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The cohort size-wage relationship in Europe

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The cohort size-wage relationship in Europe

– Preliminary draft –

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Abstract

The demographic and education composition of European countries is changing: the population share of young individuals is declining while that of the highly educated is rising. This paper estimates the impact of cohort size on wages using data on 24 European countries covering 2007-2010 to cast light on the economic consequences of these changes in the profile of the labour force. The effect of cohort size on wages is identified through an instrumental variables strategy which, in contrast to previous analyses of European data, addresses self-selection into geographical areas as well as into educational groups. The results support the hypothesis that cohort size has a negative effect on male wages, particularly for the highly educated. However, these negative cohort size effects are not persistent.

JEL classification **J10, J21, J31**

Keywords **Cohort size; wages; causal effect**

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1 Introduction

The demographic and educational composition of the European Union (EU) is changing. According to EU population projections, the population share of those aged over 65 will rise from 17.5% in 2011 to 29.5% in 2060 (European Commission, 2013). Within the population of working age, the largest fall in population share will be amongst those aged 40-45 (from 7.5% to 5.9%). However, older groups will see a smaller fall than younger groups: the population share of those aged between 45 and 65 will decline by 3.3 percentage points while that of individuals aged between 20 and 40 will fall by 5.2 percentage points. At the same time, if current trends continue, the population of the EU will become better educated as, across the EU-27, the proportion of the population aged 25-64 with tertiary education increased from 19.5% to 27.7% between 2000 and 2012 (Eurostat, 2013). In this paper, we provide evidence on the likely impact of such changes on wages.

The analysis of the effects of cohort size – i.e. the relative size of a group of individuals sharing similar characteristics (such as gender, age/experience and/or education) – on labour market outcomes was initially driven by a desire to understand the economic consequences of the entry of large cohorts of young workers into the US labour market (known as the baby boom cohorts) in the late 1960s. The literature has since been dominated by US research – a survey of which is provided by Korenman and Neumark (2000). The strand of the literature on the empirical relationship between cohort size and wages has broadly confronted three different questions:

1. Does cohort size have a negative impact on wages?
2. Are there differences in the size of the impact across educational groups?
3. Is the impact on wages permanent or temporary?

The central theoretical assumption that underlies the empirical analysis of cohort size effects is that identically educated individuals are only imperfectly substitutable across age, so that, depending on the degree of substitutability, increases in the size of a specific age(-education) group will have adverse effects on the wages of workers in that group. US empirical research (e.g. Freeman, 1977; Welch, 1979; Leveson et al., 1980; Alsalam, 1985; Berger, 1985) has generally provided evidence in favour of this hypothesis. Many studies (e.g. Welch, 1979; Leveson, 1980; Alsalam, 1985) also suggest that this cohort crowding effect is more pronounced for the highly educated which provides support for the “diminishing substitutability hypothesis” proposed by Stapleton and Young (1988) that substitutability between differently aged workers decreases with the level of education. Evidence on the third question is more mixed with some studies suggesting that depressed earnings are only a temporary phenomenon (e.g. Welch, 1979) as workers in larger cohorts experience faster earnings growth, while others (e.g. Berger, 1985) suggest that cohort size has a permanently depressing effect on wages.

Evidence on cohort size effects on wages in Europe is less prevalent. Wright (1991) uses UK data covering the period 1973-1982 to estimate the effect of cohort size on the average wage within groups of similarly aged and identically educated employed males. He finds that cohort size is negatively associated with average wages for males with intermediate and higher qualifications. However, these effects are only temporary, lasting for the first five years after assumed labour market entry for the intermediate qualifications group and for 11 years for the

high qualifications group.¹ In line with US studies, his findings suggest that cohort size effects are more negative for the more educated group. Mosca (2009), using Italian data for male workers from the European Community Household Panel (ECHP), obtains results that also indicate that cohort size is associated with depressed earnings although her empirical model does not address the consequences of self-selection into cohorts. Rather different results are obtained in two papers that use Swedish data. Klevmarcken (1993), using three waves (1984, 1986, 1988) of the Swedish Household Market and Nonmarket Activities (HUS) panel data set, regresses average hourly male earnings by age group on a measure of age-specific relative cohort size and on its interactions with educational indicator variables and age and finds that none of the cohort size-related variables are significant.² Dahlberg and Nahlum (2003) use representative longitudinal data from various registers and find that cohort size has a positive and significant effect on male wages which exists, albeit to different extents, across gender and education groupings.³ Most recently, Brunello (2010) provides an analysis of the cohort size-earnings relationship using ECHP comprising data for the period 1995-2001 from 11 countries. Collapsing individual observations of employed and unemployed males into age-education-specific averages, he regresses average hourly earnings on the relative cohort size of age-education groups and other control variables. Instrumental variables (IV) estimation using age-specific cohort size as an instrument shows that cohort size depresses wages and does so to a larger extent for more educated individuals.

Interpreting the results of previous empirical studies is complicated by the potential endogeneity of the cohort size variable which arises from individual self-selection into specific cohorts. While most of the recent literature has acknowledged that the cohort size variable is endogenous due to self-selection of individuals into specific cohorts, it has focused mainly on self-selection into educational groups through gaining qualifications as a source of endogeneity. By contrast, self-selection into geographical areas through migration into economically attractive areas remains unaddressed in cross-country European studies. Such an omission may be important using European data due to the existence of free movement of individuals within the EU. One of the main contributions of this paper is the use of an IV strategy which has not previously been applied to cross-country European data to identify the causal effect of cohort size on individual wages. We identify the causal effect of cohort size by employing birth rates from the year in which individuals were born as an instrument arguing, as Korenman and Neumark (2000) have done, that this variable is able to address both sources of endogeneity.

Using this approach, the paper addresses all three of the questions outlined above with the use of the European Union Statistics on Income and Living Conditions (EU-SILC) dataset. It differs from much of the existing literature by conducting the analysis at the level of the individual rather than using grouped data at the level of the age-education group. This allows us to control better for confounding influences on wages. We also allow for the impact of cohort size on wages to vary nonlinearly over age by including an interaction between cohort size and age squared in addition to an interaction between cohort size and age in our models. As far as we are aware, only Berger (1989) has included an interaction between cohort size

¹ From the data provided in Wright (1991) it is unclear whether the estimated negative effects are statistically significant over these periods.

² Due to the inclusion of interactions between cohort size and other variables in Klevmarcken's (1993) model, the marginal effect of cohort size on wages is a function of a number of coefficients and explanatory variables. Marginal effects of this form are not estimated and consequently, it is not clear whether their estimated cohort size effects are statistically significant.

³ Dahlberg and Nahum (2003) use birth rates as a proxy for cohort size which means that their estimates are not direct estimates of the impact of cohort size on wages.

and age squared in his model but, given that he found this term to be significant, it is surprising that others have not followed this approach.

The next section provides a description of the data set, the empirical specification and the identification strategy. The results are presented and discussed in the fourth section. The final section concludes.

2 Estimation

Data

The data are taken from the 2010 release (version 1 of August 2010) of the EU-SILC survey which consists of cross-sectional and time-series data at the individual and household level from 24 European countries over the period 2007-2010.⁴

The measure of educational attainment in EU-SILC is the International Standard Classification of Education (ISCED) which assigns every individual a value ranking from 0 (pre-primary education) to 5 (first stage of tertiary education)⁵ based on the ISCED-97 classification.⁶ In addition to ISCED 5, individuals with educational attainment ISCED 3 (secondary education) and ISCED 2 (lower secondary education) are used in the analysis. Compared to the remaining groups - ISCED 0, ISCED 1 (primary education) and ISCED 4 (post-secondary non-tertiary education) - the aforementioned categories include the vast majority of observations in the data set. While it would have been possible to merge individuals from the smaller categories into the closest of the larger groups, this may distort the results as such individuals are likely to be less substitutable with individuals in the larger group.

Individuals over the age of 45 are excluded from the analysis, to avoid any effects from non-random retirement decisions, as discussed in Brunello (2010), and because the annual birth rate data which is necessary for the construction of our instrument is not available before 1960.⁷ Following the earlier literature, females are also excluded from the analysis to avoid confounding any decisions about labour market participation with effects from cohort size on wages.

In order to estimate cohort size effects from the time when individuals can be expected to first enter the labour market, individuals with an ISCED 2 or ISCED 3 background are included in the sample from the age of 20 but individuals with an ISCED 5 background are included from the age of 25 as entry into the labour market will be delayed for this group. Furthermore, to ease interpretation of the cohort size coefficients, age is rescaled by subtracting 20 from the actual age for ISCED 2 and ISCED 3 individuals and 25 for ISCED 5 individuals.

⁴ The set of countries comprises Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Greece, Iceland, Italy, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, and United Kingdom.

⁵ Due to top-coding of the educational variable, the data does not differentiate between individuals in category ISCED 5 and ISCED 6 (second stage of tertiary education).

⁶ The more recent 2011 classification which differentiates between a larger set of educational categories is not used in the 2010 release of the EU-SILC data set.

⁷ Also excluded are those individuals that are not recorded as either employed or unemployed during the period 2007-2010 and those individuals that are not available to the labour market because they are still in education, have already retired or are associated with specific institutional occupations (e.g. the military service).

If individuals of different ages are not substitutable, the cohort size variable could be defined simply as the ratio of the number of individuals of age j with education e in country k at time t to the number of individuals with education e in country k at time t . But since it is likely that individuals compete for jobs with individuals in the same educational group of a similar, but not necessarily the same age, following Brunello (2010) and Wright (1991), the numerator of the cohort size variable is calculated as a weighted average of the number of individuals in a country with the same education that are two years younger, one year younger, the same age, one year older and two years older as follows:

$$[1] \quad CS_{jekt} = \frac{\left(\frac{1}{9}\right)N_{(j-2)ekt} + \left(\frac{2}{9}\right)N_{(j-1)ekt} + \left(\frac{3}{9}\right)N_{jekt} + \left(\frac{2}{9}\right)N_{(j+1)ekt} + \left(\frac{1}{9}\right)N_{(j+2)ekt}}{N_{ekt}}$$

A discussion of the weighted cohort size variable including the use of inverted V-shaped weights can be found in Wright (1991).⁸ The cohort size variables are separately estimated for educational attainment groups ISCED 2, 3 and 5. In order to construct an accurate estimate of the cohort size measure, it is necessary to weight the data using probability weights so that the cohort size variable is not a function of the sampling frame of the survey. Appropriate weights are provided in the EU-SILC data set.

In order to identify the causal effect of cohort size on hourly wages, the cohort size variable will be instrumented by the birth rate from the year of birth of a given age cohort. For each cohort, age and time determine the year of birth, thereby allowing the cohort size variable for any cohort to be matched with a corresponding lagged total birth rate value. Analogous to the construction of the cohort size variable, the instrument is constructed as a weighted average of the number of births (B) in the reference year and the two subsequent and preceding years relative to the size of the population in the reference year as shown by Equation [2]:

$$[2] \quad BR_{(t-j)k} = \frac{\left(\frac{1}{9}\right)B_{(t-j-2)k} + \left(\frac{2}{9}\right)B_{(t-j-1)k} + \left(\frac{3}{9}\right)B_{(t-j)k} + \left(\frac{2}{9}\right)B_{(t-j+1)k} + \left(\frac{1}{9}\right)B_{(t-j+2)k}}{N_{(t-j)k}}$$

The annual birth rate data series is obtained from the World Bank's publicly accessible online data base.⁹

⁸ We also tried specifications which included the cohort size of adjacent age groups, thereby allowing individuals in adjacent ISCED groups to have an impact on wages. Due to the high degree of collinearity between the different cohort size variables, their effects could not be identified separately.

⁹ Up to 1986, birth rates for the Czech Republic are only available at 5 year intervals. The values for the missing years were constructed by linear interpolation.

Table 1: Variable Definitions

Variable	Definition	Source
Wage	Hourly wage in Euros, adjusted by a purchasing power parity (PPP) factor, calculated by dividing annual gross wage by average number of hours worked per week times 52	EU-SILC
Cohort size	See Equation (1) and related discussion	EU-SILC
Married	Dummy variable coded one if the individual is married	EU-SILC
Part-time	Dummy variable coded one if the individual works part-time	EU-SILC
Self-employed	Dummy variable coded one if the individual is self-employed	EU-SILC
Occupation	Dummy variables for each of the following occupational groupings: 1. Legislators 2. Senior officials and managers 3. Professionals 4. Technicians and associate professionals 5. Clerks, Service workers and shop and market sales workers 6. Skilled agricultural and fishery workers 7. Craft and related trades workers 8. Plant and machine operators and assemblers 9. Elementary occupations 10. Armed forces	EU-SILC
Urban	Dummy variables for residence in an intermediate area and a thinly populated area	EU-SILC
Country	Dummy variables for residence in particular countries (see footnote 4 for a list of countries included in the analysis)	EU-SILC
Age	Age of individual minus 20 for ISCED 2 and 3, 25 for ISCED 5	EU-SILC
Year	Dummy variables for 2008, 2009 or 2010	EC-SILC
Unemployment	National unemployment rate of people aged over 25	Eurostat
Birth rate	See Equation (2) and related discussion	World Bank

Empirical model

In contrast to much of the existing literature the effect of cohort size is to be estimated on individual wages rather than on the average wages of individuals in the same age group¹⁰ which allows us to control better for individual-specific characteristics that determine wages. Consequently, the dependent variable is defined as the hourly wage rate of individual i in age group j and country k at time t .

The central explanatory variables are the natural logarithm of the previously defined cohort size variable, the interaction of this variable with an individual's age and the interaction of this variable and squared age. Inclusion of the interaction terms allows for the effect of cohort size on an individual's wages to change as the individual ages. In the absence of a clear theoretical prediction on how cohort size effects develop with individual age, the interactions allow for more flexibility in modelling this effect. The model therefore addresses the question of whether cohort size effects are persistent.¹¹ To our knowledge, no other study has addressed the question of persistence for a set of European countries.

The set of control variables includes individual-level regressors (indicators for individuals being self-employed, working part-time, being married and occupational indicator variables), age-specific regressors (age and squared age), country-specific regressors (the unemployment rates and country dummies), time-specific regressors (year dummies), age-by-time regressors (interactions between the year dummies and age and between year dummies and the

¹⁰ Examples for the latter type of analysis can be found in Brunello (2010), Wright (1991), Berger (1983), Welch (1979) and Freeman (1979) among others.

¹¹ It should also be noted that the first specification nests the second one, the latter arising if the interaction terms are found to be statistically insignificant.

occupational indicators), country-by-time regressors (interactions between the year dummies and dummies). Further details on these variables are given in Table 1. The equation to be estimated therefore takes the following form:¹²

$$[3] \ln[w_{ijkt}] = \alpha_1 \ln[CS_{jkt}] + \alpha_2 \ln[CS_{jkt}] XAge_{jkt} + \alpha_3 \ln[CS_{jkt}] XAge_{jkt}^2 + \beta X_{ijkt} + u_{ijkt} \quad ^{13}$$

The coefficients of interest are α_1 , α_2 and α_3 . Statistical (in-)significance of the associated variables and the signs of their coefficients will provide a basis on which to address the questions of whether, firstly, cohort size indeed exerts a depressing effect on an individual's wage rate and, secondly, whether this effect is persistent. The elasticity of wages with respect to cohort size is calculated as follows:

$$[4] \quad \frac{\partial \ln[w_{ijkt}]}{\partial \ln[CS_{jkt}]} = \hat{\alpha}_1 + \hat{\alpha}_2 Age_{jkt} + \hat{\alpha}_3 Age_{jkt}^2$$

The marginal effect of cohort size on wages is a function of the estimated coefficients $\hat{\alpha}_1$, $\hat{\alpha}_2$ and $\hat{\alpha}_3$ as well as the individual's age. Based on the previously described rescaling of the age variable, $\hat{\alpha}_1$ captures the effect of cohort size on wages upon the individual's (assumed) entry to the labour market.

The relationship between individual wages and cohort size is estimated separately for each educational attainment class considered (ISCED 2, ISCED 3 and ISCED 5). Because surveyed individuals are not a random sample of the population of individuals, all models are estimated using the probability of being sampled, provided as part of the EU-SILC dataset, as weights.

Identification

Individuals are not randomly allocated into different age-education cohorts, but can be assumed to self-select into cohorts through either acquiring a specific level of education or migrating to specific geographical areas. As a result, the cohort size variable is expected to be endogenous to the wage rate and estimation of Equation [3] by ordinary least squares (OLS) will give inconsistent estimates of the impact of cohort size on wages. The direction of bias is likely to be positive as high wages will induce self-selection into educational groups and geographical areas, thereby leading to an increase in the corresponding cohort size variable.

To identify the causal effect of cohort size on wages, IV estimation is employed using the annual birth rate at the time of birth of an age cohort as an instrument for the cohort size variable. Since this variable will have explanatory power for the cohort size variable and can be assumed to be uncorrelated with the error term in equation [3], it qualifies as a valid instrument.

While some recent papers (e.g. Mosca, 2009) do not address the endogeneity of cohort size at all, others, such as Wright (1991) and Brunello (2010), acknowledge self-selection into educational groups but implicitly disregard self-selection due to migration. Both use age-specific cohort size as a proxy variable or as an instrument for age-education cohort size. Being determined solely by demographic factors, they argue that this variable does not suffer

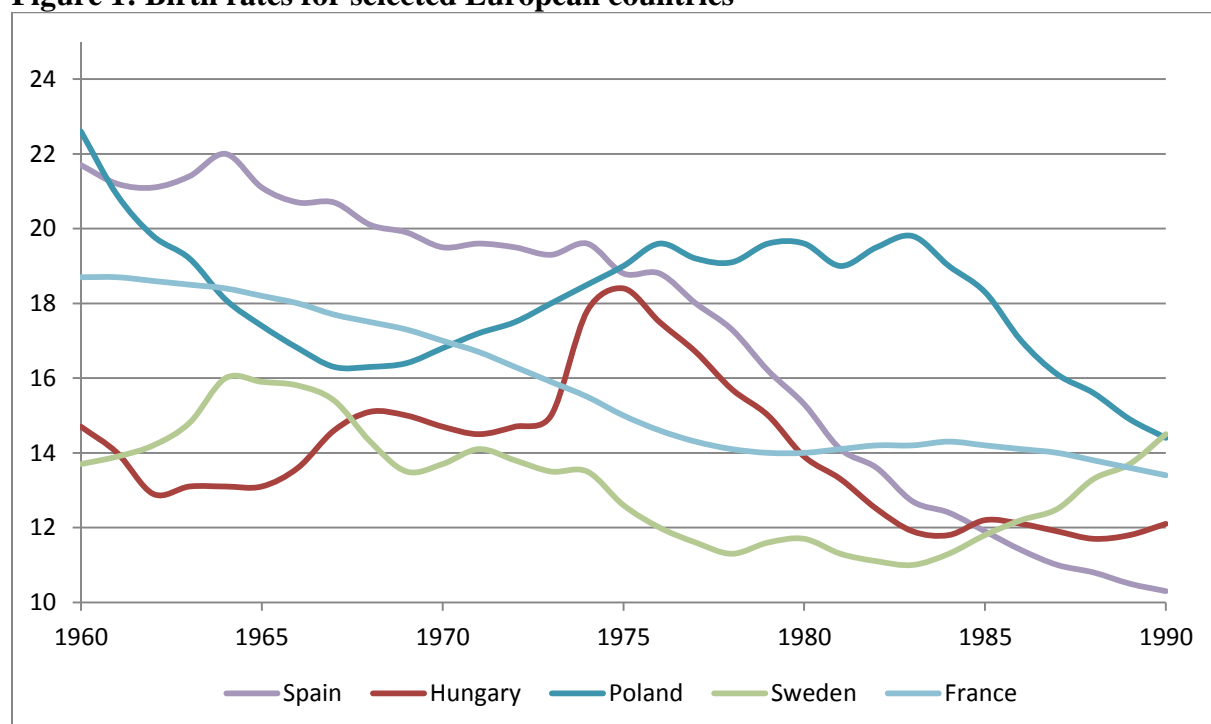
¹² The model also includes a constant.

¹³ We also experimented with including Age_{jkt}^3 and $\ln[CS_{jkt}] XAge_{jkt}^3$ but these terms were not statistically significant in any of the specifications.

from the same endogeneity problem as the age-education cohort size measure. While we agree that this adequately deals with endogeneity due to self-selection into education groups, the instrument does not deal with endogeneity arising from self-selection into geographic areas and, consequently, their estimated cohort size effects may be overstating the true effects.¹⁴

In his discussion of Klevmarcken's (1993) paper, Börsch-Supan (1993) identifies that lack of variation in the data due to the availability of only three waves of observations as the likely reason for why cohort and age effects could not be identified separately. Likewise, Korenman and Neumark (2000) stress the importance of cross-national variation for the identification of cohort size effects as reliance on time-series variation alone may lead to the confounding of period and cohort effects, especially in the case of limited longitudinal variation. In light of the short time period available in EU-SILC, the data set's advantage rests in the availability of cross-country data. As fertility patterns, i.e. the timing of baby booms and baby busts, have developed differently across European countries during the post-war period, cohort sizes differ across countries. This cross-sectional variation can therefore be exploited to identify the effect of cohort size on wages. Figure 1 provides a graphical representation of this cross-sectional variation.

Figure 1: Birth rates for selected European countries



Birth rates are the number of live birth rates per 1,000 population

¹⁴ Because the birth rate at the year of birth does not vary over time for a given individual, IV estimation of a fixed effects (FE) model of equation [3] using this instrument is infeasible. However, this limitation does not invalidate our instrument because it will also be uncorrelated with any time-invariant components of the error term.

3 Results

Table 2 shows the country-level coefficients of the three cohort size-related variables – the natural logarithm of cohort size, the interaction between cohort size and age as well as between cohort size and age squared – for each of the three education groups which have been estimated by OLS and two-stage-least squares (2SLS).

A full set of results can be found in Table A1 of the statistical appendix.

Table 2: Cohort size coefficients obtained from weighted regression (OLS and 2SLS)

Dependent Variable: <i>Ln Wage</i>	ISCED 2		ISCED 3		ISCED 5 ^a	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
<i>Ln Cohort Size</i>	0.025 (0.062)	0.123 (0.110)	0.321*** (0.061)	0.376** (0.162)	0.076 (0.079)	0.574*** (0.214)
<i>Ln Cohort Size X Age</i>	-0.008 (0.012)	-0.039** (0.018)	-0.081*** (0.011)	-0.132*** (0.018)	-0.017 (0.021)	-0.291*** (0.110)
<i>Ln Cohort Size X Age²</i>	0.001 (0.000)	0.002* (0.001)	0.003*** (0.000)	0.007*** (0.001)	0.000 (0.001)	0.017*** (0.006)
N	15,978	15,978	53,553	53,553	26,691	26,691
R²	0.642	0.641	0.785	0.784	0.636	0.627
χ^2-test of joint significance of cohort size variables	2.44*	5.02	20.34***	67.09***	0.94	7.57*
χ^2-test for underidentification^b	-	348.03***	-	1370.47***	-	110.78***

Cluster-robust standard errors are given in parentheses.

*/**/*** denotes significance at the 10%/5%/1% level

^a The age variable equals 0 for individuals aged 20 in ISCED group 2 and 3 and for individuals aged 25 in ISCED group 5

^b The χ^2 value shows the Kleibergen-Paap LM test-statistic for underidentification of the model.

The coefficients shown in Table 2 provide support to the hypothesis that cohort size is a significant determinant of individual wages for most of the education groups. For males with an ISCED 3 or an ISCED 5 background the coefficients of the cohort-size variables obtained from 2SLS are almost all individually significant at the 1%. For males at the ISCED 2 level only some cohort size related coefficients are significant at either the 5% or the 10% level.¹⁵

The first-stage statistics do not show a weak instrument problem for any of the ISCED groups. Table 3 reports Shea's partial R² which shows the explanatory power of the instruments for each of the three endogenous variables after accounting for any correlation between the instruments and the exogenous regressors.

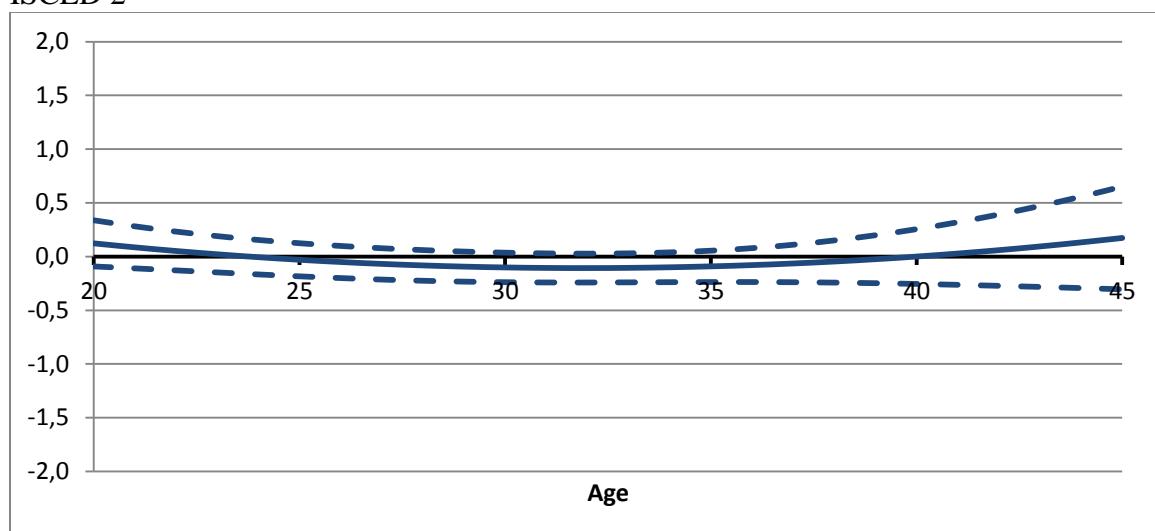
¹⁵ Testing for the joint significance of the cohort size-related variables shows that the former are not significantly different from zero at even the 10% level for ISCED 2 males.

Table 3: Shea's partial R²

	ISCED 2	ISCED 3	ISCED 5
<i>Ln Cohort Size</i>	0.3609	0.1531	0.1057
<i>Ln Cohort Size</i> <i>X Age</i>	0.4052	0.2299	0.0271
<i>Ln Cohort Size</i> <i>X Age</i> ²	0.2056	0.2711	0.0215

The partial R² is comparatively low for individuals with higher education. This result is not surprising as it would be expected that the better educated are more mobile and that there is consequently a weaker association between birth rate and cohort size for these individuals. Nevertheless, tests for underidentification reject the null hypothesis that the instruments are uncorrelated with the endogenous regressors for all educational groups.¹⁶ Furthermore, tests for the joint significance of the cohort size-related variables in the structural equation that are robust to the instruments being weak reveal that the former are significant at the 1% level for ISCED 3 males and at the 5% level for ISCED 5 males, but fail to be significantly different from zero for males with lower secondary education.¹⁷

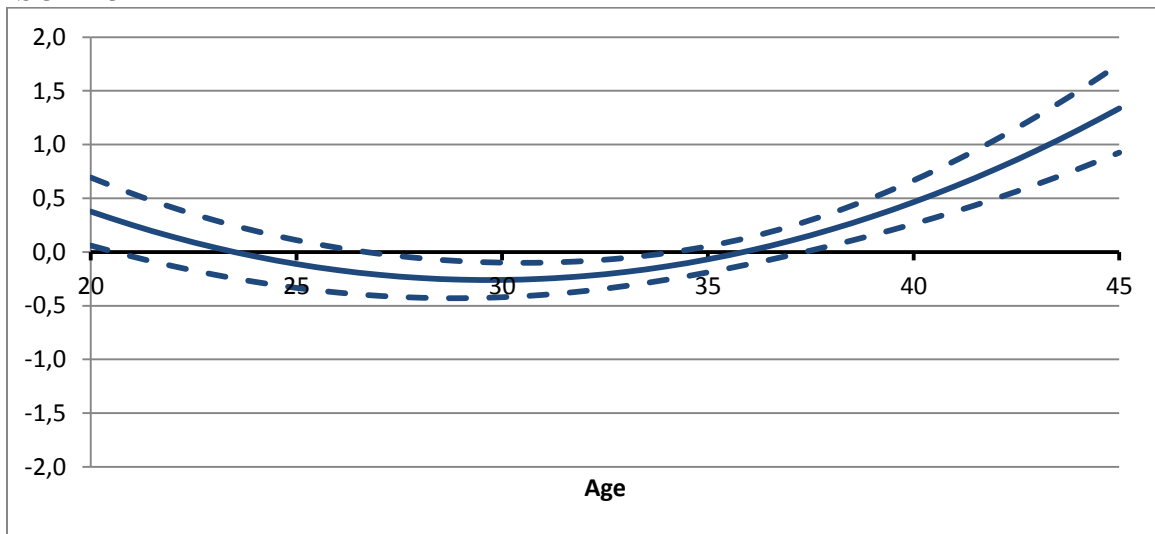
The marginal effect of cohort size on individual earnings, as derived in equation [4], represent the basis for assessing whether increases in cohort size lead to decreased earnings and whether, if such effects are present, the former are permanent or only temporary. Since the marginal effects are functions of age, Figure 1 plots the point estimate of the marginal effect of cohort size on wages as well as the upper and lower limit of the 95% confidence interval for each education group against age. Table A2 of the statistical appendix shows the marginal effect, standard error, z-value and 95% confidence interval of cohort size for each group by age.

Figure 2: Marginal effects of cohort size and 95% confidence interval
ISCED 2

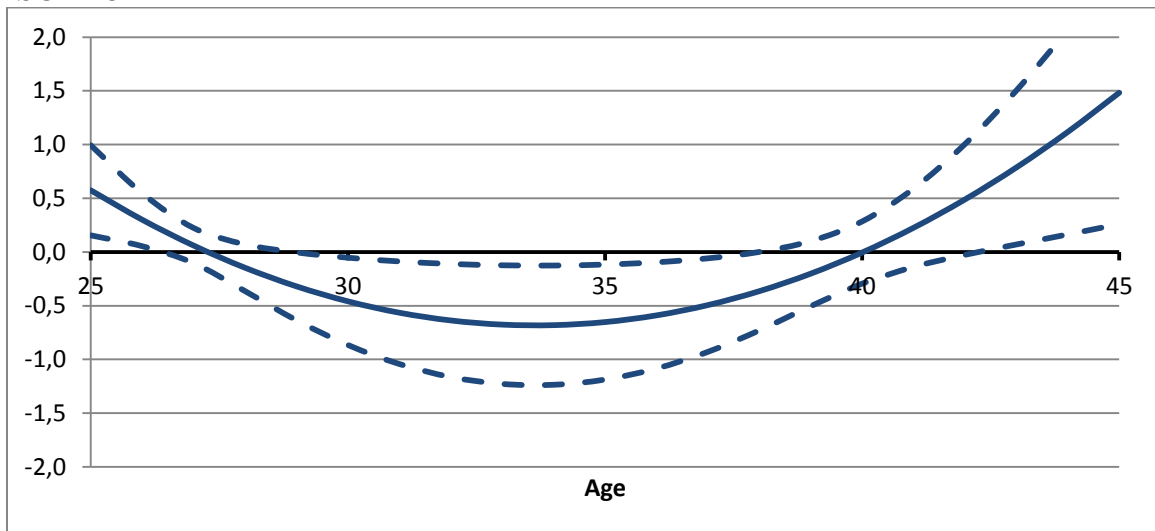
¹⁶ The test statistics take into account that the structural model's error terms are assumed to be clustered.

¹⁷ Results can be obtained from the authors upon request. The test statistics take into account that the structural model's error terms are assumed to be clustered. Cluster-robust F-statistics for the weak instruments test are 148.49 (ISCED 2), 749.27 (ISCED 3) and 39.56 (ISCED 5). It should be noted, though, that the corresponding critical values from Stock and Yogo (2005) do not include the case of a just-identified model with 3 endogenous regressors.

ISCED 3



ISCED 5



Concerning the central questions in the analysis of the relationship between cohort size and earnings outlined above, the main results are the following: first, males with at least a completed secondary education experience reductions in wages due to being in large cohorts during parts of their working lives but there are no significant marginal effects for males with a lower secondary education; second, the effects of cohort size on wages do not remain negative throughout an individual's working life but become positive as individuals age (thereby justifying the inclusion of interactions between cohort size and age as well as between cohort size and squared age); third, the largest negative (and positive) marginal effects are observed for individuals with the highest levels of education.

For males with an ISCED 2 education, marginal effects are negative but not statistically significant. This finding is compatible with the hypothesis that individuals at this level of education are perfectly substitutable across age implying that the effects of increased cohort size are not restricted to the members of that cohort.

In contrast, males with either completed secondary or tertiary education do suffer from decreased wages if the size of their age-education cohort increases. Marginal effects are significantly negative for ISCED 3 males over an 8-year period starting at age 27, while the duration of negative effects is slightly longer for ISCED 5 males (10 years) and starts later (age 35). More strikingly, the point estimates of the marginal effects are considerably more negative for ISCED 5 males than for ISCED 3 males, reaching a negative peak of -0.681 (age 34) compared to -0.260 (age 30) for ISCED 3 males. Our findings are therefore in line with earlier empirical evidence which finds that the negative effect of cohort size increases with the level of education, thereby providing support to the hypothesis that substituting identically educated individuals of different age becomes more difficult as workers become more educated.¹⁸

A common feature of the marginal effects for males with completed secondary or tertiary education is that they become significantly positive at later stages of an individual's working life (at age 38 for ISCED 3 and at age 42 for ISCED 5). This result is not directly compatible with the assumptions of perfectly flexible labour markets and imperfect substitutability among identically educated workers of different age which imply that increases in cohort size have a negative effect on cohort-specific wages.

The estimated marginal effects of cohort size on male wages can be put into perspective by comparison with the results obtained by Brunello (2010). Table 4 provides a summary of the marginal effects of cohort size on wages including the largest negative marginal effect as well as the average of the marginal effects over age.

Table 4: Comparison of marginal effects for Males

	ISCED 3		ISCED 5	
	Brunello (2010)	Own	Brunello (2010)	Own
Peak marginal effect	-0.070	-0.260	-0.175	-0.681
Average marginal effect	-0.070	+0.176	-0.175	-0.036

Brunello (2010) estimates the effect of cohort size on the average wage rate for age-education-specific cohorts. In doing so, he assumes that cohort size effects are constant with respect to age. His estimates suggest that a 1% increase in cohort size is associated with a 0.070% decrease in average earnings for ISCED 3 males and a 0.175% decrease for ISCED 5 males. In contrast, the empirical approach of this paper controls for confounding effects at the individual level and also allows cohort size effects to change as the individual ages. The results presented in this paper suggest that the marginal effects of cohort size are indeed age-specific and that effects at specific ages can be up to four times as large as the time-invariant marginal effects estimated by Brunello (2010).

A problem of conducting analysis of the cohort size-wage relationship within the country context is that individuals might not be competing for jobs within labour markets at the national level. For this reason the national analysis was supposed to be supplemented by a regional analysis for which the cohort size variable was to be constructed at the first level of

¹⁸ Due to the marginal effects being only imprecisely estimated for ISCED 5 males, the 95% confidence intervals of these effects overlap with those of ISCED 3 males. While the point estimates are different, their difference is therefore not significant at the 5% level.

the Nomenclature of Territorial Units for Statistics (NUTS 1). This approach would have been helpful as regions are more evenly sized than countries and therefore allow the construction of cohort size variables using more equally sized geographical regions that may more accurately reflect the number of potential substitutes. While the EU-SILC dataset includes information about individuals' regional residence, this analysis was made infeasible by the unavailability of birth rate data at the NUTS 1 level.

4 Conclusion

The aim of this paper has been the identification of the causal effect that the size of the age-education cohort to which an individual belongs exerts on wages. It is assumed that labour markets are segmented by educational attainment and that within each educational class differently aged workers represent distinct factors of production which are only imperfectly substitutable for each other. As such, increases in the size of a specific age(-education) group will have adverse effects on the wages of workers in that group.

In order to test the hypothesis that larger cohort size leads to reduced wages empirically the 2010 release of the EU-SILC survey, which includes observations at the household and the individual level for 24 European countries spanning the time period 2007-2010, is employed. Identification of the causal effect of cohort size on wages is complicated by that fact that an individual's cohort is likely to be the result of individual self-selection into specific educational groups and into specific geographic areas – decisions which can be assumed to be affected by the individual's expectations regarding the wage rates available in the corresponding educational groups or geographic areas. Cohort size is therefore treated as an endogenous variable. In order to identify the causal effect of cohort size on individual wages, instrumental variables estimation is applied using the birth rate at an individual's year of birth as an instrument for the size of the cohort to which he belongs. Lacking a priori assumptions on the development of cohort size effects over an individual's working life, interactions of cohort size with age and with squared age are included in order to assess whether any effects are permanent or temporary.

Cohort size and its interactions with age represent individually and jointly significant determinants of an individual's wages for males with completed secondary or tertiary education. In contrast, cohort size does not appear to affect the wages of ISCED 2 males which suggests that individuals in this educational group are perfectly substitutable across age. The marginal effects profiles of cohort size suggest that at ISCED 3 and ISCED 5 level, increases in cohort size lead to decreases in wages. Any negative effects of cohort size on wages are only temporary, lasting 8 years and 10 years, respectively. Furthermore, cohort size is found to have a larger negative effect on the wages of tertiary educated males than for males with completed secondary education peaking at values of -0.260 and -0.681, respectively, suggesting that higher educated males are less substitutable across age. Finally, the evidence suggests that cohort size effects are not constant throughout an individual's working life.

5 References

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6 Statistical appendix

Table A1: OLS and 2SLS regressions results¹⁹

	ISCED 2		ISCED 3		ISCED 5	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
<i>Ln</i> Cohort Size	0.025 (0.062)	0.123 (0.110)	0.321*** (0.061)	0.376* (0.162)	0.076 (0.079)	0.574** (0.214)
<i>Ln</i> Cohort Size X Age	-0.008 (0.012)	-0.039* (0.018)	-0.081*** (0.011)	-0.132*** (0.019)	-0.017 (0.021)	-0.291** (0.110)
<i>Ln</i> Cohort Size X Age ²	0.001 (0.001)	0.002 (0.001)	0.003*** (0.001)	0.007*** (0.001)	0.000 (0.001)	0.017** (0.006)
Age	0.009 (0.045)	-0.108 (0.068)	-0.250*** (0.041)	-0.430*** (0.072)	-0.250*** (0.041)	-0.430*** (0.072)
Age ²	0.001 (0.002)	0.005 (0.003)	0.010*** (0.002)	0.023*** (0.003)	0.010*** (0.002)	0.023*** (0.003)
Self-employed	-0.807*** (0.081)	-0.810*** (0.081)	-0.722*** (0.043)	-0.721*** (0.043)	-0.722*** (0.043)	-0.721*** (0.043)
Married	0.054** (0.018)	0.055** (0.018)	0.093*** (0.010)	0.095*** (0.010)	0.093*** (0.010)	0.095*** (0.010)
Part-time	-0.146*** (0.039)	-0.146*** (0.039)	-0.175*** (0.029)	-0.170*** (0.029)	-0.175*** (0.029)	-0.170*** (0.029)
Unemployment rate	0.043 (0.024)	-0.517 (0.277)	0.049*** (0.009)	-0.667*** (0.105)	0.049*** (0.009)	-0.667*** (0.105)
<u>Occupation Dummies</u>						
Occupation2	-0.328 (0.348)	-0.327 (0.347)	0.023 (0.069)	0.016 (0.069)	0.023 (0.069)	0.016 (0.069)
Occupation3	-0.156 (0.172)	-0.159 (0.171)	-0.106 (0.057)	-0.106 (0.057)	-0.106 (0.057)	-0.106 (0.057)
Occupation 4	-0.250 (0.128)	-0.250 (0.128)	-0.206*** (0.055)	-0.203*** (0.055)	-0.206*** (0.055)	-0.203*** (0.055)
Occupation 5	-0.312* (0.128)	-0.315* (0.128)	-0.342*** (0.055)	-0.341*** (0.055)	-0.342*** (0.055)	-0.341*** (0.055)
Occupation 6	-0.576*** (0.173)	-0.572*** (0.173)	-0.553*** (0.075)	-0.549*** (0.075)	-0.553*** (0.075)	-0.549*** (0.075)
Occupation 7	-0.314* (0.125)	-0.317* (0.125)	-0.265*** (0.051)	-0.263*** (0.052)	-0.265*** (0.051)	-0.263*** (0.052)
Occupation 8	-0.235 (0.122)	-0.239 (0.122)	-0.222*** (0.051)	-0.221*** (0.051)	-0.222*** (0.051)	-0.221*** (0.051)
Occupation 9	-0.496*** (0.126)	-0.500*** (0.126)	-0.496*** (0.055)	-0.491*** (0.055)	-0.496*** (0.055)	-0.491*** (0.055)
Occupation 10	0.028 (0.147)	0.021 (0.147)	0.079 (0.066)	0.071 (0.066)	0.079 (0.066)	0.071 (0.066)
<u>Urban Dummies</u>						
Intermediately populated	-0.028 (0.020)	-0.028 (0.020)	-0.021 (0.011)	-0.021 (0.011)	-0.021 (0.011)	-0.021 (0.011)
Thinly populated	-0.039* (0.020)	-0.039* (0.020)	-0.071*** (0.010)	-0.070*** (0.010)	-0.071*** (0.010)	-0.070*** (0.010)
Constant	2.662*** (0.299)	5.024*** (1.170)	3.672*** (0.251)	6.404*** (0.741)	3.672*** (0.251)	6.404*** (0.741)
<i>N</i>	15,978	15,978	53,553	53,553	53,553	53,553
<i>r</i> ²	0.6418	0.6412	0.7850	0.7839	0.7850	0.7839

¹⁹ Year, country, year-by-age, year-by-country and year-by-occupation effects are not reported. Results can be obtained from the authors upon request.

Table A2: Marginal effects
ISCED 2 (OLS)

Age	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
20	0,0247	0,0620	0,40	0,6900	-0,0967	0,1462
21	0,0171	0,0540	0,32	0,7520	-0,0888	0,1230
22	0,0107	0,0478	0,22	0,8230	-0,0830	0,1043
23	0,0055	0,0432	0,13	0,8990	-0,0792	0,0903
24	0,0016	0,0404	0,04	0,9680	-0,0776	0,0808
25	-0,0011	0,0391	-0,03	0,9780	-0,0777	0,0755
26	-0,0025	0,0389	-0,06	0,9490	-0,0788	0,0738
27	-0,0026	0,0395	-0,07	0,9470	-0,0801	0,0748
28	-0,0015	0,0405	-0,04	0,9700	-0,0809	0,0778
29	0,0008	0,0415	0,02	0,9850	-0,0806	0,0822
30	0,0044	0,0424	0,10	0,9180	-0,0788	0,0876
31	0,0092	0,0431	0,21	0,8310	-0,0753	0,0937
32	0,0153	0,0434	0,35	0,7250	-0,0698	0,1004
33	0,0226	0,0434	0,52	0,6020	-0,0624	0,1076
34	0,0312	0,0430	0,72	0,4690	-0,0532	0,1156
35	0,0410	0,0425	0,96	0,3350	-0,0423	0,1244
36	0,0521	0,0420	1,24	0,2150	-0,0302	0,1344
37	0,0644	0,0417	1,55	0,1220	-0,0172	0,1461
38	0,0780	0,0419	1,86	0,0620	-0,0041	0,1600
39	0,0928	0,0429	2,16	0,0310	0,0087	0,1770
40	0,1089	0,0452	2,41	0,0160	0,0202	0,1976
41	0,1262	0,0490	2,58	0,0100	0,0302	0,2223
42	0,1448	0,0544	2,66	0,0080	0,0382	0,2513
43	0,1646	0,0613	2,68	0,0070	0,0444	0,2848
44	0,1857	0,0698	2,66	0,0080	0,0488	0,3225
45	0,2080	0,0798	2,61	0,0090	0,0516	0,3644

ISCED 2 (2SLS)

Ag	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
20	0,1228	0,1096	1,12	0,2630	-0,0920	0,3375
21	0,0857	0,0998	0,86	0,3910	-0,1099	0,2813
22	0,0519	0,0921	0,56	0,5730	-0,1286	0,2324
23	0,0214	0,0862	0,25	0,8040	-0,1476	0,1903
24	-0,0059	0,0818	-0,07	0,9420	-0,1663	0,1544
25	-0,0300	0,0786	-0,38	0,7030	-0,1841	0,1241
26	-0,0508	0,0763	-0,67	0,5060	-0,2002	0,0987
27	-0,0683	0,0744	-0,92	0,3590	-0,2141	0,0776
28	-0,0826	0,0728	-1,13	0,2570	-0,2253	0,0602
29	-0,0936	0,0714	-1,31	0,1900	-0,2335	0,0464
30	-0,1013	0,0701	-1,45	0,1480	-0,2387	0,0361
31	-0,1058	0,0691	-1,53	0,1260	-0,2412	0,0296
32	-0,1071	0,0686	-1,56	0,1180	-0,2414	0,0273
33	-0,1051	0,0689	-1,52	0,1280	-0,2402	0,0301
34	-0,0998	0,0707	-1,41	0,1580	-0,2384	0,0389
35	-0,0913	0,0744	-1,23	0,2200	-0,2371	0,0546
36	-0,0795	0,0804	-0,99	0,3230	-0,2371	0,0782
37	-0,0644	0,0890	-0,72	0,4690	-0,2389	0,1100
38	-0,0461	0,1002	-0,46	0,6450	-0,2425	0,1502
39	-0,0246	0,1139	-0,22	0,8290	-0,2479	0,1987
40	0,0002	0,1301	0,00	0,9990	-0,2548	0,2552
41	0,0283	0,1486	0,19	0,8490	-0,2631	0,3196
42	0,0596	0,1694	0,35	0,7250	-0,2724	0,3916
43	0,0942	0,1922	0,49	0,6240	-0,2826	0,4709
44	0,1320	0,2171	0,61	0,5430	-0,2935	0,5575
45	0,1731	0,2440	0,71	0,4780	-0,3051	0,6512

ISCED 3 (OLS)

Age	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
20	0,3210	0,0611	5,2500	0,00	0,2011	0,4408
21	0,2433	0,0540	4,5100	0,00	0,1375	0,3492
22	0,1720	0,0483	3,5600	0,00	0,0774	0,2666
23	0,1070	0,0439	2,4400	0,02	0,0209	0,1931
24	0,0483	0,0409	1,1800	0,24	-0,0319	0,1284
25	-0,0042	0,0389	-0,1100	0,92	-0,0805	0,0721
26	-0,0503	0,0378	-1,3300	0,18	-0,1244	0,0238
27	-0,0901	0,0372	-2,4200	0,02	-0,1631	-0,0171
28	-0,1236	0,0369	-3,3500	0,00	-0,1960	-0,0512
29	-0,1508	0,0368	-4,1000	0,00	-0,2229	-0,0788
30	-0,1718	0,0365	-4,7000	0,00	-0,2434	-0,1001
31	-0,1864	0,0362	-5,1400	0,00	-0,2574	-0,1153
32	-0,1947	0,0359	-5,4200	0,00	-0,2651	-0,1243
33	-0,1967	0,0357	-5,5100	0,00	-0,2666	-0,1268
34	-0,1924	0,0357	-5,3800	0,00	-0,2625	-0,1224
35	-0,1818	0,0364	-5,0000	0,00	-0,2532	-0,1105
36	-0,1649	0,0380	-4,3400	0,00	-0,2394	-0,0905
37	-0,1418	0,0408	-3,4800	0,00	-0,2217	-0,0619
38	-0,1123	0,0450	-2,5000	0,01	-0,2004	-0,0241
39	-0,0765	0,0507	-1,5100	0,13	-0,1759	0,0229
40	-0,0344	0,0579	-0,5900	0,55	-0,1479	0,0791
41	0,0140	0,0666	0,2100	0,83	-0,1165	0,1445
42	0,0687	0,0766	0,9000	0,37	-0,0815	0,2189
43	0,1297	0,0879	1,4700	0,14	-0,0427	0,3020
44	0,1970	0,1005	1,9600	0,05	0,0001	0,3939
45	0,2706	0,1142	2,3700	0,02	0,0468	0,4944

ISCED 3 (2SLS)

Age	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
20	0,3764	0,1616	2,33	0,0200	0,0597	0,6930
21	0,2515	0,1495	1,68	0,0920	-0,0415	0,5445
22	0,1402	0,1388	1,01	0,3120	-0,1318	0,4123
23	0,0426	0,1294	0,33	0,7420	-0,2110	0,2961
24	-0,0415	0,1209	-0,34	0,7320	-0,2785	0,1956
25	-0,1119	0,1134	-0,99	0,3240	-0,3342	0,1103
26	-0,1688	0,1065	-1,58	0,1130	-0,3775	0,0399
27	-0,2120	0,1000	-2,12	0,0340	-0,4081	-0,0159
28	-0,2416	0,0939	-2,57	0,0100	-0,4256	-0,0576
29	-0,2577	0,0879	-2,93	0,0030	-0,4300	-0,0853
30	-0,2601	0,0821	-3,17	0,0020	-0,4210	-0,0992
31	-0,2489	0,0764	-3,26	0,0010	-0,3987	-0,0990
32	-0,2241	0,0712	-3,15	0,0020	-0,3636	-0,0846
33	-0,1857	0,0666	-2,79	0,0050	-0,3162	-0,0552
34	-0,1337	0,0633	-2,11	0,0350	-0,2577	-0,0097
35	-0,0681	0,0620	-1,10	0,2720	-0,1896	0,0535
36	0,0112	0,0636	0,18	0,8610	-0,1134	0,1357
37	0,1040	0,0685	1,52	0,1290	-0,0303	0,2383
38	0,2104	0,0770	2,73	0,0060	0,0596	0,3613
39	0,3305	0,0887	3,73	0,0000	0,1567	0,5042
40	0,4641	0,1033	4,49	0,0000	0,2617	0,6665
41	0,6114	0,1204	5,08	0,0000	0,3754	0,8474
42	0,7722	0,1398	5,52	0,0000	0,4982	1,0463
43	0,9467	0,1613	5,87	0,0000	0,6305	1,2628
44	1,1348	0,1847	6,14	0,0000	0,7727	1,4968
45	1,3364	0,2100	6,36	0,0000	0,9248	1,7480

ISCED 5 (OLS)

Age	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
25	0,0761	0,0787	0,9700	0,33	-0,0782	0,2303
26	0,0593	0,0650	0,9100	0,36	-0,0681	0,1866
27	0,0432	0,0554	0,7800	0,44	-0,0654	0,1519
28	0,0279	0,0504	0,5500	0,58	-0,0708	0,1267
29	0,0134	0,0493	0,2700	0,79	-0,0833	0,1101
30	-0,0004	0,0510	-0,0100	0,99	-0,1003	0,0995
31	-0,0134	0,0539	-0,2500	0,80	-0,1191	0,0923
32	-0,0256	0,0571	-0,4500	0,65	-0,1375	0,0862
33	-0,0371	0,0597	-0,6200	0,53	-0,1542	0,0799
34	-0,0479	0,0616	-0,7800	0,44	-0,1686	0,0728
35	-0,0578	0,0625	-0,9300	0,36	-0,1804	0,0647
36	-0,0671	0,0626	-1,0700	0,28	-0,1898	0,0557
37	-0,0755	0,0622	-1,2100	0,22	-0,1974	0,0463
38	-0,0832	0,0616	-1,3500	0,18	-0,2040	0,0376
39	-0,0902	0,0617	-1,4600	0,14	-0,2111	0,0307
40	-0,0964	0,0632	-1,5200	0,13	-0,2203	0,0276
41	-0,1018	0,0672	-1,5100	0,13	-0,2335	0,0300
42	-0,1064	0,0744	-1,4300	0,15	-0,2523	0,0394
43	-0,1103	0,0851	-1,3000	0,20	-0,2771	0,0564
44	-0,1135	0,0993	-1,1400	0,25	-0,3081	0,0811
45	-0,1159	0,1167	-0,9900	0,32	-0,3447	0,1130

ISCED 5 (2SLS)

Age	ME	Standard error	p-value	Prob	95% CI (lower limit)	95% CI (upper limit)
25	0,5741	0,2139	2,6800	0,01	0,1548	0,9934
26	0,3002	0,1256	2,3900	0,02	0,0539	0,5465
27	0,0599	0,0834	0,7200	0,47	-0,1035	0,2234
28	-0,1467	0,1111	-1,3200	0,19	-0,3644	0,0709
29	-0,3198	0,1612	-1,9800	0,05	-0,6357	-0,0039
30	-0,4592	0,2072	-2,2200	0,03	-0,8654	-0,0530
31	-0,5651	0,2435	-2,3200	0,02	-1,0424	-0,0878
32	-0,6373	0,2685	-2,3700	0,02	-1,1635	-0,1110
33	-0,6759	0,2817	-2,4000	0,02	-1,2281	-0,1237
34	-0,6809	0,2832	-2,4000	0,02	-1,2359	-0,1259
35	-0,6522	0,2731	-2,3900	0,02	-1,1875	-0,1170
36	-0,5900	0,2522	-2,3400	0,02	-1,0843	-0,0957
37	-0,4942	0,2221	-2,2300	0,03	-0,9294	-0,0589
38	-0,3647	0,1863	-1,9600	0,05	-0,7299	0,0005
39	-0,2016	0,1545	-1,3000	0,19	-0,5045	0,1013
40	-0,0049	0,1477	-0,0300	0,97	-0,2945	0,2846
41	0,2254	0,1860	1,2100	0,23	-0,1392	0,5899
42	0,4893	0,2631	1,8600	0,06	-0,0264	1,0049
43	0,7868	0,3657	2,1500	0,03	0,0701	1,5035
44	1,1179	0,4869	2,3000	0,02	0,1635	2,0723
45	1,4827	0,6241	2,3800	0,02	0,2595	2,7058