we perform below we use education as a measure of y.

An immediate implication of this model is that a bivariate regression of children's income/education on parent's income/education leads to overestimation of β, since those with higher endowment also have higher income/education. There is, in fact, strong evidence that a simple regression of y_t on y_{t-1} leads to an upward biased estimate of β (see Björklund, Lindahl and Plug, 2006, and Holmlund, Lindahl and Plug, 2011). However, such a result is also consistent with more complicated transmission processes than suggested in (1) and (2).

The Becker-Tomes (BT) model in (1) and (2) assumes no direct effect of grandparent's on grandchildren. Grandparents affect grandchildren only indirectly through the inheritance of endowments, or ability, which is assumed to follow an AR(1) process. In the presence of

[13] In a simple model of human capital transmission between parent and child we then get somewhat different interpretations of β, depending of whether y_t and y_{t-1} represent income or education. For income, we have that β is the product of the child's return to education and parental return on investment in child's education, whereas for education, we have that β is the product of parental return on investment in child's education and parent's return to own education

credit constraints, grandparents also influence grandchildren because grandparents have invested in the human capital of parents. Interestingly, as discussed in BT, this implies a negative effect of grandparents' outcome (y_{t-2}) on children's outcome (y_t) conditional on parent's outcome (y_{t-1}).[14]

To see this, insert (2) into (1) which generates (1'); assume that equation (1) holds across all t's, so that all the parameters are constant over time, and create a first-order lagged version of (1), which we call (1''); Solve for e_{t-1} from (1'') and insert into (1'); rearrange terms. This gives:[15]

$$(3) \qquad y_t = \alpha' + (\beta + \lambda)y_{t-1} - \beta\lambda y_{t-2} + \rho v_t + u_t - \lambda u_{t-1}$$

Note that the intuition for this negative coefficient on y_{t-2}, is that a high y_{t-2} means a low e_{t-1}, for given y_{t-1}. Since, from the first-order lagged version of (1), we have that $cov(y_{t-1}, u_{t-1}) > 0$, an OLS regression of children's outcome on parent's and grandparent's outcome generate biased estimates: The coefficient on parent's earnings/education $\beta + \lambda$ will be underestimated and the coefficient on grandparents earnings/education $-\beta\lambda$ will be overestimated. We therefore need an alternative approach.

The first serious test of the grandparent's coefficient in (3) and hence of the BT model, is conducted by Behrman and Taubman (1985). Using a sample of descendents to twins, they estimate (3) and find grandparent's education to be insignificantly related to grandchildren's education using OLS, and insignificantly or significantly positive related using IV, where uncle's education is used as instrument for child's education. The sample used is based on a peculiar sample of offspring to twins, where the twins where white males born 1917-1927 and who served in the military during WWII. Hence, the results are unlikely to be generalizable to a more representative population. The offsprings' (grandchildren's) earnings are measured on average at a relatively young age 28, which also can cause well-known problems related to life-cycle bias (see Haider and Solon, 2006). Their IV approach was both novel and creative. However, it assumes that the education of a twin has no impact on educational attainment of

[14] In Solon's interpretation: There is a negative effect of grandparents on grandchildren if all of the following is true: i) the heritability (or endowment) coefficient is non-zero; b) human capital investment is productive (credit constraints is present); c) the earnings return to human capital is positive; and d) public investment in children's human capital is not perfectly equalizing.

[15] Equation (3) follows from equations (1) and (2) simply because the latter two equations constitute an AR(1) model with an autocorrelated error term, which can be rewritten as an AR(2) model, where the coefficient on the first lagged variable will be positive and the coefficient on the second lagged variable will be negative.

the co-twin's child. This assumption may be questioned since twins often relate closely to as adults and may hence influence each other's children.

An alternative approach is used in a study by Sauder (2006) using U.K. data. He finds positive impact of grandparent's education using OLS, but no effect using IV. The IV approach exploits i) two distinct schooling reforms that took place in 1947 and 1973 in the U.K. and ii) mothers' birth order as instruments for parents and grandparents education. However, using these instruments is problematic. First, it is difficult to separate cohort from reform effects of reforms that are introduced the same time in the whole nation. Second, birth-order may also affect post-education outcomes (as found in Black, Devereux and Salvanes, 2005) through other channels than educational attainment.

Our approach, suggested already by Becker and Tomes, is to use great-grandparents education as an instrument for parent's education, in a regression of children's education on parent's and grandparent's education. The identifying assumption is that great grandparent's education has no impact on great grandchildren's education, over and above the impact through parent's and grandparent's education. This assumption necessarily holds in the Becker-Tomes model (1) and (2). Since we have four generations of data for education, we can apply this approach here.

4.2 Empirical test

In Table 7 we present results from regression of education of a child on the education of parents and grandparents. We show results for years of schooling and academic high school track, respectively. In columns 1 and 3, we show results from OLS regressions. We find that education of both parents and grandparents is positively related to education of children.

In columns 2 and 4, we present results from an IV regression were great grandparents education is used to instrument for parents education (controlling for grandparents education). The first stage estimates are shown at the bottom of column 2. Both first stage estimates are highly significant and the F-statistics for education of great grandparents is 30.9 in column 2 and 47.9 in column 4. Moving to the actual IV estimates in column 2, we find that they are very similar and not statistically different from the OLS estimates in column 1.[16] Although a 95% confidence interval covers a negative value of grandparents' education, we conclude that our data to not support the prediction of a negative effect from the Becker-Tomes model.[17]

[16] We have also checked for non-linear effects of schooling of ancestors in the OLS ad IV regressions, but quadratic terms are never statistically different from zero.

[17] Although we cannot reject zero effects of the schooling of grandparents in neither columns (see row 2), the p-value is 0.236 in column 2 and 0.189 in column 4.

Table 7 Test of the Becker-Tomes model: Coefficients are from OLS and IV regressions of children's education on parent's and grandparent's education

	Years of Schooling		Academic highschool track	
	OLS	IV	OLS	IV
Main equation:		Education of child		
Schooling of parent	0.264***	0.234	0.060***	0.045
	(0.023)	(0.196)	(0.004)	(0.038)
	[0.368]	[0.327]	[0.311]	[0.236]
Schooling of grandparent	0.060***	0.068	0.011***	0.015
	(0.021)	(0.057)	(0.004)	(0.011)
	[0.092]	[0.105]	[0.061]	[0.085]
Cluster	673	673	901	901
N	1,823	1,823	2,999	2,999
R2	0.194	0.194	0.126	0.122
First stage equation:		Schooling of parent		
Schooling of grandparent		0.241***		0.236***
		(0.023)		(0.017)
		[0.268]		[0.263]
Schooling of great grandparent		0.224***		0.203***
		(0.040)		(0.029)
		[0.137]		[0.124]
Cluster		673		901
N		1,823		2,999
R2		0.177		0.220

Notes: standard errors are clustered at the family.

Our results suggest that the standard Becker-Tomes model fails to capture how human capital is transmitted across generations. A natural extension is to consider a direct influence of grandparents on grandchildren and thus add grandparent's outcome, i.e. θy_{t-2}, to equation (1). If this is done, one can derive a revised equation (3), where the coefficient on y_{t-2} changes from $-\beta\lambda$ to $\theta-\beta\lambda$. Hence, if θ is large enough, we would find a positive sign on grandparents outcome in a regression of child's outcome on parent's and grandparent's outcome.[18]

[18] In this revised regression model (3) we would also have great grandparents outcome as an added right-hand side variable (whose coefficient would be equal to $-\theta\lambda$). Other simple extensions to the modeling framework in equations (1) and (2) are of course also possible. For example we could add e_{t-2} to equation (2), hence allowing for the endowment or cultural transmission to children to come from both parents and grandparents. This is more likely to give a positive coefficient on y_{t-2} the higher is the endowment transmission from grandparents relative the endowment transmission from the parents, and the lower is β in equation (1). Another example is to add an

5 Conclusions

We have explored intergenerational transmission of economic status across adjacent and distant generations over the span of a century. Our data enable us to link great grand-parents born at the end of the 19th century to great grand-children finishing their education in the early 21st century. We estimate intergenerational correlations in educational attainments between these generations and income correlations between the first generation and their grand children. Finally, we test implications of the well known Becker-Tomes model on intergenerational transmission of human capital using educational attainments of the first generation as an instrumental variable.

We find a striking persistence in educational attainments across generations. There is a significant correlation between the educational attainments of the first generation and their great grand children. The great grand children of the people with more than just compulsory education in the first generation are 55 percent more likely to have university education than the great grand children of those with compulsory education only. People in the highest quintile in the earnings distribution are more than twice as likely to have grand children in the highest income quintile as the rest of the population.

From the estimates of the intergenerational correlations in both educational attainments and earnings we can reject simple extrapolations from correlations between adjacent cohorts to more distant ones as suggested in elementary text books on labor economics, such as Borjas (2009). This implies that the persistence of income inequality across generations is stronger than we would expect from the numerous studies on mobility in earnings and educational attainments using only two generations. Generations before the parental generation seem to spill over in the process of human capital mobility across generations.

In the final part of the empirical analysis we extend the estimates of intergenerational correlations to also have a causal interpretation of how the human capital of parents affects the outcome of their children. The most plausible interpretation of our rejection of the Becker-Tomes model is that the model does not allow for a direct independent effect of generations beyond the parent generation. This interpretation is compatible with our results from the analysis of intergenerational correlations in the first empirical part of this paper.

interaction term $y_{t-1}e_t$ to equation (1), which would mean that endowment or culture is transmitted differently across the income distribution, perhaps because of nature-nurture interactions.

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Appendix: Institutional Background

The four generations studied in this paper span a century during which Swedish society was transformed from early industrialization to present day welfare society. While subsidized childcare, generous child allowances, free schooling through high school, generous grants and loans for higher education, social security, unemployment benefits, free health care and pensions constitute today's welfare system, society in Malmö in the beginning of the 20th century had some, but not all of these institutions in place, when the parents of the initially sampled index generation grew up.

Malmö is located in the southern part of Sweden. It was and is by population size Sweden's third city. At the beginning of the 20th century Malmö grew at a rapid pace and tripled its population from 61,000 to 192,000 between 1900 and 1950, compared to today's 300,000. Much of the population growth was a result of rapid urbanization. Malmö was early on one of the most industrialized cities in Sweden. When the original data collection of the Malmö study was initiated, in 1938, three large employers dominated.[19] After 1960, an increasing fraction was employed within the public sector and by 1980, 20% of the men and 50% of the women held public sector jobs.

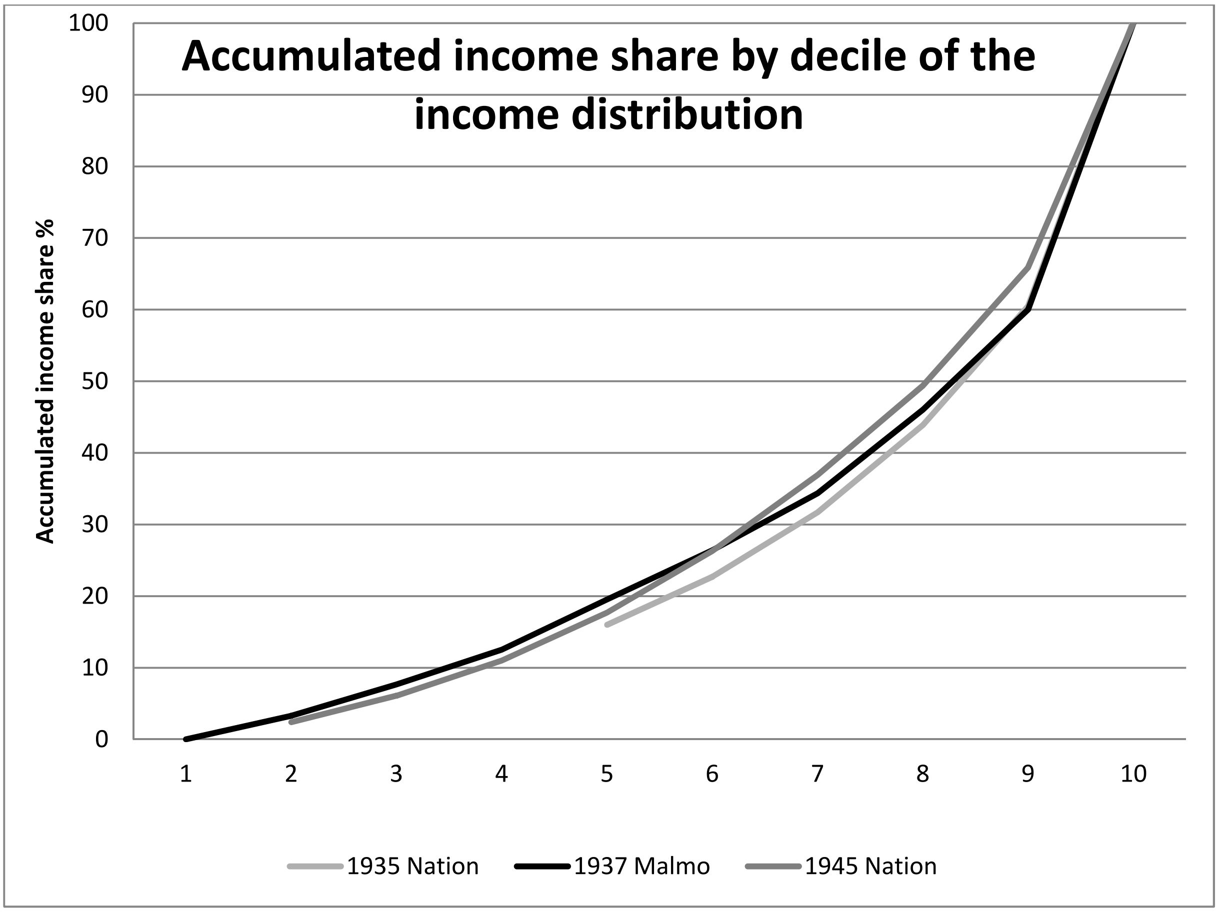
In the early 20th century, Swedish compulsory schooling was only six years, but a seventh year of was introduced already in 1914 in Malmö. Yet, many children kept leaving school after six years. Seven years of schooling only become the norm around 1920 when a municipal grant was introduced to compensate poor families for the lost earnings during the seventh year of school. This grant existed until 1936 when compulsory schooling was extended to 7 years throughout Sweden. In the late 1930's almost a third of all Malmö children continued beyond compulsory schooling. School enrolment, was hence higher than in the rest of Sweden. Malmö was also the first large municipality to extend compulsory schooling to 9 years in 1962. Arguably, basic educational infrastructure was well developed and accessible already to the index-generation studied here.

Since the 1920's, loans to help finance higher education were in principle available to the tiny fraction of young people qualified to studying at Universities. In the late 1950's student loans were also made available for studies at the high school level. The present day generous grant and loans program for university students was introduced in 1964. Since then, credit constraints are arguably unlikely to play a role for higher education choices.

[19] *Kockums*, a shipbuilding company and mechanical workshop, with 2,300 employees; *Skånska Cement*, a construction company, with almost 2,000 employes; and *Malmö strumpfabrik*, a stocking factory, with more than 1,000 employees.

Although our sample is not a random sample from the Swedish population, Malmö was (and is) a fairly representative city in Sweden. This can be seen if we compare the earnings distribution for our first generation from Malmö (using our sample) with the earnings distribution for the entire county. To do this we use estimates of the earnings distribution obtained by Bentzel (1952), who used tax registers to construct measures of the Swedish income distribution. Figure 2 compares the earnings distribution of the first generation in our data in 1937 with those obtained by Bentzel for the years 1935 and 1945. It is interesting to note that the income distribution among the Malmö families does not deviate drastically from the national income distribution.

Figure 2 A comparison of earnings distribution for the first generation in the Malmo data for 1937 with those obtained by Bentzel (1952) for Sweden in 1935 and 1945.



Source: Own computation based on Malmo data and Bentzel (1952).