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Application of the Correlated Mare Model**

James McIntosh and Martin D. Munk

For additional information please contact:

Name: Martin D. Munk

Affiliation: Aalborg University

Email Address: mdm@epa.aau.dk

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FAMILY BACKGROUND AND CHANGING EDUCATIONAL CHOICES IN DENMARK: AN APPLICATION OF THE CORRELATED MARE MODEL

James McIntosh^{1,2} and Martin D. Munk³

¹Economics Department
Concordia University
1455 De Maisonneuve Blvd. W.
Montreal Quebec, H3G 1M8, Canada

and

²Danish National Centre For Social Research
Herluf Trolles Gade 11
DK-1052 Copenhagen K, Denmark

and

³Centre for Mobility Research
Department of Economics, Politics, and Public Administration
CIT - Aalborg University, Copenhagen
Lautrupvang 2 DK-2750 Ballerup, Denmark

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E-mail Addresses and Telephone Numbers: jamesm@vax2.concordia.ca, +1-514-848 2424-3910 and mdm@epa.aau.dk. +45-9940 2335.

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Abstract

We examine the participation in upper secondary and tertiary education in 1985 and 2005 using a generalization of the famous Mare educational transition model. The large expansion of secondary education in this twenty year period was characterized by a phenomenal increase in the proportion of this age group which obtained a gymnasium

qualification. We find that factors not related to the observable characteristics of the household in which the respondent was raised have become more important relative to family background variables for upper secondary school success than they were a generation ago. As a result Denmark has become a more mobile society. This conclusion is based on a new mobility index which we have developed to measure the relative dependence of respondent educational success on family background variables.

1 Introduction

The purpose of this research is to determine whether there have been any changes in intergenerational educational mobility for recent cohorts of Danes. In this paper we first examine participation in upper secondary education of two cohorts of Danish males and females who were aged 23 in 1985 and 2005, respectively. This is done by estimating Lillard-Willis (1994) bivariate probability models or correlated Mare models on each cohort for both males and females and comparing the degree of dependency of educational attainment outcomes on the respondents' family background across these two cohorts. The approach used here can be seen as a generalization of the Mare (1980) model where the random components in the latent variables which determine each stage outcome are no longer independent. We also look at attendance rates in tertiary education at age 23 in 1985 and 2005 for these cohorts to see whether the trends that have appeared at the upper secondary level are likely to continue on into post-secondary education.

Upper secondary education is the place to begin the analysis of educational mobility since, as Table 1 shows, there have been phenomenal changes in the way Danish students have completed their upper secondary schooling. For example, the proportion of females who had completed a gymnasium qualification by the age of 23 increased from 34.1% in 1985 to 54.9% in 2005, a huge increase for such a short period of time. Upper secondary educational attainments and their dependence on family background variables is an important issue in its own right. For individuals who do not continue in the educational system past upper secondary schooling their life-time earnings are much influenced by their lack of educational qualifications. But, of course, the most important reason for looking at upper secondary educational attainments is because what respondents achieve

at this level largely determines what educational opportunities are available at the tertiary level, especially for gaining entrance to university.

To summarize our results we find that household background variables explain a significant amount of the variation in upper secondary educational attainments for both males and females. The educational attainment of the respondent's parents and household income in which the respondent resided at age 23 turned out to be the most important variables. However, the occupations of both parents, the number of siblings that the respondent had and whether the respondent's father was unemployed or had a single mother were also significant explanatory variables. Consequently, intergenerational dependence of upper secondary educational attainments continues to be a prominent feature of Danish society. But the degree of this dependence has become relatively less important over the twenty years under consideration. We construct a new dependency index, which provides a relative measure of the overall dependence of educational outcomes on traditional observable family background variables. This index has declined significantly for both males and females. Traditional family background variables have become less important relative to the intercept terms which have increased dramatically in our statistical models. Like the regression model, these capture unobservable effects like changes in the structure of the Danish educational system and social policy as well as possible changes in preferences for educational streams, or changes in the importance of further education.

These intercept term increases also generate higher probabilities of completing a gymnasium qualification for respondents coming from socially disadvantaged backgrounds, especially for females. The large increases in the proportion of successful gymnasium completions by age 23 has been matched by an even more impressive increase in the university participation rate, especially by individuals who have parents with low levels of education, low status occupations, or low level of household income.

However, the index that we employ gives results that may not necessarily agree with conventional notions of mobility. While the probabilities of going to gymnasium have improved for all social groups some social groups like high income households have improved their relative advantage in their ability to send their children to a gymnasium. How our index relates to what other researchers use is discussed in detail in section 6.

The paper is organized in the following way. The next section discusses some methodological problems that arise in educational mobility research. Section 3 reviews the relevant literature on changes in educational mobility. Section 4 outlines the data used in the study. Section 5 describes a new estimation procedure which is based on a generalization of the Mare transition model. The results appear in section 6 and are discussed in section 7. The analysis of upper secondary education is done first. We then briefly discuss what has happened at the tertiary level at the end of this section.

2 Methodological issues and modelling procedures

The question that we address in this paper is whether there has been any change between 1985 and 2005 in the dependence of upper secondary educational choices on the family backgrounds of Danish students making them. While the question is quite straightforward providing an answer is not. To illustrate what the problems are we will consider a number of simple examples beginning with the classical regression model and then going on to models which deal with discrete outcomes.

Suppose that we want to examine the dependence of the continuous variable y_{it} on another continuous variable x_{it} where the subscripts i and t refer to the respondent and the time period, respectively. We will assume that there are two times t_1 and t_2 with $t_1 < t_2$. Most researchers would examine this type of data in a regression context and estimate the model

$$y_{it} = \alpha_0 + \alpha_1 x_{it} + \epsilon_{it} \tag{1}$$

for both time periods and then determine whether the dependence of y on x had increased or decreased by looking at the ordinary least squares estimates of (α_0, α_1) . In equation (1) ϵ_{it} is an error term with a zero mean and is identically distributed over individuals and independent from x_{it} .

Dependence will have certainly decreased if the estimate of α_1 is lower in the second period. But it will have also decreased if the intercept term, α_0 , is higher in the second period. The reason for this is because the intercept term captures the effect on y of variables which have been omitted from equation (1). To see why this is the case suppose

that the true data generation process is given by

$$y_{it} = \alpha_1 x_{it} + \alpha_2 w_{it} \quad (2)$$

where w_{it} is orthogonal to x_{it} but can not be observed by the researcher. This can be made to look like the standard zero mean error regression model in equation (1) by letting \bar{w}_t be the sample mean of w_{it} and then adding and subtracting $\alpha_2 \bar{w}_t$ to and from the right hand side of equation (2) which makes $\alpha_0 = \alpha_2 \bar{w}_t$ which is the average effect of the unobservable variables and $\epsilon_{it} = \alpha_2 (w_{it} - \bar{w}_t)$ is the effect of the unobservables which are specific to individual i .

When the intercept term increases dependence has declined relatively in the sense that x is less important relative to the omitted variables in time 2 than it was in period 1 although α_2 has remained constant over the two times.

There is a third case where dependence decreases over the two times and that is when σ_t , the standard deviation of ϵ_{it} increases. When this happens dependence decreases because the importance of random effects on y have increased over the two time periods. This is also a relative comparison since more of the variation in y is being explained by random effects relative to the effects which are due to x . Björklund and Jäntti (2000) have also noted this in their analysis of intergenerational income mobility.

The situation becomes more complicated when there are many regressors. This means that α and X_{it} are now vectors with the first element of X_{it} being a vector of ones making α_0 the intercept term as in the case in equation (1). This leads to

$$y_{it} = \alpha X_{it} + \epsilon_{it} \quad (3)$$

It is possible to compare the individual coefficients but often a summary statistic which depends on all of the regression parameters can be needed. If an index, whose purpose is for making intertemporal comparisons, is going to be constructed the coefficients upon which the index is based have to reflect the importance of the regressors. Equation (3) does not do this but it can be replaced by

$$y_{it} = \beta Z_{it} + \epsilon_{it} \quad (4)$$

where Z_{it} is a vector of normalized (zero mean and unit variance) variables. Note that the inferences for β are the same as those for α and the statistical properties of the model

have not changed but now the size of the β coefficients reflects the importance of the variable.

As an index which can be used for comparative purposes we propose

$$I(\beta) = \|\beta\|/\|\beta_0, \beta\| \quad (5)$$

In equation (5) $\|\beta\|$ is the norm of the ‘slope’ coefficients and $\|\beta_0, \beta\|$ is the norm of the vector which also contains the intercept. The norm of a vector is just its length¹. This index is a simple way of expressing the importance of the slope coefficients relative to the intercept term and low values of the index indicate low levels of dependence. This index gives equal weighting to all of the regression coefficients once they have been normalized to take account of their importance. In section (6) the index will be expanded to take account of random effects in probability models (changes in σ_t).

In our view mobility is about inheritance mechanisms or equivalently about how an individual’s life chances depend on the characteristics of the household in which they resided as a child and an adolescent. $I(\beta)$ is a measure of this dependence and it takes the value zero if all of the slope coefficients are equal to zero which is the case when the outcome in question is not determined by any of the individual’s family background variables like the wealth or social position of the individual’s parents. When $I(\beta) = 0$ this describes a society which exhibits perfect mobility. For other sociologists a perfectly mobile society is one in which the odds associated with categories i and j in an outcome variable are the same for all social groups which occurs when $I(\beta) = 0$. We will have more to say on this point in section 7.

The data that researchers have to use to get results in the economics and sociology of education are often not suitable for the application of regression methods. Educational choices are most often described by qualitative measures. In a classic paper Robert Mare (1980) laid the foundations for the analysis of individual progress through the educational system. In Mare type stage models the outcome variable is a vector $D_i = (D_{i1}, D_{i2}..D_{iS_i})$ Which is a sequence of ones followed by a zero for the last component indicating successful completion of first $S_i - 1$ stages but a failure to complete stage S_i . Success at each stage

¹The norm of β , $\|\beta\| = \sqrt{\sum_{k=1}^K \beta_k^2}$. And $\|\beta_0, \beta\| = \sqrt{\beta_0^2 + \sum_{k=1}^K \beta_k^2}$ where K is the number of regressors.

is modelled as a random process where success occurs when the latent variable

$$D_{is}^* = \beta_s Z_{is} + \gamma_s \theta_i + \epsilon_{is} \quad s = 1, 2 \dots S_i \quad (6)$$

is non-negative. θ_i is the ability or some other attribute of individual i and ϵ_{is} is a random effect whose distribution is usually assumed to be logistic with variance $\pi^2/3$. The ϵ_{is} are assumed to be independent across individuals and stages. When θ_i can be observed by the researcher the probability of being successful at stage s is

$$\Pr\{D_{is}^* \geq 0\} = \frac{\exp(\beta_s Z_{is} + \gamma_s \theta_i)}{1 + \exp(\beta_s Z_{is} + \gamma_s \theta_i)} \quad s = 1, 2 \dots S_i \quad (7)$$

These probabilities can be used to construct a likelihood function whose contribution from individual i is

$$L_i(D) = \prod_{s=1}^{S_i-1} \Pr\{D_{is}^* \geq 0\} \Pr\{D_{iS_i}^* < 0\} \quad (8)$$

On the other hand when θ_i can not be observed serious estimation problems arise. When there is no information on θ_i the error term for stage s becomes $\gamma_s \theta_i + \epsilon_{is}$. As Lillard and Willis (1994) noted these errors are correlated across stages because of the common dependence on θ_i and while the probability of passing or failing stage one is based on a univariate distribution, the probabilities involving first and second stage outcomes are described by a bivariate distribution, those involving the first three stage outcomes by a trivariate distribution etc. Consequently, the likelihood function in equation (8) is not the correct one for this model and when the correct model is used the estimation of the parameters quickly becomes intractable as the number of stages increases. The correct likelihood function for the three stage model can be found in Lillard and Willis page 1138.

What actually happens when researchers estimate Mare educational stage models and ignore the presence of unobservable factors like ability was first explored by Mare (1993: 365) himself and later in a classic paper by Cameron and Heckman (1998). By simulating a simple stage model with one regressor and the unobservable θ_i and $\beta_s = 1$ for all s Cameron and Heckman were able to show that the estimates, $\hat{\beta}_s$, declined as the stage increased, although the true values of β_s were all equal to 1. The cause of this is what they refer to as dynamic selection bias. Even if θ_i is normalized to have a zero

mean and unit variance for the population that starts at the beginning of the simulation the successive application of the passing criterion to each stage will select on the more able as the less able fail to succeed to higher stages. After the first stage mean ability of those who remain in the system will be greater than zero and this will increase with each stage. In order to accommodate the increasingly positive mean of $(\gamma_s \theta_i + \epsilon_{is})$, $\hat{\beta}_s$ will have to be smaller than the true parameter value and it will decline as s increases.

From these simulations Cameron and Heckman concluded that the definitive result that so many sociologists of education had found was based on a statistical flaw in the model that was being used. The major claim that many sociologists have made is that the respondent's dependence on family background variables (particularly, parental levels of education) on academic success diminishes the further the respondent advances in the schooling system. This may or may not be correct but when it is shown that this is what will happen when there are inadequate controls for the effects of unobservable variables the only alternative is to start afresh and develop statistical procedures which can deal with the problems that arise with this type of data.

The Danish data that will be used in this paper exhibit some of the complexities mentioned in this section. There are characteristics of Danish adolescents which are not observable to us. But we want to draw valid inferences about what matters in the decision making processes of our respondents and whether this has changed over time. This invariably means models which take explicit account of these unobservables and, consequently are more elaborate and complicated than many readers are used to or would like to use. But the remark attributed to Einstein 'make everything as simple as possible but not simpler' should be the guiding principle here.

3 Literature review

There are a large number of studies that attempt to relate individual performance as measured by educational attainment, earnings, or occupation to the characteristics of the household in which the individual grew up. These are seen as crucial in determining children's outcomes as adults, both in the educational system and in the labour mar-

ket. This literature is reviewed in Dustmann (2004) and in McIntosh and Munk (2007) who also found a considerable degree of dependence on family background variables for educational attainments for Denmark.

However, there is a literature *on changes* in economic, educational, and social mobility over time and across cohorts but a smaller literature on intergenerational changes in choice of secondary education. Recent trends in European stratification and mobility are examined by Shavit *et al* (2007) and Breen and Jonsson (2007). Both monographs report little change in educational mobility. However, and Breen *et al* (2009) using different data reverse these results.

For Canada Wanner (1999) found the standard sociological results but these are reversed by the McIntosh (2010) study which employs statistical techniques to deal with the unobservability problems.

For the US, Hauser (1998) concluded that ‘there is no global trend in the intergenerational persistence of education from the 1960’s to the 1990’s’. Similar results were found by Lucas (2001:1679) who reported that his results were consistent with maximally maintained inequality hypothesis. Cameron and Heckman (1998) report the effects of several family background variables on educational attainment. However, these are mixed with the effect of household income showing a slight decline in importance towards the end of their sample period. On the other hand, their parental education variables retain their importance. For France, Vallet (2004) reports a decline over thirteen cohorts over the period 1908-1972 using log-linear models to examine changes in associations between social origin and educational destination. He also notes that ‘The decline in origin-destination education association in France therefore seems largely independent of major secondary school reforms introduced to promote equality of educational opportunity (p. 31)’. For Sweden, in many ways close to Denmark, Jonsson (1993), Erikson and Jonsson (1996), Jonsson and Erikson (2000) tried to show a decline in the social inheritance effect on educational attainment, including low and intermediate transitions. Esping-Andersen (2004) examined educational mobility in several countries and found that the results depended on the country with increases in Scandinavia and declines in the UK and US. Marks and McMillan (2003) found a decline in the dependence of educational attainment on social background variables for Australia for cohorts born during the period 1961-1985.

Bynner and Joshi (2002) examined sample survey data from the 1958 and 1970 cohorts in Britain. They found no change in the response of the probability of leaving school at age sixteen to family or social origin variables. Blanden and Gregg (2004) found an increased dependence of tertiary educational attainments on household income over the period 1958 to 1970 using the British National Child Development and British Cohort Surveys. Individuals were aged 33 and 30, respectively. We also find an increase in household income dependence. In another British study Galindo-Rueda and Vignoles (2005) also found an increase in the importance of some family background variables but a decline in the importance of cognitive ability as a determinant of educational attainment. This is in part due to the fact that low ability children from high economic status families experienced the largest increases in educational attainment. They also looked at secondary education, and discovered that “The reduction of secondary school selection on the basis of age 11 ability is likely to have reduced the role of early cognitive ability in determining a student’s eventual outcome.” (p. 352). Blanden, Gregg and Machin (2005) examine educational mobility at both the secondary and tertiary levels and find first a rise and then a decline in cohort educational inequality at the secondary level but an increase at the tertiary level. They attribute the latter change to increased financing constraints for higher education. However, it should be noted that most of these studies use a rather limited number of family background variables.

Most of these studies have focused on final educational attainment. The closest study to our work on upper secondary education is a recent paper by Dustmann (2004) who uses the German Socio-Economic Panel data base to examine the secondary school outcomes of a sequence of cohorts the first of which was born in 1925 and the last in 1965. He finds using ordered probability models that the probability of completing German high school for respondents with ‘working class’ parents increases moderately over the ten cohorts and is higher for males than females. This is much lower for respondents with ‘academic’ parents whose probabilities also increase with females overtaking males by about 1960. The large gaps between these two probabilities leads him to conclude that considerable educational immobility still exists in Germany.

There is one recent study by Jaeger (2007) which attempts to examine whether there have been any changes in Danish educational mobility using data from a small number of respondents. Unfortunately, the computations which are used to support the authors

claims on the number of latent classes are not consistent with the claims, themselves. See Table 3 of the paper. As a result it is difficult to draw any useful conclusions from the study that relate to the issue of Danish intergenerational educational mobility.

In summary, results differ by country and sometimes by type of procedure employed. Perhaps the most striking feature of the research on the evolution of intergenerational mobility is the almost uniform neglect of unobservable characteristics. Mare (1993) is an exception.

4 Data and variables

The data used in this study comes from Statistics Denmark register data on two cohorts of 23 olds. The two cohorts were born in 1962 and 1982, respectively. Danish registers are very comprehensive and contain a great deal of information on every individual.² Everyone who was aged 23 and was born in Denmark was included in the sample. These registers contain the central population register numbers for the parents of each individual. Hence, for each cohort it is possible to assemble a data set which contains personal information on the individual as well as a set of variables relating to his or her family background. This was done for each cohort. Register data for individuals born prior to 1962 is not as comprehensive and is characterized by large numbers of missing values for parental information so 1982 is the earliest cohort that could be used.³

For the dependent variable our choice is the three category variable: completed level of secondary education at age 23. In Denmark all students are compelled to complete primary education which is grade nine; but about 60% go on to grade ten. After grade nine or ten there are two further educational choices at the upper secondary level in addition not continuing at all. The individual can elect to enroll in a vocational programme. Welding, carpentry, hair dressing, or being an electrician are typical options. Vocational programmes can take quite a long time to complete and involve apprenticeships. The entire programme can take up to five years to complete.

²The construction of the dataset was built on ideas from an earlier research project about Education and Inequality (see Munk 2003b).

³In what follows we refer to a cohort by the year when the respondent was aged 23 and not the year of birth.

Gymnasiums, the other option for those to continue at the upper secondary level, offer four types of curricula: a general program with various theoretical programmes in the humanities, natural and social sciences, a technical program, a business program, and a preparatory programme for university. After grade nine or ten students can enroll in these programmes which typically last about three years and provide qualifications that are required for entrance to a university. Many programmes involving short or intermediate tertiary educational programmes also require a completed gymnasium certificate for entry. In the data set here an individual is in the designated category if the individual had completed the programme associated with it.

The numbers and percentage allocations for each cohort are displayed in Table 1. There are number of variables for parental characteristics. Parents education is a six category variable where the first category is no education past grade nine or ten. The second category is a vocational qualification, the third is gymnasium only and the next are three categories of tertiary education which in Denmark are characterized by their durations: short, medium and long, and the varying level of academic content in them. Examples for the three types are police training, primary school teacher training and university, respectively. The residual category is no education past grade nine or ten. There are eight parental occupations; the first three are white collar occupations starting with high level managerial, low level managerial and ordinary employee. Occupations four, five, and six are self-employed and skilled and unskilled blue collar workers and occupation seven is the missing category. For the first cohort there are many parents whose occupations are not known and it does not seem appropriate to combine them with the unemployed so they are represented a separate category for all of the cohorts although there is very little missing parental information for the last cohort. The residual category consists of those who are unemployed or not in the labour force.

The data set also contains the number of siblings, whether the father was unemployed, whether the respondent's mother was a single mother, and household income, all collected when the respondent was 23.

Table 4 contains information on university participation rates for the same two cohorts. Unlike the data in Table 1 these are not completions but simply enrollments in university programmes. Unfortunately, since Danes tend to start late and take a long

time to finish an advanced educational programme completion rates are not really reliable unless the respondent is sampled in his or her late twenties. Since the large increases in gymnasium attendance are of rather recent origin researchers will have to wait another three years or so before it can be determined whether the trends established at the upper secondary level continue at the tertiary level.

5 Estimation methods and models

The three choices open to Danish students who have completed lower secondary education can be achieved by making two decisions. The first decision is whether to be involved in any type of upper secondary education at all and the second is, given the decision to participate in further upper secondary education, whether the student will attend a gymnasium or take a more practically oriented vocational type of training. This is, of course, a purely conceptual framework for analyzing these three decisions but we see this as a realistic characterization of this decision process and as will be shown later this way of modelling these decisions is statistically superior to other alternatives which could be used to explain the data.

To go further in the educational system first requires a desire or some motivation to make the sacrifices necessary to turn an educational programme into a successful educational qualification. Success in this endeavor also requires some ability. Attitudes, desires and ambitions are in part determined by the environment in which the student resided when these decisions are made. So let us suppose that there is an index which depends on these environmental variables which represents the intensity of the desire to make a success of oneself. Let this be

$$y_{iI}^* = \beta_{0I} + Z_{iI}\beta_I + \gamma_I\theta_i + \epsilon_{iI} \quad (9)$$

where Z_{iI} is a set of normalized family background and other variables which describe the environment of the respondent and $(\gamma_I\theta_i + \epsilon_{iI})$ is an error term with two components. θ_i is an individual specific random effect which could represent the respondent's ability or some other unobservable attribute and ϵ_{iI} measures other random effects that are important in the first decision. The sum of these two components will be assumed to be normally distributed with a variance σ_I^2 . The value of this latent variable will determine

how the respondent makes his or her first choice. In keeping with traditions associated with latent variable models we will assume that the respondent decides to pursue some additional education past grade 9 or 10 if $y_{iI}^* \geq 0$.

If the respondent decides to continue in the educational system the decision of which type of upper secondary educational stream to pursue has to be made. We assume that this decision is also determined by the value of another latent variable

$$y_{iII}^* = \beta_{0II} + Z_{iII}\beta_{II} + \gamma_{II}\theta_i + \epsilon_{iII} \quad (10)$$

Here y_{iII}^* represents a number of attributes including preferences for occupations which depend more on academic and intellectual skills, analytical ability, and time preferences which can accommodate the longer durations of programmes of which attending a gymnasium is the first step. Individual i will take the gymnasium option if $y_{iII}^* \geq 0$ and the choice will be to go to a vocational school if $y_{iII}^* < 0$. Like y_{iI}^* , this will depend on the respondent's environmental background and some random effects, but perhaps not in exactly the same way so that β_I and β_{II} will not be the same.

This two stage representation of the decision process reflects some of the realities of the way Danish students actually made their decisions. At the time the data was generated students who wanted to go on to a gymnasium were evaluated by their lower secondary school teachers who then made a recommendation to the gymnasium on their suitability for this option.

These latent variables generate the probabilities of the three decisions. The probability that respondent i will go no further in the educational system is

$$\Pr\{y_{iI}^* \leq 0\} = \Phi(-X_{iI}\beta_I/\sigma_I) \quad (11)$$

where $\Phi()$ is the cumulative normal distribution function.

The probability the respondent i takes a vocational course after completing high school is more complicated because the error terms are not independent. In keeping with the assumption that both marginal distributions are normal we also assume that the joint distribution of $\{(\gamma_I\theta_i + \epsilon_{iI}), (\gamma_{II}\theta_i + \epsilon_{iII})\}$ is bivariate normal with correlation coefficient ρ . Here the reason for our use of normal (probit) marginal distributions rather

than the more usual logistic (logit) model is because there is no suitable bivariate logistic distribution that could be used.

It is important to note that θ_i has a different parameter associated with it in each error term. This is required to allow for the possibility for a negative value of ρ which can arise only when the signs of γ_I and γ_{II} are different. What θ_i actually represents will depend on the sign of ρ . This issue is discussed at the beginning of section 7.

The vocational choice event occurs when $y_{iI}^* \geq 0$ and $y_{iII}^* < 0$. This probability is

$$\Pr\{y_{iI}^* \geq 0, y_{iII}^* < 0\} = \int_{-Z_{iI}\beta_I/\sigma_I}^{\infty} \int_{-\infty}^{-Z_{iII}\beta_{II}/\sigma_{II}} \phi(x_I, x_{II}, \sigma_I, \sigma_{II}, \rho) dx_I dx_{II} \quad (12)$$

where $\phi()$ is the bivariate normal density function. Likewise, the probability of going to a gymnasium is

$$\Pr\{y_{iI}^* \geq 0, y_{iII}^* \geq 0\} = \int_{-Z_{iI}\beta_I/\sigma_I}^{\infty} \int_{-Z_{iII}\beta_{II}/\sigma_{II}}^{\infty} \phi(x_I, x_{II}, \sigma_I, \sigma_{II}, \rho) dx_I dx_{II} \quad (13)$$

It is clear from the discussion in section 2 that this model has the same formal structure as the Mare (1980) grade transition model. Although the stages here refer to a sequence of decisions rather than a sequence of grade transitions through the educational system the models share the same mathematical structure. The possibility of allowing for unobserved heterogeneity in these stage models by including the random effect, θ_i , in each error term was first proposed by Lillard and Willis (1994). Consequently our model is analogous to their model but it is also a correlated version of the Mare model.

Since the objective of this research is to compare the degree of educational mobility for two cohorts born twenty years apart an aggregate mobility index which measures this is required. The index that we are going to use is a version of the one proposed in section 2, which for probability models, becomes

$$I(\beta) = \|\beta/\sigma\|/\|(\beta_0/\sigma, \beta/\sigma)\| \quad (14)$$

This index involves all of the β parameters as well as the variance of the latent variable. Only parameters divided by the standard deviation of the error term, σ_i , are identifiable

in probability models. In addition the properties of the index mentioned in section 2 another feature of the index which makes desirable for our purposes is that it does not depend on σ so that comparisons across cohorts are not going to be contaminated by changes in the variance terms. This has been a major problem in much of the research on intergenerational educational mobility (including studies that rely on logistic models) and to our knowledge this is the first real solution to this problem.

On the other hand, there is nothing in the index which allows us to say anything about the relative importance of random effects and how these have changed over the two cohorts.

6 Results

The results for the model outlined in section 5 are shown in Table 2. The first and most important point to note is that our mobility indices decline as the cohorts get younger. It is clear from the first two rows of this table that for males $\Delta I(\beta_{II})$, the reduction in the index for the second latent variable over the two cohorts, is $0.289^{**}(0.025)$ and is highly significant. But for males $\Delta I(\beta_I) = 0.008(0.010)$ is not. For females, $\Delta I(\beta_I) = 0.229^{**}(0.013)$ and $\Delta I(\beta_{II}) = -0.016(0.081)$ and only the first difference significantly different from zero indicating a decline in the dependence of educational choices on family background variables arising from changes in the ambition latent variable index.

It is interesting to note that the responses by the males and females are different, For the males it is the preference for type of education that has changed whereas for the females it is the ambition variable which has become more important.

All of the variables representing the characteristics of the respondent's parents are highly significant for both cohorts. Household income, the number of siblings and whether the respondent was brought up by a single mother have somewhat larger coefficients associated with them than the other regressors. In Table 2 the effects parent education and occupation are captured by the averages of the coefficients of the category dummy variables in order to keep the tables from being too large. For example, for males the

estimate for the average effect of father's education is $0.049^{**}(0.004)^4$.

Changes in the individual parameter estimates across the two cohorts are not particularly large for some of the regressors but there are some major differences across the two cohorts and some of the parameter estimates, like those associated with parent educational attainments or household income, are actually significantly larger for the younger cohort. However, the reason why the mobility indices decline is because the intercept terms are much larger for the 2005 cohort. These are displayed in the last two rows of Table 2. There are other consequences of the increases in the intercept terms and these will be discussed later.

Our approach to mobility is to examine the dependence of educational outcomes on environmental and family background variables. However, this is not how other researchers look at intergenerational educational mobility so it is of some interest to contrast what we have found with the results of more traditional procedures.

In Table 3 the probabilities of the three educational outcomes are compared across four household income quartiles. Mobility researchers are interested in how these probabilities or ratios of these probabilities change over time. For males the probability of obtaining a gymnasium qualification is higher in 2005 than it was in 1985 for all household income quartiles. Furthermore, the odds of graduating from a gymnasium as opposed to getting no further education past grade 9 or 10 are also higher for all household income quartiles in 2005 than they were in 1985. The one characteristic of the male part of this table which should be a cause for concern is the fact that males from the bottom quartile of the household income distribution are more likely not to have gone further in the educational system by 2005 than they would have had they been 23 in 1985.

The results are even more startling for females. For all household income quartiles women have a much higher probability of getting a gymnasium qualification and lower probabilities of getting nothing in 2005 than they did in 1985. That there is a 56.3% increase in the probability that a woman from the lowest household income quartile

⁴For father's education in 1985 the 6 β_I coefficients and their standard errors are 0.050^{**} (0.006), 0.064^{**} (0.006), 0.034^{**} (0.006), 0.009^{**} (0.004), 0.099^{**} (0.006), and 0.037^{**} (0.004). The average of these 6 coefficients is 0.049^{**} (0.004) as reported in table 2.

Readers interested in the detailed coefficients associated with the other variables can obtain them from the authors.

should have a gymnasium certificate is quite remarkable.

Now the reasons why these probabilities have increased so dramatically over this period is because of the large absolute increases in the intercept terms, β_{0I}/σ_I and β_{0II}/σ_{II} . When these increase relative to the regression coefficients the mobility indices $I(\beta_I)$ and $I(\beta_{II})$ decline indicating an increase in mobility. But when they increase absolutely, increased mobility is accompanied by higher success rates at the gymnasium level. Thus Danish society has not only become more mobile but it is better off since more individuals are participating in the educational system than in 1985.

Some sociologists view Table 3 differently. They are interested in comparing odds ratios over time. Many of them would see a decline in what they perceive as mobility over this twenty year period. In 1985 they would see that the educational system favoured the rich since the odds of getting a gymnasium qualification as compared with no further education were higher for the top household income quartile than for the bottom household income quartile: 2.113 vs. 0.306 for males. In 2005 these two odds are 4.145 vs. 0.415 so that these twenty years have seen the wealthy increase their advantage over the lowest quartile. Many mobility theorists would view this is a decrease in mobility.

Can these two apparently conflicting views be reconciled? As we mentioned earlier while our mobility indexes declined there were some β coefficients that had increased significantly over the two cohorts. These were associated with parent educational attainments and household income. Because household income has become much more important it is reasonable to believe that this is the reason why respondents from high income households were able to do relatively better than those coming from the bottom of the quartile of the income distribution. This shows that it is possible to have an increase in inequality while at the same time there is an increase in mobility as measured by our index.

Turning now to some statistical issues. First, Table 3 contains the predicted outcome probabilities by household income quartile for each of the 3 educational choices. These are not the same as the actual proportions for these outcomes. However, differences between actual and predicted are quite small, on average about 5%, so the models do a reasonable job of fitting the data.

As we mentioned earlier, our model is one of several alternatives that could be applied to this data but that it was preferred to other possible alternatives on statistical grounds. The three educational categories could be explained by a single index logistic ordered probability model which is generated by the latent variable crossing two threshold points⁵. The two index multinomial logit model can also be used to explain these choices. The values of the maximized ln-likelihood function and the (number of parameters) for 2005 males for the ordered logit, multinomial logit, Mare and correlated Mare model are, respectively, -27074.284 (31), -26469.166 (60), -26437.273 (57) and -26427.217 (58). The multinomial logit model dominates the ordered logit model in terms of both AIC and BIC criteria. A Vuong (1989: 320) test indicates that the Mare model has a significantly higher ln-likelihood function than the multinomial logit model, and the correlated Mare model is superior to the Mare model when ρ is significantly different from zero. Similar results hold for females, hence the correlated Mare or Lillard-Willis model is the vehicle of choice for the data used in this study.

The significance of the correlation coefficient has implications far beyond goodness of fit. Allowing correlation between the error terms in the two latent variables is our way of introducing the effects of unobservables into the determination of educational choices. It turns out that unobservables are extremely important for male decisions. In the uncorrelated Mare model $I(\beta_{II})$ increases from 0.684**(0.047) to 0.981**(0.004) so that by neglecting unobserved heterogeneity we would have erroneously concluded that there had been a significant decrease in male intergenerational educational mobility over the period.

7 Discussion and Conclusions

We have stressed the importance of including a random effect, θ_i , for individual i in the model; now, given the actual estimates, we can provide some insight as to what this effect really measures. Usually, in educational attainment models the unobservable is viewed as some measure of ability. This could be the case here but because the correlations between the two error terms are negative it is likely that there are components in θ_i that represent

⁵We also tried to estimate latent class (mixture) ordered probability models but serious convergence difficulties were encountered.

other attributes of the respondent. This variable could represent, for example, individual preferences for doing something practical as opposed to something esoteric or theoretical. Individuals with high values of θ_i want to make something of themselves ($\gamma_I > 0$) and be successful, but they also want fulfillment in a practical sense and do not want to be involved with abstract or theoretical issues which they would have to deal with if they went to a gymnasium ($\gamma_{II} < 0$). As a result they take the vocational option. Since there is a good selection of variables which can serve as proxies for individual ability, like parent educational attainments, it is possible that the unobservable component of ability is quite small which leaves θ_i free to represent other characteristics.

Turning to more general issues, the main result of this research is that mobility, or dependence on family background, has improved because other factors have replaced the more traditional variables that represent the characteristics of the households in which the respondents grew up in explaining Danish upper secondary schooling outcomes. And, as we showed, these new factors that have come to play such an important role in educational success are captured by the intercept terms in our probability models. Since these intercept terms, by definition, are picking up the average effects of the variables that have been omitted from the statistical models, additional information with respect to how Danish society has changed over this period is needed to interpret them. We turn to this issue now and consider a number of changes in Danish society that may have been responsible for the increase in educational mobility.

Recent changes to the gymnasium system have given students more choice and introduced technical options. These can very well have made the gymnasium choice more attractive to members of the younger cohort. In addition, there has been a change in attitudes or perceptions about the value of going to a gymnasium in terms of the options it gives to attendees for acquiring tertiary education as noted by Andersen (2004: 60-61).

Social programmes including welfare support and unemployment insurance programmes had been well established prior to the 1990's. But this was a period of considerable change in Danish social policy and there were some new policies that could have affected educational decisions. Reduced entitlements to welfare programmes (Rosdahl 2003: 123) and the tying benefits to schooling decisions made the costs of not getting more education much higher (Munk 2001: 94, 2003a). Esping-Andersen (2004: 131) has

also suggested that the cohorts who were making educational choices in 1990's were the first to fully benefit from the expansion of the day-care programmes at the end of the 1970's.

While there have been dramatic changes in gymnasium participation at the secondary level should they encourage us to believe that similar results will eventually be found at the tertiary level? The results are even more startling than those associated with the increase in proportions of respondents obtaining a gymnasium qualification.

For example, in Table 4 the percentage of females who had started at university rises from 6.3% in 1985 to 19.1% in 2005. This is truly a remarkable change and it is accompanied by an even larger percentage change for those females whose parents came from the bottom of the household income distribution. The same pattern holds for males but the changes are not as great. Thus it is reasonable to conclude that the trends that emerged in upper secondary education in the 1990's will continue in the tertiary educational system. Of course, this result should be interpreted with some caution since some of the attendees will drop out and there will be entrants at ages above 23. However, these changes in attendance behaviour patterns appear to be of fairly recent origin so a comprehensive analysis of tertiary educational attainments will have to be deferred until the relevant data becomes available in three years time.

One of the major results here is the gender difference in the proportion obtaining a gymnasium qualification. Our models provide some insight here. The first latent variable is an indicator of overall enthusiasm, ambition, or a desire for self-betterment. For females, the intercept term in equation (1) has almost doubled whereas for males it has remained constant. Males in 2005 were no more ambitious than they were in 1985 but females were much more ambitious. Only males experienced an increase in the second latent variable. Since it was the female participation gymnasium rate that experienced the largest increase we conclude that it is the ambition variable that is the main driver of success in terms of attending a gymnasium.

Finally, one of the more important variables which matters in educational choices is household income. Like Blanden and Gregg (2004) we also find highly significant parameter estimates associated with this variable. This is consistent with our results using sample survey data. In Denmark, like Britain, the effect of household income on choices

is very important and has actually increased over the period. The probability of attending a gymnasium for males coming from households with incomes in the top quartile is 4.145 times that of males coming from the bottom quartile of the household income distribution. In McIntosh and Munk (2007), we interpreted high household incomes as proxies for parental competence rather than something which eases credit constraints since secondary education is free in Denmark. However, it is possible that higher income households are able to provide more of the things for their children that matter in the human capital accumulation process like access to personal computers, reading materials in the home, choice of high quality day-care, living in a good neighbourhood etc. But, whatever the causal mechanism happens to be household income has a dramatically increased impact on upper secondary school outcomes and the benefits of these high incomes are not equal across all income groups.

However, it should not be forgotten that in spite of this increase in the importance of household income; when all factors are considered the dependence of secondary educational choices on family background variables has actually declined over the period. It would be interesting to see whether this is what has happened in Britain, and other countries where household income is important, when a full selection of family background variables is used in addition to household income.

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TABLES

Table 1
The Distribution of Completed Upper Secondary

Type of Education	Males		Females	
	1985	2005	1985	2005
Gymnasium	8914 (0.233)	10792 (0.388)	12587 (0.341)	14685 (0.549)
Vocational	16959 (0.442)	8144 (0.292)	10681 (0.289)	5012 (0.187)
None	12257 (0.320)	8793 (0.316)	13481 (0.365)	6956 (0.260)
Total	38130 (1.000)	27737 (1.000)	36749 (1.000)	26653 (1.000)

TABLE 2

Parameter Estimates

Parameter (se)	Males 1985	Males 2005	Females 1985	Females 2005
	$\mathbf{I}(\beta_I)$	0.601**(0.007)	0.609**(0.007)	0.729**(0.008)
$\mathbf{I}(\beta_{II})$	0.973**(0.022)	0.684**(0.045)	0.519**(0.049)	0.535**(0.055)
ρ	-0.738**(0.001)	-0.707**(0.062)	-0.785**(0.057)	-0.306 [†] (0.187)
Father's Education				
$\bar{\beta}_I(FE)$	0.049**(0.004)	0.057**(0.003)	0.035**(0.004)	0.065**(0.007)
$\bar{\beta}_{II}(FE)$	0.124**(0.009)	0.149**(0.011)	0.078**(0.008)	0.147**(0.013)
Father's Occupation				
$\bar{\beta}_I(FO)$	0.084**(0.005)	0.062**(0.003)	0.010**(0.005)	0.063**(0.007)
$\bar{\beta}_{II}(FO)$	0.064**(0.007)	0.079**(0.006)	0.032**(0.007)	0.059**(0.010)
Mother's Education				
$\bar{\beta}_I(ME)$	0.038**(0.002)	0.044**(0.003)	0.048**(0.004)	0.038**(0.006)
$\bar{\beta}_{II}(ME)$	0.091**(0.004)	0.117**(0.006)	0.083**(0.005)	0.109**(0.008)
Mother's Occupation				
$\bar{\beta}_I(MO)$	0.038**(0.002)	0.045**(0.003)	0.033**(0.004)	0.063**(0.007)
$\bar{\beta}_{II}(MO)$	0.091**(0.004)	0.054**(0.006)	0.010*(0.004)	0.059**(0.006)
Number of Siblings				
$\beta_I(NS)$	-0.148**(0.006)	-0.086**(0.009)	-0.129**(0.006)	-0.093**(0.010)
$\beta_{II}(NS)$	-0.018 (0.011)	0.006 (0.010)	-0.040**(0.008)	-0.024* (0.012)
Household Income				
$\beta_I(HI)$	0.126**(0.007)	0.218**(0.014)	0.112**(0.009)	0.193**(0.016)
$\beta_{II}(HI)$	0.058**(0.007)	0.027**(0.011)	0.052**(0.009)	0.122**(0.022)
Father Unemployed				
$\beta_I(FU)$	-0.041**(0.006)	-0.045**(0.008)	-0.037**(0.006)	-0.035**(0.009)
$\beta_{II}(FU)$	0.019*(0.008)	0.049** (0.011)	0.013 [†] (0.011)	0.002 (0.002)
Single Mother				
$\beta_I(SM)$	-0.116**(0.006)	-0.117**(0.008)	-0.087**(0.006)	-0.137**(0.009)
$\beta_{II}(SM)$	0.031**(0.009)	0.045**(0.010)	-0.047**(0.008)	0.035**(0.014)
Intercept terms				
β_{0I}	0.507**(0.007)	0.534**(0.008)	0.379**(0.007)	0.721**(0.009)
β_{0II}	-0.079**(0.034)	0.475**(0.040)	0.473**(0.020)	0.809**(0.067)

[†], *, and ** indicate significant at 10, 5, and 1 percent levels, respectively.

TABLE 3
The Distribution of Completed Upper Secondary Educational Attainments
By Household income Quartile, 1985 and 2005.

Males						
Household Income Quartile	1985			2005		
	None	Vocational	Gymnasium	None	Vocational	Gymnasium
Q1	0.447	0.396	0.137	0.525	0.248	0.218
Q2	0.348	0.477	0.175	0.350	0.367	0.281
Q3	0.291	0.501	0.208	0.237	0.338	0.423
Q4	0.194	0.396	0.410	0.152	0.218	0.630
All	0.320	0.442	0.233	0.316	0.293	0.388

Females						
Household Income Quartile	1985			2005		
	None	Vocational	Gymnasium	None	Vocational	Gymnasium
Q1	0.487	0.270	0.229	0.446	0.183	0.358
Q2	0.392	0.317	0.290	0.292	0.247	0.462
Q3	0.361	0.318	0.321	0.193	0.209	0.598
Q4	0.222	0.253	0.525	0.110	0.112	0.778
All	0.487	0.290	0.341	0.260	0.187	0.549

TABLE 4
Household Income Quartile Proportions of Respondents Aged 23

Who had Started University in 1985 and 2005

Household Income Quartile	Males		Females	
	1985	2005	1985	2005
Q1	0.052	0.086	0.036	0.110
Q2	0.054	0.098	0.039	0.119
Q3	0.071	0.162	0.045	0.173
Q4	0.169	0.318	0.133	0.360
All	0.086	0.166	0.063	0.191