Instrumental variable analysis of the quantity-quality trade-off in German children's educational achievement

Sergiy Radyakin

Institute of Labour Economics, Leibniz University of Hannover

This version: 27.02.2007

Abstract. The quantity-quality trade-off theory speculates that as the number of children increases, the quality (commonly understood as educational achievement) of the children declines. In this paper an instrumental variable approach is chosen to analyse the secondary school tracks attendance of German pupils as an early educational outcome. Sibship size of the parents and their age at first birth are employed as instruments for the number of children in the family. In contrast to OLS estimates the results of IV analysis suggest larger negative effects of family size on the attendance of the upper secondary school track (Gymnasium)[1].

1. The theories of the quantity-quality trade-off

There are three competing theories aimed to explain the negative correlation observed between a family size and educational outcomes of the children (Heer 1985, Downey 1995, Steelman et. al, 2002).

The first theory (Ernst and Angst 1983) postulates that actually there is no effect and any observed correlations are the results of failure to include all relevant controls. However, as the data quality increased and more and more relevant factors were included in the

[1] *This research was supported by the Anglo-German Foundation within the project 'The Economics and Politics of Employment, Migration and Social Justice' which is part of Foundation's research initiative "Creating Sustainable Growth in Europe"*
The data used in this publication was made available by the German Socio-Economic Panel Study (SOEP) at the German Institute for Economic Research (DIW Berlin).

analysis, the effects of sibship size on education were still a common finding thus casting doubts on the validity of this theory of no effect.

Alternatively, the resource dilution theory (Anastasi 1956, Blake 1981, Hanushek 1992) focuses on the distribution of parental resources as the sibship size changes. The theory is very intuitive indeed. Assuming that the amount of resources the parents can provide is fixed, the higher number of siblings will decrease the amount of resources each sibling is going to receive. Provided that there is a casual interrelation between the resources and the educational achievement, the higher sibship sizes cause lower educational achievement. The theory is easily generalisable to take into account that some of the resources (e.g. parental time) can not be accumulated. Thus the amount of this resource for each sibling depends on his position in the sibship and the spacing between the siblings. This allows for the birth order effects also often found in the literature.

Empirical investigations generally confirmed the predictions of this theory; however, some irregularities were noted. The resource dilution theory predicts that the only children enjoy the higher amount of resources, since they don't have to share them. Contrary to the expectations, the educational achievement of the only children is not as high as predicted and often lower than the achievement of the children with other siblings (Belmont and Marolla 1973, Steelman and Mercy 1980, Van Eijck and De Graaf 1995). Another inconsistency was the phenomenon of the last born children. The decline in their outcomes is larger than one might expect by observing the decline in outcomes of the immediately preceding siblings.

At the same time another theory of the sibship size and birth order effects on achievement comes from the field of sociology. The confluence theory (Zajonc and Markus 1975) stresses the importance of the family intellectual environment for the development of a child. In this theory the initially low intellectual level of a new born child grows with the rate related to a function of the intellectual level in the family, often defined as an average of all of the family members (parents and children). Intellectual development then translates into educational achievement. According to the model, later born siblings experience the environment already diluted by the presence of their older siblings and thus exhibit lower rates of development and achievement. As such, the theory predicts the higher rates of development for only children, for the same reason that they enjoy the intellectual environment not diluted by the presence of siblings, and thus suffers from the same drawback.

An analysis of the inconsistencies found in empirical evaluations of the resource dilution model has shown that these inconsistencies are similar in magnitude, and thus might be caused by a common reason. By noticing that the only children are at the same time the last children, the common trait was found and the confluence model was augmented by a "teaching function" of the siblings. Indeed the observations of the siblings' interactions suggest that the older siblings often perform a role of tutors to their younger siblings. This interaction might range from explaining the rules of a new game to help with home assignments. Notably this process benefits not only the younger sibling who is being taught, but also the older sibling who teaches. As the only children and the last-born do not have any younger siblings to teach, they both suffer the "teaching handicap" which is hold responsible for both inconsistencies.

The empirical investigations of the teaching effects are still rare. The "teaching function" of the confluence theory was first investigated by Smith (1984) and Smith (1990) where sibling interaction was measured directly. Smith finds a substantial negative relationship between self-reported school grades and the number of siblings. As the degree of responsibility for the younger siblings increases, the school grades improve which agrees with the positive effect of teaching on the teacher. However large responsibility is associated with a decline in grades, suggesting diversion child's attention from schooling to child care. Smith also finds race effects, as the school grades of blacks do not seem to improve when they perform the teaching function.

Another notable feature of the confluence theory is that it is flexible in the spectrum of predictions one can make. Rather than predicting a monotonic decline in the achievements of the children born to larger families, the confluence theory provides the possibility for the positive effects of the sibship size as well. Indeed, if the first sibling reaches maturity by the time the second is born, the intellectual level of the environment will not be reduced that much by the new birth as it would in the absence of the older sibling. Here another important component of the sibship configuration – sibling spacing comes into play. The negative effect of the widely spaced siblings onto the intellectual environment is not as large as the effect of closely spaced siblings. That is similar to the predictions from the resource dilution theory, which postulates that closely spaced siblings put more stress on the parental resources. In both theories, however, some positive effects of close spacing are possible. While the confluence theory allows for a larger interaction between the closely spaced children (exchange of experiences, etc), the resource dilution theory underlines the possibility of returns to scale.

It is only recently however that the underlying principles of the above named theories came under the scrutiny. While earlier researchers focused on children outcomes, the mechanism of the propagation of the family size effects was often left behind the scenes. Downey (1995) examines availability of different educational resources by family size and finds that children living in smaller families indeed have more educational resources. As the family size grows the availability of resources declines. While interpersonal resources (such as "frequency of talk") exhibit linear pattern of decline, economic resources exhibit hyperbolic decline ("money for college") or even a distinct fall after a threshold is reached ("computer in the home"). The occurrence and amount of parental financial support is investigated in Powell and Steelman (1995). Using the data from High School and Beyond sample they consistently find a negative relationship between the number of siblings and the presence and amount of parental support. Higher siblings density is also associated with fewer parental support.

The remaining part of the paper is organised as follows: section 2 introduces the secondary school tracks in Germany and explains why Gymnasium attendance can be considered as an educational outcome, section 3 discusses the instrumental variables studies of the family size effect on educational achievement, section 4 presents the econometric model, section 5 introduces the dataset, section 6 presents some descriptive statistics, and section 7 presents the results and their discussion. Section 8 concludes.

2. Gymnasium track as an early educational outcome

German secondary educational system is a multi-track system with pupils after reaching the age of 10 having to choose one of the three main school types Hauptschule, Realschule and Gymnasium. These schools provide different curriculums preparing their graduates for different future careers. The highest track, Gymnasium, is the main gateway to the university education. The curriculum in Gymnasiums is the most demanding and the duration of study is the longest – the pupils will typically graduate from Gymnasiums at the age of 19. In contrast, the lowest track, Hauptschule, provides the least demanding curriculum and relatively short duration of study with the pupils completing their studies at the age of 15. They can then acquire some on-the-job-training. The middle track, Realschule, educates the pupils until the age of 16, and provides an opportunity to study in a professional school later to obtain a professional certificate.

The importance of attending Gymnasiums is described in detail in Dustmann (2004) where the German SOEP data is used. Being the highest of the three major secondary educational tracks, Gymnasiums open significantly better opportunities in terms of future earnings. After taking into account vocational training, occupational group, age and cohort effects, Dustmann finds that graduating from a Gymnasium leads to about 26% wage increase for men and about 31.7% for women compared to the lowest secondary school track (both coefficients are statistically and economically significant).

Cooke (2003) focuses on the differences in trajectories of wages of the graduates of the different school tracks by studying their initial wages and their development in the first years of working. Using German SOEP data Cooke shows that graduation from a Gymnasium (Abitur) alone does not predict higher initial wages compared to the middle track (Realschule), but rather significantly lower. It is the combination of Abitur and apprentice certification which is found to be rewarded by initial wages on the market. While the effect of Hauptschule on wages is found to be slightly negative, it is, however, not persistent. By looking at the further stages of human capital formation Cooke discusses the effects of apprenticeship and vocational certification. The importance of apprentice certification has risen in 1994 when compared to 1984, which may be interpreted in a signaling framework. Indeed, the number of pupils following the Gymnasium track was steadily increasing in West Germany 1980s. While having Abitur could be a signal of higher abilities in the early 1980s, this is no longer true in the 1990s. Another finding was a variation in the effectiveness of vocational certification by school tracks, which predicted higher initial wages for those trainees, who graduate from Realschule or Gymnasium, but not from the lowest, Hauptschule, track. Finally, Cooke finds that although vocational certification has a positive impact on the initial wages, this effect vanishes in time, thus necessitating life-long learning.

These studies have shown practical importance of the secondary educational tracks suggesting that they could be an early outcome in the human capital acquisition having important consecutives for the future life by largely shaping the future employment, wages and career. A number of factors seem to influence the choice of the track with the most important being parental background characteristics.

Several studies investigated the influence of living in non-intact families on the educational outcomes of children. Winkelman (2006), using SOEP data documents about 20% disadvantage in Gymnasium attendance for children from non-intact families. Yet there is no significant impact on child's (subjective) well-being once the other factors are controlled for. Although generally the effects of parental separation are found to be negative, there are some doubts on their significance. Björklund and Sundström (2006) using a large dataset of about 100,000 Swedish full biological siblings found in a sibling-difference approach no significant effect of parental separation on the earnings-weighted education. Frick and Wagner (2001) find the effect of living with a single parent to be not significant on the probability of attending Gymnasium at least when the duration of stay in Germany is accounted for. Recently Mahler and Winkelmann (2004) studied the impact of an episode of living with a single mother on the secondary school track using German SOEP data. In a framework of an ordered probit model they find no significant effects, though they admit relatively low incidence of single motherhood.

3. Instrumental variable estimation of the sibship size effects

Although the negative correlation between sibship size and educational achievement has been established for a long time already, only recently the causality of this relationship has been questioned. Guo and VanWey (1999) built up a family fixed effects model and estimated it using National Longitudinal Survey of Youth data. They benefit from the panel structure of the data by using repeated measures of cognitive development and find no evidence of negative effects of sibship size.

The treatment of the sibship size in the achievement models as an exogenous variable does not allow to question exogeneity of this factor. Indeed the sibship size might be determined simultaneously with the child's outcome and thus endogenously by other factors, already in the achievement model such as parental education or family income.

If this is the case, estimation of simple linear models controlling for both sibship size and other factors which supposedly determine sibship size will not yield only a biased estimate of the effect of sibship size.

In order to be able to identify the separate effect of the sibship size one might use an instrument variable, which is a variable correlated with sibship size, but not affecting the child's outcome directly, but only through the sibship size. Recent studies have suggested several candidates for an instrument.

Twins studies argue that the multiple births can't be foreseen and thus constitutes an externality, providing a "natural experiment" by unexpectedly increasing the family size beyond the family size that the parents find optimal. Several conditions apply, however, for multiple births to be a viable instrument. Multiple births must occur on the margin (no more younger siblings after the birth of the twins). Even then the birth of twins has only a 50% chance to overshoot the optimal family size as seen by the parents. The use of twins samples is also limited by data availability. Early studies involved only a few dozens of observations, as low as 25 twin pairs in Rosenzweig and Wolpin (1980). Later studies (Black 2005, Angrist, Lavy and Schlosser 2006) use large (nationwide) data. Recent medical developments have also contributed to the critique of the twins instrument. Indeed modern medical treatment allows affecting the probability of giving multiple births and the birth of twins may have a direct impact on siblings outcomes.

Another instrument that is commonly used is based on parental preferences for a particular gender composition of their children. In some cultures boys and girls are treated differently, with parents exhibiting preferences towards children of a particular sex. Having first children of the other sex will induce parents to have more children thus increasing the family size beyond what the parents would otherwise choose (Lee 2004). In other societies the parents might have preferences for having children of both sexes and thus having first children of the same sex might again induce higher fertility (Andersson et al. 2006, Conley and Glauber 2005). Using this instrument also means that the families with only one child are excluded from the analysis, since the instrumental variable "sex composition of the first two children" can't be defined. Finally there is also a suspicion that sibship sex composition has a direct effect on child outcomes (Dahl and Moretti, 2004).

Yet another instrument was recently suggested. Grawe (2005) argues that religious denomination might work as an instrument since it is found to be correlated with the family size (catholic families are generally larger than other Christian families), but does not affect educational achievement on its own. Using this instrument Grawe finds no negative effects of sibship size on educational outcomes in the British National Child Development Study. It is not clear however how to take into account non-religious families with this instrument, rather than ignoring them in the analysis.

In a recent work Jaeger (2006) suggested using sibship sizes of the parents as instruments to the sibship size of their own family. Indeed many studies document a persistent relationship between the sibship sizes of parents and children (Murphy and Knudsen 2002, Axinn, Clarkberg and Thornton 1994). It is not clear however whether this persistence is caused by genetic or cultural factors.

The idea is that the reproductive ability of the spouse can be assumed to be unknown until marriage, hence the resulting sibship size is a product of a "natural experiment" – where the family size is now determined not only by genetic/cultural/individual properties of one partner, but also of the other causing an exogenous variation in the family size. There is also no direct effect of the sibship size of the parents on the educational attainment of the children (since parental siblings will almost surely live in their own families). Thus it is reasonable to expect that suggested instruments are valid instruments. Formal tests of instrument validity follow in section 7.

4. Econometric model

A typical regression model estimated in the literature will include the family size (*Children*) and a number of family background characteristics (*X*) to control for such as income, parental education and occupation. As the outcome variable "attending upper secondary school track" is qualitative, the model effectively predicts the probability of this outcome.

$$\Pr(Gymn) = \beta_0 + \beta_1 Children + \beta_2 X + \varepsilon \tag{1}$$

However, family size and educational achievement may be jointly determined by other factors and the above regression will yield biased estimates. Thus family size will first be instrumented with the variables discussed above: number of siblings and age at first birth for the mother and father respectively.

The model is thus:

$$Children = \alpha_0 + \alpha_1 FS + \alpha_2 MS + \alpha_3 FA + \alpha_4 MA + \alpha_5 X + \eta \tag{2}$$

$$\Pr(Gymn) = \beta_0 + \beta_1 IChildren + \beta_2 X + \varepsilon \tag{3}$$

where *FS* and *MS* denote the number of siblings, and *FA* and *MA* the age at first birth for the father and mother respectively; *IChildren* is the instrumented family size coming from the first stage; *X* represents all other family background characteristics; *Gymn* is a dummy variable for attending Gymnasium.

The second equation of the model (equation 3) will be estimated as a linear probability model and as a probit model. And an OLS estimate of equation (1) will be provided as a benchmark for comparison.

5. Data

I use German Socio-Economic Panel (SOEP), an annual longitudinal household survey to estimate the effect of the family size on educational attainment. SOEP provides all of the necessary variables and a decent number of observations to make the estimation feasible.

I start with the sample of individuals (N=2,308) who filled in the youth questionnaire in the years 2000-2005[2]. All of the individuals were born between 1982 and 1988, and the majority (86%) were 17 year old. 98% of them were still living in parental household.

I use mothers' birth histories to determine the biological mother[3], family size, and the age of the mother at first birth for each individual in the sample. The information about parental family size can only be determined if the parent had filled in the questionnaire in 2003. This is the only year where the question about the presence of siblings does not imply the siblings to be alive. The exact formulation of the question was "Do you or did you have brothers and sisters? If yes: how many brothers and how many sisters?".[4] The individuals then reported the number of brothers and sisters that they have ever had. I use these answers to generate the variables *FS* (father's siblings) and *MS* (mother's siblings).

---

[2] Only adult household members fill in the questionnaires. Child-related information is provided by household heads. Youth questionnaire is filled in by 16-17 year olds interviewed for the first time.

[3] Both biological and adoptive children are included (but not foster or stepchildren since they can't be found in the birth biographies).

[4] The question about siblings asked in previous years was targeted at measuring social interaction and thus the sibling must necessarily be alive.

Once a child is found in the birth history file of a woman, this history can be traced back to determine the year when the first child was born. The difference between this year and the year of birth of the mother (father) will give the age at first birth for the mother (father).

I am using the highest reported education years for parental education and the level of income reported in the year when the youth questionnaire was filled in.

The outcome variable is a binary success variable taking values of 1 for those who attended Gymnasium track and zero for those in Realschule and Hauptschule.

Immigrant status is based on the answer to the question regarding country of birth and the origin of the parents. The immigrant status variables distinguish between three cases: children born to German parents, children born in Germany with at least one parent reporting foreign country of origin (second-generation immigrants), and children born not in Germany (first-generation immigrants).

Single parent families were excluded from the sample. First, observing parental sibship sizes of both parents is essential in this model, and second parental separation or death might have a separate effect on a child's educational outcome as it is documented in Winkelmann (2006) and other studies. Since not all of the children in the sample were observed since their birth (the Socio-Economic Panel expanded several times since the first data collection in 1984), the following procedure was used to select children not affected by single parenthood. First the children must report living in a parental household, second both parents must be present, and third the question in the youth questionnaire regarding the duration of life with biological parents must have a value of 15 (i.e. all childhood). For similar reasons children whose parents were under 16 years old when their first child was born were excluded from the sample.

6. Descriptive statistics

The final sample consists of 1,171 individuals for whom all of the required variables are observed. Table 1 reports the means of the variables by school track and in the whole sample. The weights provided with the SOEP data were used in all estimation procedures described below.

About 40% of the pupils are in Gymnasium track, and about 60% are in Hauptschule or Realschule. The pupils in Gymnasiums live in smaller families, having on average 0.3 sibling less than their counterparts in the other tracks. Girls are overrepresented in Gymnasiums, and boys in other school tracks. Overall fathers have somewhat more years of education than the mothers, with the difference being larger among the pupils attending Gymnasiums. Parental education differs dramatically by track, with the students in Gymnasiums having more educated parents. Fathers of the pupils in Gymnasium track have on average 2.72 years more of education, and the corresponding figure for mothers is 2.02. Gymnasium pupils live in richer families (49.3 vs. 37.7 thousand EUR).

The occupation of fathers is classified into the following groups: blue-collar worker, white-collar worker, civil servant, self-employed and out of the labour force. The two largest groups: blue-collar worker and white-collar worker account for about 66% of all occupations. The fathers of children attending Gymnasiums are more likely to be white-collar workers (42.32%) than blue-collar workers (20.64%) and the reverse is true for the other tracks. There the fathers are more likely to be blue-collar workers (47.14%) then white-collar workers (20.49%). Similar pattern arises for the other occupational groups, with children attending Gymnasiums being more often in the families of civil servants, and children from other tracks in the families where the fathers are not in the labour force.

Fathers of the children in Gymnasium track on average have fewer other siblings (2.38) than the fathers of the children in the other tracks (2.76) and they are older when they have their first child born (28.2 vs. 26.4 years old). The same pattern applies to the mothers: those who have their children attending Gymnasiums have fewer siblings (2.04 vs. 2.79) and are about 2 years older (25.5 vs 23.3) when their first child is born.

About 26% of all children in the sample are either first- (11.7%) or second-generation immigrants (14.3%). These children show lower Gymnasium attendance rates (about 30.5% in each immigrant group) than the German children do (about 43%). This can also be seen from the distribution of children being in one school track by immigrant groups. While German children constitute 74% of all children, they account for 80% of all children attending Gymnasiums. The reverse is true in the lower tracks, where the German children account for under 70% of all children in those tracks.

Table 2 shows the distribution of the children by family size and corresponding Gymnasium attendance rates. Children from two-child families constitute 47.6% of the sample, followed by children from three-child families, who comprise about 23.3% of the sample. 12.9% of the children are the only children and about 16.2% are born to the families of four or more. Gymnasium attendance declines with increasing family size from about 49% for the only children to about 18% for children from the families with five children. Then there is a sudden jump in educational achievement for the "six or more children" group. This is perhaps explained by a small number of observations (under 30) in this group. Indeed if the last two groups are combined together, the Gymnasium attendance rate in this group is lower than among the children from the families with four children. No disadvantage in educational attainment of the only children similar to the one documented by Belmont and Marolla (1973) or Van Eijck and De Graaf (1995) can be seen from these data. This does not contradict either theory, however, since the confluence theory does not predict a constant "teaching handicap" of the only children, but rather suggests it's dynamic influence over the course of child development. Zajonc (2001) estimates that the "teaching handicap" may not be present up to 11±2 years, which is already after the decision regarding a secondary school track is made.

7. Estimation results

Results from OLS. Table 2 presents the results of the OLS estimates of the educational achievement model. The first column of table 3 relates Gymnasium attendance to the family size, child's sex and immigrant status. The coefficient for the number of children is negative and significant meaning that as the family size grows, the children experience a decline in the probability to attend Gymnasium by about 3.9 percentage point for each additional child. The coefficient for child's sex is also highly significant and shows that boys experience a relative disadvantage in Gymnasium attendance of about 17 percentage points. The immigrant status variables are not significant.

The second model adds parental education and net family income to the set of control variables. All of the newly included variables seem to have a high impact on the probability of Gymnasium attendance as each of them is significant at 1% level. Notably, the educational level of the father seems to be more important for the child's educational track than the educational level of the mother. The estimated value of the coefficient for income suggests that a €10,000 increase in family income increases the chances of attending a Gymnasium by about 2.9 percentage points.

The third model adds the occupation of the father to the set of control variables as a proxy for the social status. Taking the children of the blue-collar workers as a comparison, the model predicts 15.2% higher Gymnasium attendance rates for the children of the white-collar workers. Children of self-employed and civil servants are also predicted to have higher Gymnasium attendance rates (about 11% in each group), though these coefficients are not different from zero at the standard 5% significance level.

Results from IV-Estimation. Table 3 presents the results of the IV estimation using the parental sibship size and age at birth of the first child as instrumental variables. Each of the models I to III in table 3 controls for exactly the same variables as the OLS models 1-3 presented in table 2, with the only difference that the number of children in the family is now being instrumented with the above mentioned variables. Odd-numbered columns present the estimates of the first-stage equations (number of children) and even-numbered columns present the estimates of the second stage equations (Gymnasium attendance).

The estimates of the first stage equations suggest that child's sex is not a good predictor for the family size, immigrant's status positively affects family size, and child's sex and the education of father seem to be irrelevant, while higher educational levels of mothers induce lower family sizes. With respect to occupation, those out of the labour force seem to have larger family sizes as compared to the blue-collar workers, with the results for the other occupational groups not significantly different.

Three of the included instruments invariantly show high level of significance: sibship size of each of the parents, and the age of the mother at first birth. The model confirms that the more siblings the parents have, the more children will they have themselves (other things being equal). Similarly, the earlier the first birth for a woman occurs, the more children she is expected to have. The age of the father at first birth does not seem to matter once the other factors are hold constant, the estimated coefficient itself is small in comparison with the (significant) coefficient of mother's age at first birth and changes the sign across the models. This can be explained by a high correlation between the ages of the parents at the time of first birth (in the data it is about 68%). A formal test for redundancy of an instrument confirms this (chi-square statistic is 2.190 with associated p-value of 0.1389). Similarly, mother's age at first birth is also redundant if father's age is controlled for. Exclusion of any of these two related variables creates a new (smaller) set of instruments with no instrument being redundant anymore. No other instrument seems to be redundant as p-values of the test are all equal to 0.000. The exclusion of this variable from the set of instruments does not change the results presented in table 3, though.

Table 4 presents some of the common tests of the instruments. Both F-statistic and Anderson canonical correlations test suggest that the instruments are relevant and the model is identified. Specifically, the value of F-statistic is much larger than the “rule-of-thumb” value 10, which means that the chosen instruments are not “weak”. The Sargan-Hansen test confirms that the instruments are uncorrelated with the error term. So the instruments seem to be valid in a sense that they satisfy the two requirements for instrumental variables: they are correlated with the instrumented variable (number of children) and are not correlated with the error term.

The results of the instrumented linear probability model generally agree with the OLS estimates. Boys experience a significant disadvantage in Gymnasium attendance rates of about 17 percentage points (which is equal to the uncontrolled Gymnasium attendance differential between boys and girls). Immigrant status does not seem to affect educational achievement in IV models either[5]. Each additional year of father’s education increases child’s chances to follow higher school track by about 6 percentage points, while the same figure for mothers is lower at about 2 percentage points. Occupation of father seems to be relevant to the secondary school track choice of his child in the IV model too. Children of the white-collar workers are estimated to have 15% higher Gymnasium attendance rates.

Finally, the variable of interest number of children is still significant as in the OLS regressions, but the estimated coefficient is three times as large in magnitude suggesting that simple OLS estimates may underestimate the true negative effect of the number of children in the family on their educational achievement.

[5] After the number of children is controlled for.

Results from IV-Probit estimation. As the diagnostics of the instrumental variables suggested redundancy of one of the instruments being used, it was removed from the set of instruments and the probit model was estimated using the following three instruments: number of siblings of the father, number of siblings of the mother, and age at first birth of the mother.

The results of the IV-Probit presented in table 6 generally agree with the previous findings. Parental education is found to be a significant factor in explaining the educational attainments of children with an additional year of education of fathers increasing the probability to attend Gymnasium track by about 7 percentage points when evaluated at the mean education of fathers (12.51 years). The corresponding figure for the education of mothers is smaller, about 7 percentage points, but highly significant. The gender effect is somewhat amplified in the probit model up to 22 percentage points disadvantage for boys. The trade-off between the number of children and their educational achievement at the means of all variables appears to be much larger than in both linear OLS and IV models.

Figure 2 illustrates the size of the effect of family size by educational levels of fathers, mothers and both parents. The effect remains negative and significant and its nonlinear change is an artefact of the assumed probit model specification (since no interaction term between parental education and the number of children is present in the model).

Figure 3 illustrates the modelled probabilities of Gymnasium attendance by different levels of education of the parents holding all other variables at their mean levels. As expected, high levels of education of both of the parents almost guarantee Gymnasium attendance, while low education effectively rule s it out.

Figure 4 illustrates both the probability of Gymnasium attendance and the effect of sibship size by varying level of parental education. The three curves represent the modelled probability at the average number of children in the family, and one child more or less than that. The order of the curve agrees with the quantity-quality trade-off at all points, suggesting that the children growing in larger families experience disadvantage in Gymnasium attendance irrespective of the educational level of their parents. It follows from the model predictions that the chances to attend Gymnasium of the children in the family where both parents have nine to ten years of education are effectively halved by a birth of an additional child. Though the absolute effect is about the same in the families of highly educated parents, its relative significance is smaller, changing Gymnasium attendance probabilities by just a few percent.

8. Conclusion

Family size has long been an important factor in explaining a child’s educational achievement. It is a robust finding that children from larger families perform worse than the children from smaller families. While one theory suggests that this observed difference is due to the differences in other characteristics important for acquiring human capital, such as parental education and income, others posit that family size has a direct negative impact on the educational achievement.

It is only recently that the causality of this relationship undergone detailed investigation, and a prominent tool here is the use of instrumental variables. With a few exceptions, siblings sex composition and twins have been the two most often used instruments. This paper utilizes a relatively new instrumental variables, parental sibship size and age at the birth of the first child, to obtain the estimates of the family size effects in Germany. The secondary school track is being used here as an early educational outcome since it largely determines the future educational career and, as documented by Dustmann (2004), the earnings as well.

The results suggest that the trade-off between the quantity and the quality of children exists, and its magnitude is larger, than the ordinary least squares model estimates. The instruments have shown satisfactory performance based on the standard validity tests.

There seems to be no evidence for educational disadvantage of the immigrant pupils whether first- or second-generation in any of the estimated models after the family size has been controlled for, even though there is a distinct underrepresentation of the immigrant children in the upper secondary school track for both immigrant groups.

Similarly to the linear models, probit estimates confirm that the negative effect of the family size exists. The effect is significant both statistically and economically. An additional child reduces the chances of children in an average family to attend Gymnasium by about 12 percentage points which represents a large relative decline in educational perspectives of the children growing in the families of lower educated parents. Numerically, the effect of one less child is equivalent to the effect of one more year of education for each of the parents, if their educational levels are low (below 11 years).

References

Anastasi, Anne (1956) "Intelligence and Family Size", *Psychological Bulletin*, 53(3): 187-209.

Andersson, Gunnar, Karsten Hank, Marit Ronsen, and Andres Vikat (2006) "Gendering Family Composition: Sex Preferences for Children and Childbearing Behavior in the Nordic Countries", *Demography*, 43(2): 255-267.

Angrist, Joshua, Victor Lavy and Analia Schlosser (2006) "New Evidence on the Causal Link between the Quantity and Quality of Children", NBER Working Paper Nr. 11835.

Axinn, William G., Marin E. Clarkberg and Arland Thornton (1994) "Family Influences on Family Size Preferences", *Demography*, 31(1): 65-79.

Blake, Judith (1981) "Family size and the quality of children", *Demography*, 18(4): 421-442.

Belmont, Lillian and Francis A. Marolla (1973) "Birth Order, Family Size, and Intelligence", *Science*, 182: 1096-1101.

Björklund Anders and Marianne Sundström. (2006) "Parental Separation and Children's Educational Attainment: A Sibling Analysis on Swedish Register Data", *Economica*, 73: 605-624.

Black, Sandra E., Paul J. Devereux, and Kjell G. Salvanes (2005) "The more the merrier? The effect of family size and birth order on children's education", *The Quarterly Journal of Economics*, 120(2): 669-700.

Conley, Dalton and Rebecca Glauber (2005) "Parental Educational Investment and Children's Academic Risk: Estimates of the Impact of Sibship Size and Birth Order from Exogenous Variation in Fertility", NBER Working Paper Nr. 11302.

Cooke, L.P. (2003) "A comparison of initial and early life course earnings of the German secondary education and training system", *Economics of Education Review*, 22: 79-88.

Dahl, Gordon B. and Enrico Moretti (2004) "The Demand for Sons: Evidence from Divorce, Fertility, and Shotgun Marriage", NBER Working Paper Nr 10281.

Downey, Douglas B. (1995) "When Bigger is not Better: Family Size, Parental Resources and Children's Educational Performance", *American Sociological Review*, 60: 746-761.

Dustmann, Christian (2004) "Parental background, secondary school track choice, and wages", *Oxford Economic Papers*, 56: 209-230.

Ernst, Cecile and Jules Angst. (1983) "Birth Order: It's Influence on Personality". Berlin: Springer-Verlag.

Frick, Joachim R. and Gert G. Wagner (2001) "Economic and Social Perspectives of Immigrant Children in Germany", IZA Discussion Paper No. 301.

Goux, Dominique and Eric Maurin (2005) "The effect of overcrowded housing in childrens's performance at school", *Journal of Public Economics*, 89: 797-819.

Grawe Nathan D. (2005) "Be Fruitful and Multiply: Religious Denomination as Instrumental Variable in Estimates of the Family Size Effect". Carleton College Department of Economics, Working Paper #2005-05.

Guo, Guang and Leah K. VanWey (1999) "Sibship Size and Intellectual Development: Is the Relationship Causal?", American Sociological Review, 64(2), 169-187.

Hanushek, Eric A. (1992) "The Trade-off between Child Quantity and Quality", *The Journal of Political Economy*, 100(1): 84-117.

Heer, David M. (1985) "Effects of Sibling Number on Child Outcome", *Annual Review of Sociology*, 11:27-47.

Jaeger, Mads Meier (2006) "Does Sibship Size Affect Educational Attainment? A Re-evaluation of the Resource Dilution Hypothesis Using Instrumental Variables." The Danish National Institute of Social Research, Social policy and welfare working paper #05:2006.

Lee, Jungmin (2007) “Sibling Size and Investment in Children’s Education: An Asian Instrument”, Journal of Population Economics, forthcoming.

Mahler, Philippe and Rainer Winkelmann (2004) “Single Motherhood and (Un)Equal Educational Opportunities: Evidence for Germany”, IZA Discussion Paper No. 1391.

Murphy, M. and L.B. Knudsen (2002) “The intergenerational transmission of fertility in contemporary Denmark: The effects of number of siblings (full and half), birth order, and whether male or female”, *Population Studies*, 56:235-248.

Powell, Brian and Lala Carr Steelman (1995) “Feeling the Pinch: Child Spacing and Constraints on Parental Economic Investments in Children”, *Social Forces*, 73(4): 1465-1486.

Rosenzweig, Mark R. and Kenneth I. Wolpin (1980) “Testing the Quantity-Quality Fertility Model: The Use of Twins as a Natural Experiment”, *Econometrica*, 48(1): 1980.

Smith, Thomas Ewin (1984) “School Grades and Responsibility for Younger Siblings: An Empirical Study of the ‘Teaching Function’ ”, *American Sociological Review*, 49:248-260.

Smith, Thomas Ewin (1990) “Academic Achievement and Teaching Younger Siblings”, *Social Psychology Quarterly*, 53(4): 352-363.

Steelman, Lala Carr and James A. Mercy (1980) “Unconfounding the Confluence Model: A Test of Sibship Size and Birth-Order Effects on Intelligence”, American Sociological Review, 45: 571-582.

Steelman, Lala Carr, Brian Powell, Regina Werum, and Scott Carter (2002) “Reconsidering the Effects of Sibling Configuration: Recent Advances and Challenges”, *Annual Review of Sociology*, 28: 243-269.

Van Eijck, Koen and Paul M. De Graaf (1995) “The Effects of Family Structure on the Educational Attainment of Siblings in Hungary”, *European Sociological Review*, 11(3): 273-292.

Winkelmann, Rainer (2006) “Parental separation and well-being of youths: Evidence from Germany”, *The Journal of Socio-Economics*, 35: 197-208.

Zajonc, R.B. and Gregory B. Markus (1975) “Birth Order and Intellectual Development”, *Psychological Review*, 82(1): 74-88.

Zajonc, R.B. (2001) “The Family Dynamics of Intellectual Development”, *American Psychologist*, 56(6/7): 490-496.

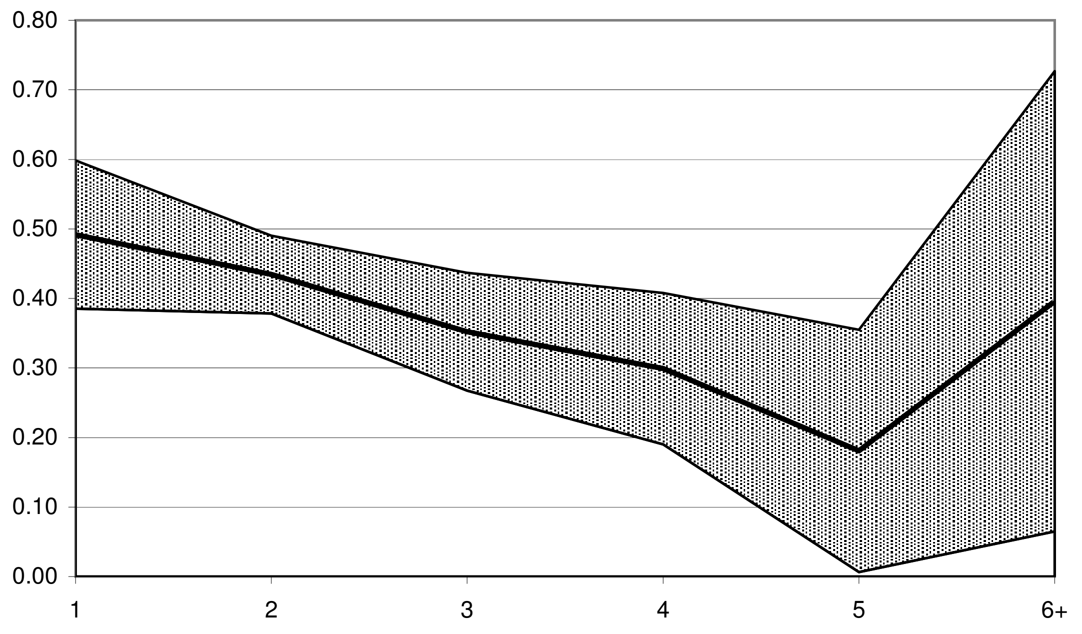
Table 1. Descriptive statistics

	Gymnasium Track	Other Tracks	All Tracks
Population proportion	0.4004	0.5996	1.0000
	(0.0204)	(0.0204)	---
Family size	2.3532	2.6556	2.5345
	(0.0840)	(0.0619)	(0.0504)
Sex	0.3794	0.5535	0.4838
	(0.0315)	(0.0251)	(0.0206)
Father's education	14.1414	11.4233	12.5117
	(0.1794)	(0.0922)	(0.1098)
Mother's education	13.3700	11.3451	12.1559
	(0.1637)	(0.1115)	(0.1068)
Father's siblings (FS)	2.3773	2.7632	2.6086
	(0.1353)	(0.1156)	(0.0883)
Mother's siblings (MS)	2.0377	2.7936	2.4909
	(0.1079)	(0.1350)	(0.0942)
Father's age at first birth (FA)	28.1686	26.4302	27.1263
	(0.4029)	(0.2404)	(0.2236)
Mother's age at first birth (MA)	25.4677	23.3407	24.1924
	(0.2662)	(0.1796)	(0.1623)
Income, thousands	49.3275	37.7426	42.3816
	(1.4098)	(0.7599)	(0.7770)
Occupation of the father:			
Out of the labor force	0.0583	0.1847	0.1341
	(0.0137)	(0.0189)	(0.0128)
Blue-collar worker	0.2064	0.4714	0.3653
	(0.0279)	(0.0262)	(0.0207)
Self-employed	0.1646	0.0822	0.1152
	(0.0225)	(0.0123)	(0.0117)
White-collar worker	0.4232	0.2049	0.2923
	(0.0341)	(0.0175)	(0.0186)
Civil-servant	0.1476	0.0567	0.0931
	(0.0209)	(0.0107)	(0.0106)
Immigrant status:			
German	0.8015	0.6986	0.7398
	(0.0353)	(0.0280)	(0.0220)
First-generation immigrant	0.0895	0.1353	0.1170
	(0.0286)	(0.0273)	(0.0201)
Second-generation immigrant	0.1090	0.1661	0.1432
	(0.0261)	(0.0177)	(0.0148)
Number of observations (N)	446	725	1171

Sex is coded: boy(1), girl(0)
Parental education is measured in years
Parents' sibship variables measure other siblings that the parent had

Figure 1. Family size and gymnasium attendance rates

Number of children in the family	Population proportion	Gymnasium attendance
1	0.1291 (0.0132)	0.4918 (0.0543)
2	0.4761 (0.0204)	0.4344 (0.0285)
3	0.2330 (0.0183)	0.3522 (0.0431)
4	0.1088 (0.0139)	0.2990 (0.0554)
5	0.0253 (0.0053)	0.1809 (0.0888)
6+	0.0278 (0.0083)	0.3958 (0.1687)



Notes: standard errors in parenthesis; shaded area is 95% confidence interval for gymnasium attendence

Table 2. Linear probability model of gymnasium attendance

	Linear probability model		
	(1)	(2)	(3)
Number of children	-0.0389	-0.0317	-0.0254
	(0.023)	(0.006)	(0.022)
Sex	-0.1682	-0.1724	-0.1694
	(0.000)	(0.000)	(0.000)
Immigrant status[1]:			
Second generation	-0.0950	-0.0364	-0.0195
	(0.174)	(0.457)	(0.673)
First generation	-0.1028	0.0024	0.0549
	(0.152)	(0.969)	(0.374)
Education of father		0.0656	0.0559
		(0.000)	(0.000)
Education of mother		0.0268	0.0278
		(0.000)	(0.000)
Income, thousands		0.0029	0.0018
		(0.000)	(0.048)
Occupation of father[2]:			
Out of the labor force			-0.0546
			(0.158)
Self-employed			0.1143
			(0.081)
White-collar worker			0.1528
			(0.000)
Civil servant			0.1106
			(0.074)
Constant	0.6059	-0.6994	-0.6301
	(0.000)	(0.000)	(0.000)
Observations	1171	1171	1171
R-squared	0.0512	0.3074	0.3242

Notes: p values in parentheses

1) Omitted category: German

2) Omitted category: blue-collar worker

Table 3. Instrumented linear probability model of gymnasium attendance

	IV LP Model-I		IV LP Model-II		IV LP Model-III	
	(1)	(2)	(3)	(4)	(5)	(6)
Number of children		-0.3160		-0.0823		-0.0762
		(0.000)		(0.023)		(0.028)
Sex	-0.0596	-0.1716	-0.0678	-0.1732	-0.0773	-0.1708
	(0.492)	(0.000)	(0.418)	(0.000)	(0.346)	(0.000)
Immigrant status1:						
Second generation	0.5679	0.1405	0.5429	0.0039	0.5781	0.0201
	(0.006)	(0.265)	(0.005)	(0.949)	(0.002)	(0.724)
First generation	0.3727	0.0936	0.4834	0.0410	0.4267	0.0891
	(0.049)	(0.253)	(0.011)	(0.534)	(0.018)	(0.169)
Education of father			0.0139	0.0653	0.0227	0.0563
			(0.619)	(0.000)	(0.404)	(0.000)
Education of mother			-0.0368	0.0230	-0.0355	0.0240
			(0.047)	(0.004)	(0.045)	(0.002)
Income, thousands			0.0132	0.0034	0.0162	0.0025
			(0.000)	(0.000)	(0.000)	(0.012)
Occupation of father2:						
Out of the labor force					0.6411	-0.0299
					(0.000)	(0.489)
Self-employed					-0.2412	0.0968
					(0.099)	(0.160)
White-collar worker					0.0509	0.1492
					(0.641)	(0.000)
Civil servant					-0.0449	0.0992
					(0.727)	(0.111)
Father's siblings	0.0657		0.0755		0.0720	
	(0.004)		(0.001)		(0.002)	
Mother's siblings	0.0878		0.0832		0.0804	
	(0.000)		(0.000)		(0.000)	
Father's age at 1st birth	0.0022		0.0013		-0.0130	
	(0.855)		(0.912)		(0.229)	
Mother's age at 1st birth	-0.0680		-0.0776		-0.0710	
	(0.000)		(0.000)		(0.000)	
Constant	3.6326	1.2533	3.5839	-0.5522	3.5094	-0.4976
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1171	1171	1171	1171	1171	1171
R-squared	0.1776		0.2198		0.2526	

Notes: p values in parentheses
1) Omitted category: German
2) Omitted category: blue-collar worker

Table 4. Redundancy tests for instrumental variables

Variable	Model with both parents' age at first birth included as instruments	Model with mother's age at first birth included as an instrument	Model with father's age at first birth included as an instrument
Father's number of siblings	19.349 (0.0000)	18.706 (0.0000)	23.379 (0.0000)
Mother's number of siblings	23.766 (0.0000)	24.148 (0.0000)	26.147 (0.0000)
Father's age at first birth	2.190 (0.1389)	--- (---)	52.902 (0.0000)
Mother's age at first birth	5.012 (0.1709)	88.323 (0.0000)	--- (---)

Notes: p values in parenthesis; parental sibship size included in all tests along with child's sex, immigrant status, parental education, household income and father's occupation.
Test statistic is chi-squared distributed under the null hypothesis that the instrumental variable is redundant.

Table 5. Diagnostics of the instruments

	Model-I	Model-II	Model-III
Test of exclusion of instruments in the first stage Test statistic is F-distributed under the null, that the instrumental variables can jointly be excluded from the first-stage equation	22.52 (0.0000)	27.09 (0.0000)	32.28 (0.0000)
Anderson canonical correlations test Test statistic is chi-squared-distributed under the null hypothesis of underidentification	131.21 (0.0000)	141.33 (0.0000)	154.27 (0.0000)
Sargan-Hansen test of overidentifying restrictions Test statistic is chi-squared-distributed under the null hypothesis that the instruments are uncorrelated with the error term	3.9100 (0.2713)	5.0690 (0.1668)	5.0110 (0.1710)

Notes: p values in parenthesis

Table 6. Instrumented probit model of gymnasium attendance

	IV Probit Model-I	IV Probit Model-II	IV Probit Model-III
	(1)	(2)	(3)
Number of children	-0.2622	-0.1219	-0.1205
	(0.000)	(0.013)	(0.013)
Sex	-0.1306	-0.2176	-0.2191
	(0.000)	(0.000)	(0.000)
Immigrant status[1]:			
Second generation	0.1134	-0.0338	-0.0195
	(0.243)	(0.693)	(0.817)
First generation	0.0819	0.0604	0.1337
	(0.213)	(0.500)	(0.133)
Education of father		0.0760	0.0667
		(0.000)	(0.000)
Education of mother		0.0290	0.0303
		(0.006)	(0.004)
Income, thousands		0.0042	0.0032
		(0.000)	(0.013)
Occupation of father[2]:			
Out of the labor force			-0.0691
			(0.297)
Self-employed			0.0956
			(0.263)
White-collar worker			0.1720
			(0.001)
Civil servant			0.0918
			(0.247)
Observations	1171	1171	1171

Notes: Second-stage results only.
Reported values are marginal effects at the means.
Values in parentheses are p values.
1) Omitted category: German
2) Omitted category: blue-collar worker

Figure 2. Marginal effect of sibship size by parental level of education

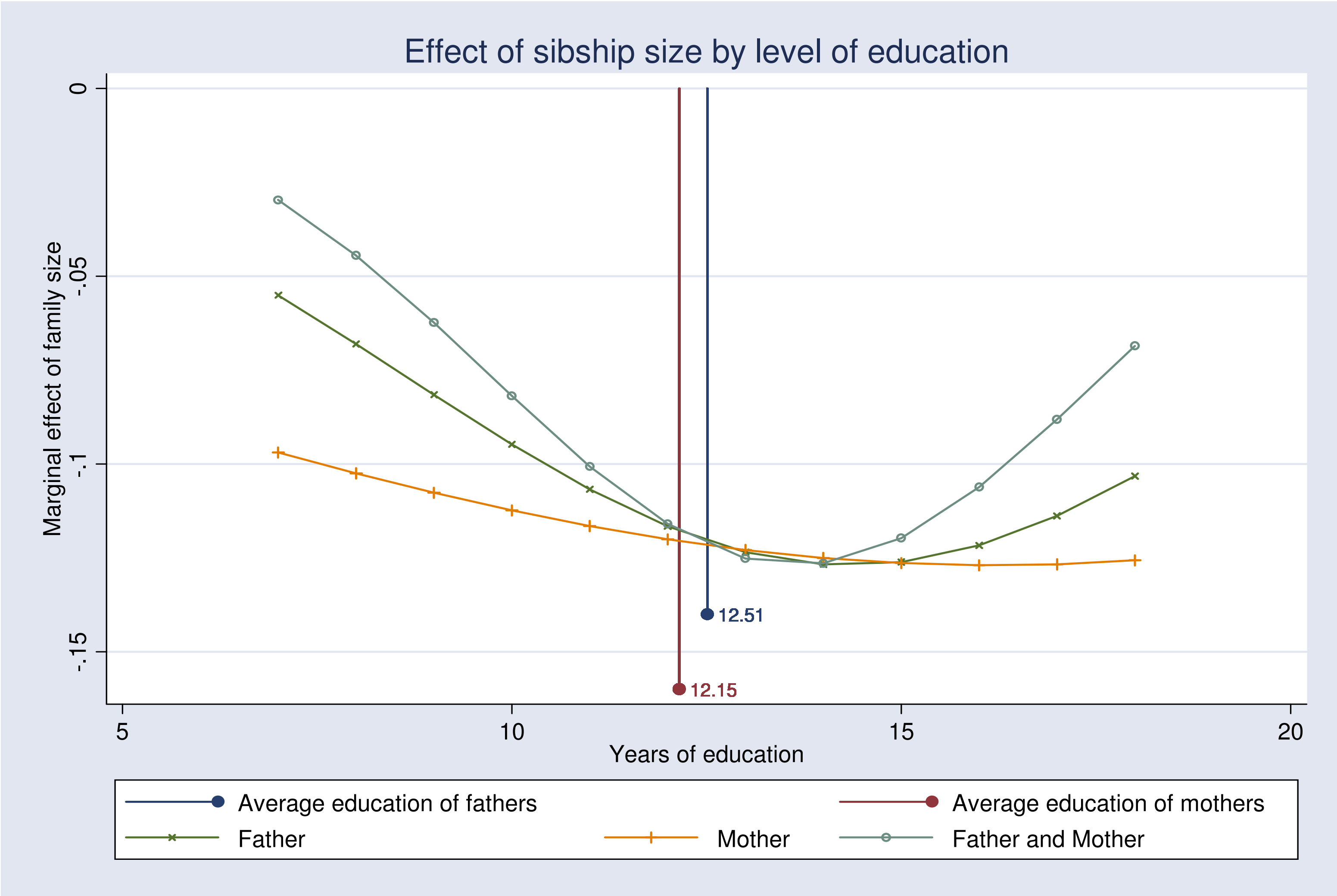


Figure 3. Modelled probability of gymnasium attendance by parental level of education

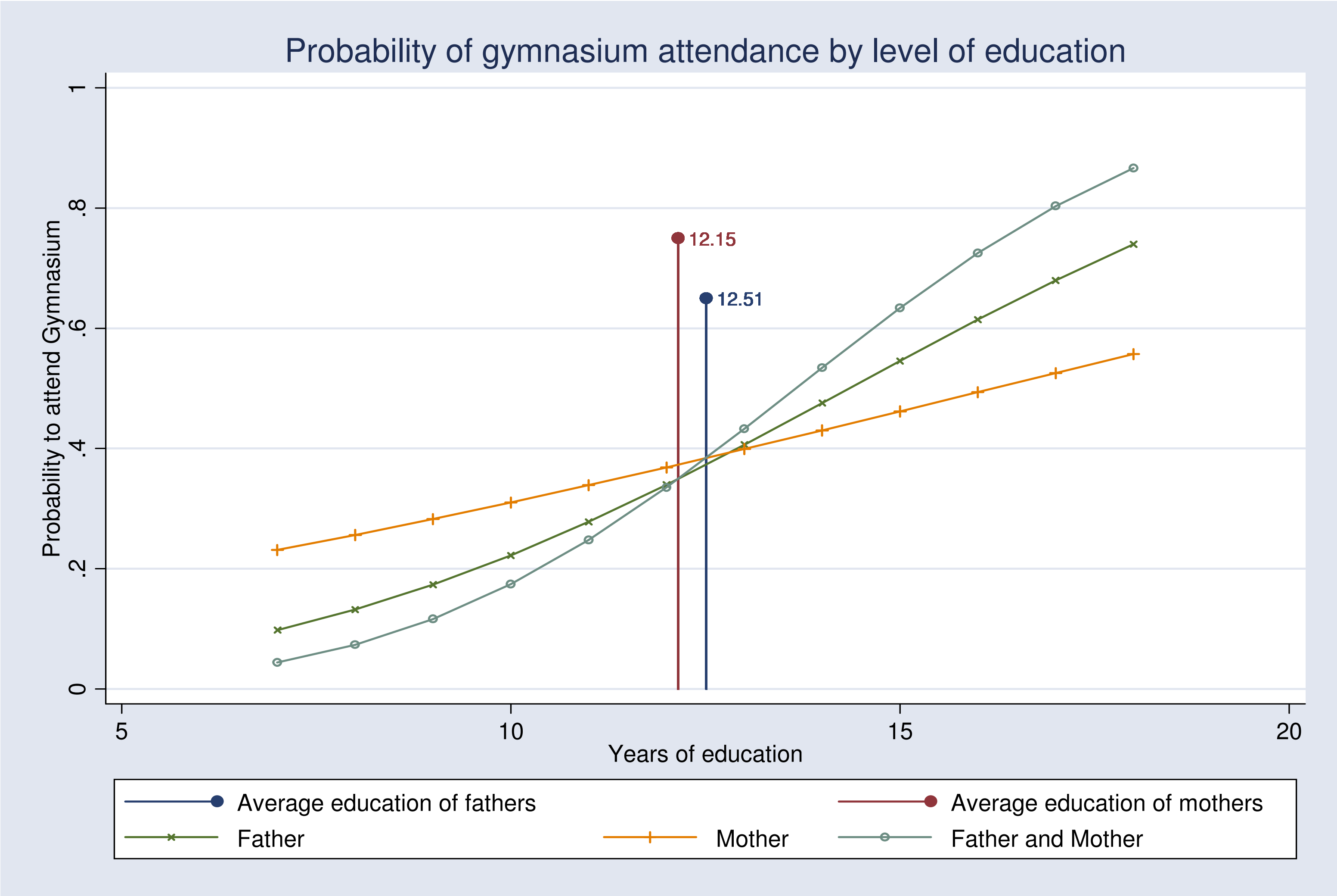


Figure 4. Modelled probability of gymnasium attendance by parental level of education