DISCUSSION PAPER SERIES

No. 5048

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PUBLIC POLICY

Centre for Economic Policy Research

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ISSN 0265-8003

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Discussion Paper No. 5048
May 2005

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CEPR Discussion Paper No. 5048

May 2005

ABSTRACT

Must Try Harder. Evaluating the Role of Effort in Educational Attainment*

This paper is based on the idea that the effort exerted by children, parents and schools affects the outcome of the education process. We test this idea using the National Child Development Study. Our theoretical model suggests that the effort exerted by the three groups of agents is simultaneously determined as a Nash equilibrium, and is therefore endogenous in the estimation of the education production function. Our results support this, and indicate which factors affect examination results directly and which indirectly via effort; they also suggest that affecting effort directly has an impact on results.

JEL Classification: I220 and H420
Keywords: educational achievement, educational attainment, educational outcomes, effort at school and examination results

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*We would like to thank Karim Abadir, Sarah Brown, Gabriele Fiorentini, Andrea Ichino, Andrew Jones, Steve Machin, Kevin Reilly, Karl Taylor, and the audience at the Education Department in Leicester for helpful suggestions and comments on an earlier draft.

Submitted 13 April 2005

NON-TECHNICAL SUMMARY

This paper is based on the very simple observation that the educational attainment of students is affected by the effort put in by those participating in the education process: the schools attended by the students, the students' parents, and of course the students themselves. Although psychologists and educationalists have long acknowledged the importance of schools', parents' and students' effort, the economic literature on educational achievement has so far paid only limited attention to the role of effort as a separate input to the education process, both at a theoretical and at an empirical level.

We build a theoretical model where educational attainment is positively affected by students', parents' and schools' effort and where the effort of these three groups of agents is jointly determined: students respond to the effort exerted by their parents and their schools, and, correspondingly, schools respond to the effort exerted by their students and their parents, and parents to the effort exerted by their children and their children's schools. All agents have a common interest in the realisation of the best educational outcome for the students, but the complex interactions among them may lead to counterintuitive results. For example, students may respond to an increase in school effort with a lower level of their own effort.

We then estimate the theoretical model using the National Child Development Study, a very rich dataset which follows a cohort of individuals born in 1958, from birth until the age of 42. We use information obtained by comprehensive questionnaires completed when the individuals were 7, 11, and 16. We also have detailed results of all examinations taken up to the age of 20. We construct our measures of effort using many indicators of a student's, her parents' and her school's attitudes. For students, for example, we use the answers given by 16-year-olds to questions such as whether they think that school is a "waste of time", and the teacher's views about the students' laziness. Other questions regard the parents' interest in their children's education, measured, for example, by whether they read to their children or attend meetings with teachers, and the teacher's perception of this interest. For schools we use variables such as the extent of parental involvement initiated by the school, whether 16-year old students are offered career guidance, and the type of disciplinary methods employed. We also include many other standard explanatory variables. These can refer to individual, family, or school characteristics, as well as geographical indicators. They comprise the students' ability, measured by administered tests independent of formal examinations and taken at the ages of 7, 11 and 16, the parents' social class and education, and the type of school, whether state or private.

Our empirical estimates seem to confirm our theoretical prediction of joint determination of the effort levels of the three groups of agents. Moreover, our measures of effort seem appropriate, especially so for students and parents. For example, we find a trade-off between the quantity of children and their parents' effort: a child's number of siblings affects negatively the effort exerted by that child's parents towards that child's education. Our econometric model allows us to determine whether explanatory variables influence educational attainment directly, or indirectly by affecting effort. For example, our results suggest that family socio-economic conditions influence attainment more strongly via effort than directly. In this case, policies that attempt to stimulate parental effort might be effective ways to improve the educational attainment. Affecting parental effort is likely to be easier than modifying social background.

We also find that the children's own effort has the least important effect on educational attainment: schools and parents matter more. Interestingly, the school's effort matters more than the parents' for girls, and, vice versa, it matters less than the parents' for boys. This may provide an explanation for the recent trend of improvement in educational achievement, a trend which is stronger for girls than for boys in the UK, and which is occurring at a time when increasing attention is paid to schools' results, and to the provision of financial incentives to schools and teachers. To the extent that these incentives stimulate schools' effort, our analysis indicates that girls' educational attainment should improve more than boys'.

1 Introduction

This paper is based on a very simple idea: the educational achievement of a student is affected by the effort put in by those participating in the education process: schools, parents, and of course the students themselves. This is natural, and indeed psychologists and educationalists have long been aware of the importance of effort for educational attainment. Student's effort is usually proxied by the amount of homework undertaken that is unconstrained by the scheduling practices of the schools (Natriello and McDill (1986)). However, empirical research in this area is still far from reaching clear conclusions. This is due partly to ambiguities in the interpretation of homework: it could be seen as an indicator of either students' effort, operating at the individual level, or teachers' effort, operating at the class level (Trautwein and Köller (2003)). As well as students' effort, the educational psychology literature has also studied the relationship between school attainment and parental effort. A variety of dimensions of parental effort has been considered, ranging from parents' educational aspirations for their children, to parent-child communication about school matters, to education-related parental supervision at home, and to parents' participation in school activities. As Fan and Chen (2001) note, much of this literature is qualitative rather than quantitative and most of the quantitative studies rely on simple bivariate correlations rather than on regression analysis. Results are not clear-cut here either: if at all, parental effort appears to affect educational attainment only indirectly, to the extent that it supports children's effort (Hoover-Dempsey *et al.* (2001)).

The lack of specific data quantifying effort as a separate variable affecting educational attainmenthas also hindered studies carried out by economists. For example, Hanushek (1992) proxies parental effort with measures of family socio-economic status (permanent income and parents' education levels). Intuition – confirmed by our results – would however suggest that effort and socio-economic conditions are in fact distinct variables. Indeed, Becker and Tomes' (1976) theoretical model of optimal parental time allocation suggests a *negative* relationship between household income and parental effort.[1] Bonesrøning (1998; 2004) and Cooley (2004) are among the very few authors in the economics literature who measure the effort exerted by students and parents

[1] Their idea is that parents try to maximise the welfare of their children, and they may decide to allocate more time and effort to their children's education if they perceive limits to their ability to transfer income through inheritance; this is more likely to be the case for low-income families.

and estimate its effects on examination results.

Theoretical analyses of the role of effort in the education process are also scarce.[2] Our paper attempts to fill this gap, by developing a theoretical model of the determination as a Nash equilibrium of the effort exerted by students, their parents and their schools, and subsequently by estimating empirically the determinants of the effort levels, the interaction among of them, and the effect of effort on educational attainment.

We test the theoretical model with the British National Child Development Study (NCDS). This is a well suited dataset, as it contains a large number of variables which can be used as indicators of effort: there are variables which denote a student's attitude, for example whether they think that school is a "waste of time", and the teacher's views about the student's laziness. Other questions regard the parents' interest in their children's education, whether they read to their children or attend meetings with teachers, and the teacher's perception of this interest. For schools, we use variables such as the extent of parental involvement initiated by the school, whether 16-year old students are offered career guidance, and the type of disciplinary methods used.

Our empirical estimates of the determinants of effort are encouraging: the theoretical assumption of joint interaction of the effort levels of the three groups of agents appears to be borne out by the data. Moreover, our measures of effort seem appropriate, especially so for children and parents. For example, as a by-product of our analysis, we find confirmation of Becker's (1960) intuition that there is a trade-off between quantity and quality of children: a child's number of siblings influences the effort exerted by that child's parents towards that child's education.

Our econometric model allows us to determine whether explanatory variables influence educational attainment directly or indirectly, that is by affecting effort. For example, our results suggest that family socio-economic conditions affect attainment more strongly via effort than directly. In this case, policies

[2] This contrasts sharply with the extensive literature which studies the role of effort in firms; a seminal contribution is the theory of efficiency wages (Shapiro and Stiglitz (1984)), and an extensive survey is provided by Holmstrom and Tirole (1989). There have also been several attempts to estimate empirically the role of effort in firms: an early test of the efficiency wage hypothesis is Cappelli and Chauvin (1991), who measured workers' effort by disciplinary dismissals. More recently, effort has been measured by the propensity to quit (Galizzi and Lang (1998)), by misconduct (Ichino and Maggi (2000)) and by absenteeism (Ichino and Riphahan (2004)). Peer pressure, measured by the presence of a co-worker in the same room, also appears to affect a worker's effort (Falk and Ichino (2003)).

that attempt to affect parental effort might be effective ways to improve the educational attainment, since affecting parental effort is likely to be easier than modifying social background.[3] We also find that the children's own effort has the least effect on educational attainment: schools and parents are more important. Interestingly, the school's effort matters more than the parents' for girls, and, vice versa, it matters less than the parents' for boys (see Figure 4 below). This may provide an explanation for the recent trend of improvement in the education achievement in the UK, a trend which is stronger for girls than for boys, and which is happening when increasing attention is being paid to schools' results, and financial incentives are being provided to schools and teachers. To the extent that these incentives stimulate the schools' effort, our results indicate that girls' education attainment should improve more than boys.

The paper is organised as follows: the theoretical model is developed in Section 2; the agents' strategic behaviour is illustrated in Section 3 with a graphical analysis of the Nash equilibrium; the empirical model is presented in Section 4; Section 5 describes the data and the variables used; our results are summarised in Section 6, and concluding remarks are in the last section.

2 Theoretical Model

We model the interaction among the pupils at a school, their teachers and their parents. Pupils attend school, and, at the appropriate age, they leave with a qualification. This is a variable q taking one of m possible values $q \in \{q_1, ..., q_m\}$, with $q_{k-1} < q_k$, $k = 2, ..., m$. Other things equal, a student prefers a better qualification: apart from personal satisfaction, there is substantial evidence showing a positive association between qualification and future earnings in the labour market: let $u(q)$ be the utility associated with qualification q, with $u'(q) > 0$.

When at school, pupils exert effort, which we denote by $e^C \in E^C \subseteq \mathbb{R}$ (the superscript C stands for "child"). The restriction to single dimensionality is made for algebraic convenience, though it is also supported by the data, see Section 6 below. e^C measures how diligent a pupil is, how hard she works and so on, and has a utility cost measured by a function $\psi_C\left(e^C\right)$, increasing and

[3] One example could be the provision of direct financial rewards to parents helping their children with homework, or attending parenting classes, similarly to the policy of providing financial incentives to disadvantaged teen-agers for staying on at school beyond the compulsory age (Dearden *et al.* (2003)).

convex: $\psi'_C\left(e^C\right), \psi''_C\left(e^C\right) > 0$. Notice that there is no natural scale to measure effort, and so the interpretation of the function ψ_C (and the corresponding ones for schools and parents), is cost of effort *relative* to the benefit of qualification. Pupils also differ in ability, denoted by a. A student's education attainment is affected by her effort and her ability. Formally, we assume that qualification q_k is obtained with probability $\pi_k\left(e^C, a; \cdot\right)$ (the " $\cdot$ " represents other influences on qualification, discussed in what follows). We hypothesise, naturally, a positive relationship between effort and the expected qualification: $\sum_{k=1}^{m} \frac{\partial \pi_k\left(e^C, a; \cdot\right)}{\partial e^C} q_k > 0$, and between ability and the expected qualification: $\sum_{k=1}^{m} \frac{\partial \pi_k\left(e^C, a; \cdot\right)}{\partial a} q_k > 0$. A student's objective function is the maximisation of the difference between expected utility and the cost of effort:

$$\sum_{k=1}^{m} \pi_k\left(e^C, a; \cdot\right) u\left(q_k\right) - \psi_C\left(e^C\right). \tag{1}$$

A student's education attainment depends also on her parents' effort. Parents may help with the homework, provide educational experiences (such as museums instead of television), take time to speak to their children's teachers, and so on: we denote this effort by $e^P \in E^P \subseteq \mathbb{R}$; as before, this is treated as single dimensional. Consistently with common sense, and with the idea that the education process is best thought of as a long term process (e.g. Hanushek (1986) and Carneiro and Heckman (2003)), the variable e^P should be viewed as summarising the influence of parental effort throughout the child's school career: the NCDS dataset is well suited to take on board this view, as each subject is observed at three dates, at age 7, at age 11 and at age 16. Parents differ also in education, social background and other variable which affect their children's education attainment; we capture this by means of a possibly multidimensional variable, s^P.

Parents care about their children's qualification, and so they will exert effort e^P, even though it carries a utility cost, measured by the function $\psi_P\left(e^P\right)$, increasing and convex: $\psi'_P\left(e^P\right), \psi''_P\left(e^P\right) > 0$. Parents may have more than one child and so they care about the average qualification of all their children:[4]

[4] Rigorously, we should consider the utility of the qualification, for example $u_P\left(q\right)$. It is not in general obvious which shape the function $u_P\left(q\right)$ should have: some parents may obtain a higher utility gain if the qualification of a less bright child is increased, than if the qualification of a more able child is increased equivalently; other parents, who value achieving excellence more than avoinding failure may take an opposite view; given this potential ambiguity, it seems a good approximation to take the average attainment as the objective function.

if parents have n children, their payoff function is given by:

$$\sum_{j=1}^{n} \pi_k \left(e_j^C, a_j; e_j^P, s^P; \cdot\right) q_k - \psi_P \left(\sum_{j=1}^{n} e_j^P\right),$$

where e_j^P is the effort devoted by parents to child j, whose ability is a_j, and who exerts effort e_j^C.[5]

A student's qualification will also be affected by the quality of her school, the last component of the " $\cdot$ " in the arguments of the probabilities in (1). The school influences its pupils' attainment through its own effort, measured by a variable $e^S \in E^S \subseteq \mathbb{R}$ (again assumed one-dimensional). This captures the idea that a school can take actions which affect the quality of the education it imparts. Improving the quality of buildings, classroom equipment and sporting facilities, using computers appropriately, upgrading teachers' qualifications are all examples. Other examples are the teachers' interest and enthusiasm in their classroom activities, the time they spend outside teaching hours to prepare lessons, to assess the students' work, to meet parents, and so on.[6] Effort has increasing marginal disutility, and can thus be measured by a function $\psi_S\left(e^S\right)$ increasing and convex, $\psi_S'\left(e^S\right), \psi_S''\left(e^S\right) > 0$.

To wrap up this discussion, the probability that a student obtains qualification q_k can therefore be written as

$$\pi_k \left(e^C, a; e^P, s^P; e^S, s^S\right),$$

where, in analogy to s^P, s^S is a vector which captures the school's exogenously given characteristics. A school's objective function is a function which depends positively on the *average*[7] qualification of its students and negatively on the

[5] The interaction between parental effort and the number of children was first proposed by Becker (1960). We ignore the potential endogeneity of the number of children. Blake (1989) is a demographic analysis of the relationship between family size and achievement.

[6] Note that the activities in the first group are fixed before the students are enrolled at school and can therefore be observed by parents prior to applying to the school; while those in the second group are carried out once the students are at school. Since the extent of school choice was fairly limited in the period covered by our data, this distinction will be disregarded in what follows. The theoretical analysis of De Fraja and Landeras (2005) argues that a different equilibrium concept should be used according to whether schools and students choose one after the other or simultaneously: Stackelberg and Nash equilibrium respectively. As they show, this does not affect the qualitative nature of the interaction.

[7] As with parents, the average qualification may not be the most suitable approximation for the school's objective function. Teachers may care more about the best or the weakest students in their class. If this were the case, appropriate weighting could be included to account for these biases in the school's payoff function (2).

teaching effort:

$$\sum_{k=1}^{m} q_k \sum_{h=1}^{H} \pi_k \left(e^C(h), a; e^P(h), s^P; e^S(h), s^S\right) \lambda_h - \psi_S\left(e^S\right). \tag{2}$$

(2) assumes that the effort levels e^C, e^P, and e^S are affected by a number of exogenous variables described by the multi-dimensional vector h: thus $e^C(h)$ (respectively $e^P(h)$, respectively $e^S(h)$) is the effort level exerted by students (respectively parents, respectively schools) whose vector of relevant variables takes value h. h will of course also include ability and other variables which are also in the vectors s^P and s^S, as these can have a direct effect on qualification, or an indirect effect, via the effort level exerted by the participants in the education process. H is the number of all the possible values which the variables affecting effort can take, and λ_h is the proportion of pupils at the school with this variable equal to h.

Additivity between the disutility of effort and the students' average qualification is an innocuous normalisation. The relative importance of these two components of the school's utility will in general depend on how much teachers care about the success of their pupils, which in turn can depend on government policy: there could be incentives for successful teachers (both monetary and in terms of improved career prospects; De Fraja and Landeras's (2005) theoretical model studies the effects of strengthening these incentives). The dataset we have available, which refers to schools in the late '60s and early '70s is not suited to the study of these effects, since there has been no observable change in the power of the incentive schemes for schools and teachers in that period.

3 A graphical analysis of the equilibrium

All agents have a common interest in the realisation of a high qualification for the child, but their interests are not perfectly aligned, and their strategic behaviour may lead to complex interactions among them, with counterintuitive outcomes.

In this brief section we illustrate this point in an extremely simple case. We assume that all students in a given school are identical in terms of ability, parental status, and number of siblings. This is obviously unrealistic, but the point here is to illustrate that, even with highly special assumptions, the interaction between the parties may turn out to be extremely complex. We capture this interaction with the game theoretic concept of Nash equilibrium:

each party is choosing their effort in order to maximise their utility, taking as given the choice of effort of the other parties. An equilibrium is given by the set of values e^C, e^P, and e^S, satisfying the first order conditions

$$\sum_{k=1}^{m} u\left(q_k\right) \frac{\partial \pi_k\left(e^C, a; e^P, s^P; e^S, s^S\right)}{\partial e^C} - \psi_C'\left(e^C\right) = 0, \tag{3}$$

$$\sum_{k=1}^{m} q_k \frac{\partial \pi_k\left(e^C, a; e^P, s^P; e^S, s^S\right)}{\partial e^P} - \psi_P'\left(e^P\right) = 0, \tag{4}$$

$$\sum_{k=1}^{m} q_k \frac{\partial \pi_k\left(e^C, a; e^P, s^P; e^S, s^S\right)}{\partial e^S} - \psi_S'\left(e^S\right) = 0. \tag{5}$$

where the appropriate second order conditions are satisfied. (3)-(5) are the best reply function[8] of each of the three agents: their intersections identify the Nash equilibria. The graphical analysis is best conducted in two dimensions. Let therefore the parental effort be fixed, at e^P. Total differentiation of (3) and (5) gives the slope of the best reply function in the relevant Cartesian diagram ($E^C \times E^S$ for fixed e^P):

$$\left(\sum_{k=1}^{m} u\left(q_k\right) \frac{\partial^2 \pi_k\left(\cdot\right)}{\partial e^C \partial e^S}\right) de^S - U_C''\left(\cdot\right) de^C = 0,$$

$$\left(\sum_{k=1}^{m} q_k \frac{\partial^2 \pi_k\left(\cdot\right)}{\partial e^C \partial e^S}\right) de^C - U_S''\left(\cdot\right) de^S = 0,$$

where $U_C''\left(\cdot\right) = \sum_{k=1}^{m} u\left(q_k\right) \frac{\partial^2 \pi_k(\cdot)}{(\partial e^C)^2} - \psi_C''\left(e^C\right) < 0$ is the second derivative of the child's payoff, and analogously for $U_S''\left(\cdot\right)$. From the above:

$$\left.\frac{de^S}{de^C}\right|_{\substack{\text{child}\\ BRF}} = \frac{U_C''\left(\cdot\right)}{\sum_{k=1}^{m} u\left(q_k\right) \frac{\partial^2 \pi_k(\cdot)}{\partial e^C \partial e^S}}, \tag{6}$$

$$\left.\frac{de^S}{de^C}\right|_{\substack{\text{school}\\ BRF}} = \frac{\sum_{k=1}^{m} q_k \frac{\partial^2 \pi_k(\cdot)}{\partial e^C \partial e^S}}{U_S''\left(\cdot\right)}. \tag{7}$$

[8] Mathematically, for the representative student (that the we can take a representative student is shown in De Fraja and Landeras (2005)), this is a function from the product of the other two effort spaces into the child's: $E^P \times E^S \longrightarrow E^C$. This a dimension 2-manifold in the 3-dimensional Cartesian space $E^C \times E^P \times E^S$. Analogously for the parents and the school. The intersection of three dimension 2-manifolds is (generically) either empty, or a dimension 0-manifold, that is a set of isolated points. Existence of at least one Nash equilibrium is ensured by the fact that each player has a compact and convex strategy space, and that their payoff functions are continuous and quasi-concave in their own strategy (Fudenberg and Tirole 1991, p 34).

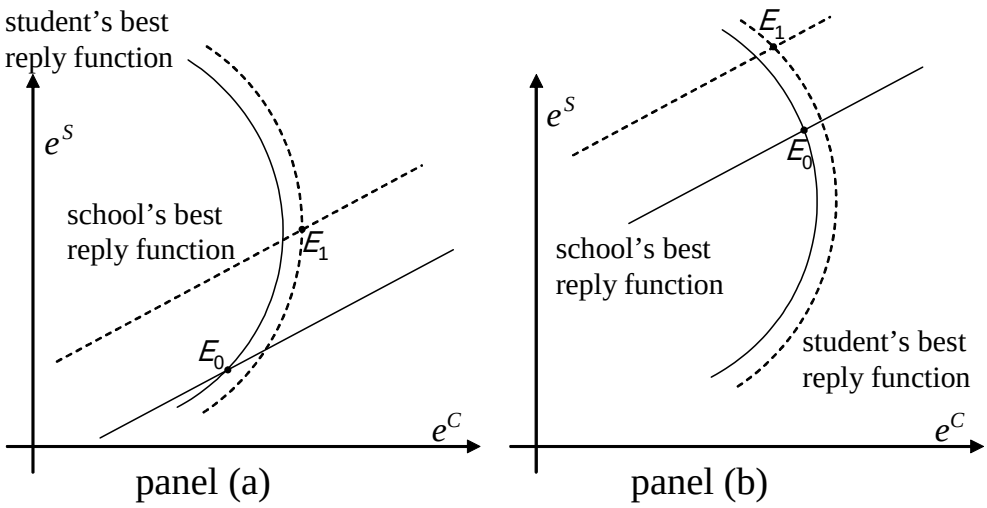


Figure 1: Best reply functions of the representative student and of the school.

Both can have either sign:[9] to see what this implies, consider Figure 1. It illustrates the best reply functions for the student and the school. In panel (a), the case is depicted where both (6) and (7) are positive at their intersection. The solid lines are the best reply functions associated with the parameter vector h taking value h_0. The dashed lines depict the best reply functions associated to a different set of exogenous variables, say h_1, associated with a higher value of the students' effort, for every given level of the school's effort, and a higher value of the school's effort, for every given level of the students' effort levels. For example, the dashed lines may represent the best reply functions of students and the school for a student with higher ability and a larger school (the data suggests that these comparative statics changes are associated to higher effort levels). Graphically, this is a shift upward (for the school) and eastward (for the student) of the best reply function. In panel (a) both equilibrium effort levels are higher: compare E_0 with E_1.

Consider panel (b), however. It differs from panel (a) only in that the best reply functions meet at a point where the student best reply function is negatively sloped. In the case depicted in panel (b), the equilibrium effort levels that result as a consequence of a different value in the exogenous parameters vector h, associated with higher effort levels results in a *lower* equilibrium effort exerted by the student. This is so even though the student's best reply function

[9] Note instead that, in this special case of one student per school, the parents and the school's best reply function have the same sign.

shifts eastward: h_1 is associated to *higher values* in the student's effort *for any given level of the school's effort.* The reason for the lower equilibrium value of the student's effort is the strategic interaction of schools and students. The vector h_1 would be associated to a higher value of the student's effort *if the school's effort were the same.* However, the student's and the school's efforts are "strategic substitutes" (Bulow *et al* 1986), and the student responds to the higher school effort (associated to the vector h_1) with a lower level of their own effort. This, in panel (b) in the diagram, more than compensates the direct increase in the student's effort caused by the different value of h. This simple example illustrates the potential ambiguity of changes in the exogenous variables h on the equilibrium effort levels; in more general settings the situation will be even more complex.

4 Empirical Model

Given this theoretical ambiguity, the overall effect of children's, parents' and school's efforts on educational attainment, and whether these effort levels are strategic complements or substitutes, is therefore largely an empirical matter, to which we turn in this section.

The educational outcome variable considered here, Q_i, is child i's academic results over a number of secondary school examinations, normally taken between the ages of 16 and 18. The explanatory variables are measures of the effort exerted by the child, her parents and her school, and a suitable set of controls for heterogeneity in socio-economic, demographic and other relevant factors. Formally, the academic achievement is specified as:

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\beta}_1 + \beta_2 e_i^C + \beta_3 e_i^P + \beta_4 e_i^S + u_i, \qquad i = 1, ..., n, \tag{8}$$

where $\mathbf{x}_i^Q$ is a set of control variables for demographic and socio-economic background factors affecting the educational outcome, e_i^C, e_i^P, and e_i^S are the measures of the effort exerted by child i, by child i's parents and by child i's school, and u_i the error term.

Our theoretical analysis in Sections 2 and 3 suggests that the interaction between the three types of agents is best captured as a Nash equilibrium. This implies that the effort levels, which are educational inputs, simultaneously determine each other; together with possible omitted variables, this in turn implies that the error term in the estimation of a standard educational production function (Hanushek (1986) is correlated with the observed input variables and

the estimates of the effect of observed inputs on educational outcome are inconsistent. The very rich set of background variables in our dataset should lessen the problem of omitted variables.

To address the endogeneity of the effort variables, note that the interdependent system:

$$e_i^C = \mathbf{x}_i^{C\prime}\boldsymbol{\gamma}_1^C + \gamma_2^C e_i^P + \gamma_3^C e_i^S + v_i^C, \qquad i = 1, ..., n, \tag{9}$$

$$e_i^P = \mathbf{x}_i^{P\prime}\boldsymbol{\gamma}_1^P + \gamma_2^P e_i^C + \gamma_3^P e_i^S + v_i^P, \qquad i = 1, ..., n, \tag{10}$$

$$e_i^S = \mathbf{x}_i^{S\prime}\boldsymbol{\gamma}_1^S + \gamma_2^S e_i^C + \gamma_3^S e_i^P + v_i^S, \qquad i = 1, ..., n, \tag{11}$$

is a linear approximation to the Nash equilibrium. In (9)-(11), $\mathbf{x}_i^C$, $\mathbf{x}_i^P$ and $\mathbf{x}_i^S$ are the background factors affecting child i's effort, child i's parents' effort, and the effort of child i's school, respectively, and v_i^C, v_i^P and v_i^S are error terms, possibly correlated.

The NCDS dataset contains many variables that capture aspects of individual effort levels, e_i^C, e_i^P and e_i^S. Described in detail in Section 5, these take the form of categorical variables, which have different scales and are in general non-comparable. We therefore use factor analysis[10] to construct a single aggregate continuous indicator of the three effort levels.

We next need to ascertain whether the effort variables are endogenous as suggested in Sections 2 and 3. We do so using the Durbin-Wu-Hausman (DWH) augmented regression test suggested by Davidson and MacKinnon (1993). The test is performed by obtaining the residuals from a model of each endogenous right-hand side variable as a function of all exogenous variables, and including these residuals in a regression of the original model. In our case, we first estimate the system

$$e_i^C = \widetilde{\mathbf{x}}_i^{C\prime}\boldsymbol{\delta}_1^C + \delta_2^C e_i^P + \delta_3^C e_i^S + r_i^C, \tag{12}$$

$$e_i^P = \widetilde{\mathbf{x}}_i^{P\prime}\boldsymbol{\delta}_1^P + \delta_2^P e_i^C + \delta_3^P e_i^S + r_i^P, \tag{13}$$

$$e_i^S = \widetilde{\mathbf{x}}_i^{S\prime}\boldsymbol{\delta}_1^S + \delta_2^S e_i^C + \delta_3^S e_i^P + r_i^S, \tag{14}$$

[10] We use the principal factor method. Alternative approaches include principal components, principal-components factor analysis and maximum-likelihood factor analysis (Harman (1976), Everitt and Dunn (2001)). Since our original variables are defined on an ordinal rather than an interval scale, they are not suited to being analysed by the maximum-likelihood factor method, due to the assumption of normality implied by this procedure. We have instead experimented using principal components as an alternative to the principal factor method. The difference in the results provided by the two methods is only of order 10^{-3} at most. Our results indicate that retaining only the first factor is the appropriate strategy for the children's and the parents' effort; a second factor should perhaps be retained for the school's effort, but, for symmetry and ease of interpretation, we retain only the first factor for the school as well.

where r_i^C, r_i^P and r_i^S are error terms and the vectors $\widetilde{\mathbf{x}}_i^C$, $\widetilde{\mathbf{x}}_i^P$ and $\widetilde{\mathbf{x}}_i^S$, are the union of the set of variables which form the vectors $\mathbf{x}_i^C$, $\mathbf{x}_i^P$ and $\mathbf{x}_i^S$ in equations (9)-(11), with the variables which form the vector $\mathbf{x}_i^Q$ in equation (8) (for example, $\widetilde{\mathbf{x}}_i^C$ are background factors affecting either educational attainment, or the child's effort, or both; and similarly for $\widetilde{\mathbf{x}}_i^P$ and $\widetilde{\mathbf{x}}_i^S$). We then estimate the following augmented regression:

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\eta}_1 + \eta_2 e_i^C + \eta_3 e_i^P + \eta_4 e_i^S + \eta_5 \widehat{r}_i^C + \eta_6 \widehat{r}_i^P + \eta_7 \widehat{r}_i^S + \widetilde{u}_i, \qquad (15)$$

where $\widehat{r}_i^C$, $\widehat{r}_i^P$, and $\widehat{r}_i^S$ are the residuals obtained from the estimates of (12)-(14). According to Davidson and MacKinnon (1993), if the parameters η_5, η_6 and η_7 are significantly different from zero, then OLS estimates of equation (8) are not consistent due to the endogeneity of e_i^C, e_i^P and e_i^S. We test the null hypothesis $\eta_5 = \eta_6 = \eta_7 = 0$ applying a likelihood-ratio test and, as we show below in Section 6, we find endogeneity of the effort variables.

The estimation method we use is 3SLS, because of the interdependent nature of the effort variables, and the possible dependence of the error terms across equations. Ideally, the four equations (8)-(11) should be estimated simultaneously. However, the dependent variable in equation (16) is discrete, and cannot therefore be estimated with standard 3SLS methods. We therefore estimate the educational attainment equation (16) using the *predicted* values $\widehat{e}_i^C$, $\widehat{e}_i^P$ and $\widehat{e}_i^S$ obtained from a three-stage least squares estimation of equations (9)-(11) instead of the three original effort variables:

$$Q_i = \mathbf{x}_i^{A\prime}\boldsymbol{\beta}_1 + \beta_2 \widehat{e}_i^C + \beta_3 \widehat{e}_i^P + \beta_4 \widehat{e}_i^S + u_i, \qquad i = 1, ..., n. \qquad (16)$$

Equation (16) is estimated as an ordered probit as the examination results variable Q_i is a discrete ordered variable, taking eleven possible values. Identification is achieved by the inclusion in the sets $\mathbf{x}_i^U$, $U = Q, C, P, S$, of some statistically significant variables unique to each of the four equations (8)-(11).

5 Data and variables

The National Child Development Study (NCDS)[11] follows the cohort of individuals born between the 3rd and the 9th of March 1958, from birth until the age of 42. We use information obtained by detailed questionnaires when the

[11] This dataset is widely used (see www.cls.ioe.ac.uk/Cohort/Ncds/Publications/nwpi.htm). For a discussion of its features, including ways of dealing with non-response and attrition problems, see Micklewright (1989) and Connolly *et al.*(1992).

individuals were 7, 11, and 16. We also use data from the Public Examinations Survey, also a part of the NCDS, which gives detailed results of examinations taken until the age of 20. The dataset contains examination results for 7017 girls and 7314 boys; after eliminating observations with insufficient information we were left with a sample of 5611 girls and 5860 boys.

5.1 Dependent variables

5.1.1 Effort

Table 1 contains the scoring coefficients for the child's, the parents' and the school's effort indicators obtained from the factor analyses performed separately for boys and for girls. The scoring factors are the weights actually entering the construction of the effort indicators. To reduce the loss of information due to non-response, we impute the factor scores for the cases with missing data in some of the originally observed variables on which the indices are based. The imputation method is such that the new variable created includes predictions for the missing values based on the best available subset of otherwise present data. We have imputed 7%, 13.1% and 6.9% of the child's, the parents' and the school's effort information, respectively.

The child's effort indicators used to construct the child's effort measure e_i^C are the child's answers (at age 16) to questions about her attitude towards school, wishes and expectations about school leaving age, and the frequency of reading (a higher value denotes higher effort).[12] This information is complemented by the teacher's assessment of the child's effort when the individuals are 16 (the last row in the first part of Table 1). Columns 3 and 5 of Table 1 provide the scoring coefficients for each of the variables reflecting the effort indicators, namely the weights actually entering the construction of the effort indices. For the children the variable with the highest scoring coefficient is whether the child likes school or not.[13]

The parents' effort measure e_i^P is produced using both parents' interest in the child, their initiative to discuss the child's progress in school, the father's role in the management of the child, the parents' wishes and anxiety over the child's school achievement, and how often both parents read to their children.

[12] The exact description of how we have constructed these and all the other variables is in an Appendix available on request or at www.le.ac.uk/economics/gdf4/curres.htm. This appendix also reports the factor loadings.

[13] The proportion of explained variance is approximately 1. This provides very strong evidence that selecting only one factor is the most appropriate decision.

Child's effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
School is not a waste of time	0-4	3.3066	0.1502	3.1523	0.1517
I get on with classwork	0-4	2.4068	0.0923	2.2482	0.0997
Homework is not boring	0-4	1.6646	0.1354	1.4648	0.1387
It is not difficult to keep my mind on work	0-4	2.2991	0.1259	2.2444	0.1119
I take work seriously	0-4	3.1059	0.1766	3.0291	0.1650
I like school	0-4	2.5038	0.1994	2.3741	0.2109
There is a point in planning for future	0-4	3.0085	0.0666	3.0913	0.0533
I am always ready to help my teacher	0-4	2.6583	0.0524	2.3195	0.0478
I often read in my spare time	0-3	2.0848	0.0448	1.8286	0.0543
Age I am likely to leave school	0-3	0.9243	0.1186	0.8868	0.1266
I wish I could leave school at 15	0-2	1.4158	0.1798	1.2814	0.1805
Teacher thinks child is lazy or hardworking	0-4	2.4132	0.1288	2.0627	0.1266
Proportion of explained variance		1.0332		1.0210	
Parents' effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
Mother's interest in child's education at age 7	0-4	2.9828	0.1227	2.9042	0.1203
Father's interest in child's education at age 7	0-4	1.9504	0.0806	2.0035	0.1011
Parents' initiative to discuss child with teacher at age 11	0-3	1.0442	0.1326	1.1031	0.1323
Fathers' interest in child's education at age 11	0-4	2.2679	0.1510	2.3271	0.1574
Mothers' interest in child's education at age 11	0-4	2.8462	0.1389	2.7436	0.1239
Father's interest in child's education at age 16	0-4	2.4919	0.2253	2.5030	0.2362
Mother's interest in child's education at age 16	0-4	2.7763	0.2049	2.6552	0.1903
Parental hopes about child's school leaving age at age 11	0-2	1.6942	0.1007	1.7112	0.1162
Parents want further education for child at age 11	0-2	1.7664	0.0760	1.8210	0.0733
Father's role in management of child at age 11	0-3	2.3685	0.0420	2.4470	0.0419
Mother reads to child at age 7	0-3	2.3150	0.0664	2.2961	0.0812
Father reads to child at age 7	0-3	2.0037	0.0891	1.9788	0.0963
Father's role in management of child at age 7	0-3	2.3701	0.0488	2.4172	0.0535
Parent's initiative to discuss child with teacher at age 7	0-1	0.5596	0.0834	0.5705	0.0833
Substantial help from parents to school at age 7	0-1	0.5191	0.0303	0.5229	0.0251
Parents and teacher discuss child at age 16	0-3	1.0724	0.1110	1.1680	0.1170
Parent's anxiety over child's school achievement at age 16	0-4	3.2070	0.0210	2.9779	0.0060
Parents wish child goes to higher education at age 16	0-1	0.3219	0.0974	0.3286	0.0870
Proportion of explained variance		0.6265		0.6020	
School's effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
Teachers' initiative to discuss child at age 11	0-1	0.4274	-0.0112	0.4317	0.0598
Child's age group streamed by ability at age 11	0-1	0.3140	0.0073	0.3347	0.0019
Paid hours of career guidance	0-1	0.8832	0.0613	0.8774	0.0712
Parent-teacher meetings to discuss child at age 16	0-3	2.0272	0.0495	2.0139	0.1174
Parents are shown teaching methods at age 16	0-3	0.5648	0.0781	0.5891	0.1318
School has parent-teacher association at age 16	0-1	0.6259	0.0748	0.6445	0.1867
Disciplinary methods-suspension at age 16	0-2	0.9427	0.1364	0.9978	0.1067
Disciplinary methods-corporal punishment at age 16	0-2	1.0074	0.1053	1.3376	-0.0407
Disciplinary methods-physical/manual activities at age 16	0-2	0.3679	0.1293	0.4789	0.0999
Disciplinary methods-extra school work at age 16	0-2	1.6247	0.1995	1.6975	0.0920
Disciplinary methods-detention at age 16	0-2	1.4329	0.1445	1.4665	0.2313
Disciplinary methods-loss special status at age 16	0-2	0.5990	0.1127	0.6553	0.0072
Disciplinary methods-exclusion from activities at age 16	0-2	0.8040	0.1565	0.8360	0.0684
Disciplinary methods-report to parents at age 16	0-2	1.9212	0.1538	1.9079	0.1414
Disciplinary methods-special reports at age 16	0-2	1.6275	0.2342	1.6822	0.2354
Streaming in English at age 16	0-1	0.7270	0.1604	0.7408	0.0859
Streaming in maths at age 16	0-1	0.8652	0.1369	0.8527	0.1596
School has parent-teacher association at age 7	0-1	0.1667	-0.0066	0.1670	0.0531
Educational meetings arranged for PTA at age 7	0-1	0.5963	-0.0103	0.5943	0.0800
Social functions arranged for parents at age 7	0-1	0.5048	-0.0100	0.5068	0.0494
Teachers' initiative to discuss child at age 7	0-1	0.2319	0.0122	0.2691	0.0355
Proportion of explained variance		0.4772		0.4865	

Table 1: Factor analysis for effort measures

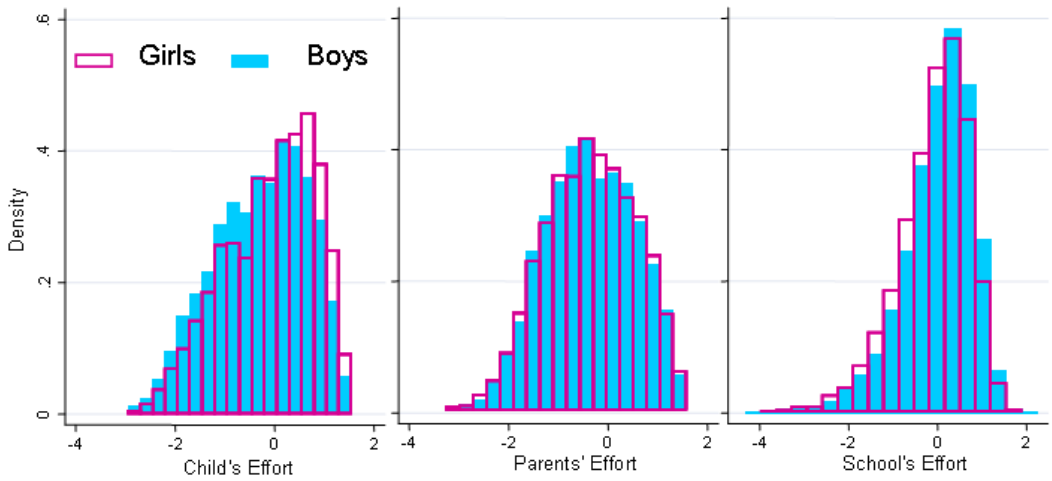
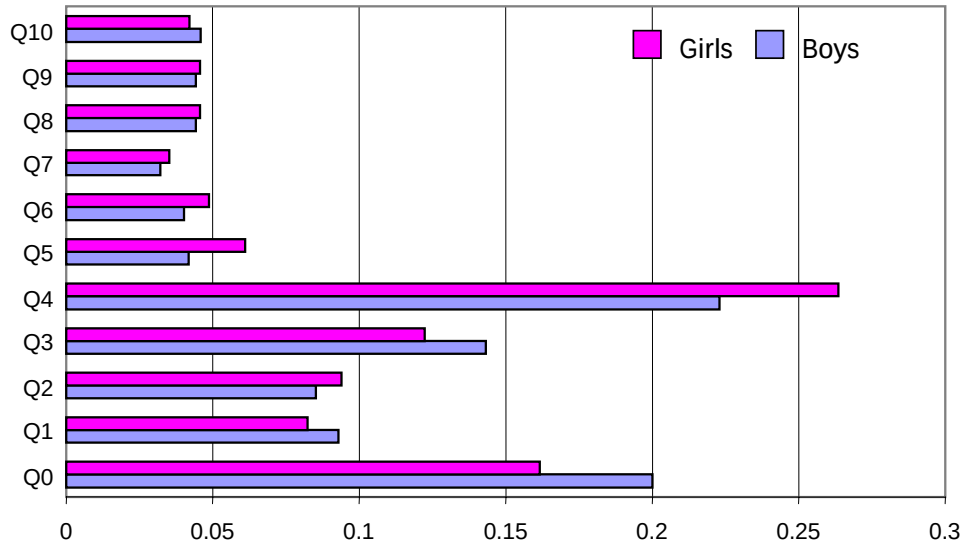


Figure 2: Density of effort for child, parents, and schools

From the second part of Table 1, we find that the parents' interest in the child's education at different points in time is the most salient contributor, while on the other side of the spectrum, reading to the child and the father's role in the management of the child seem to contribute least to the index.

Our measure of the school's effort, e_i^S, is constructed (see the third part of Table 1) from information on the extent of activities which school and teachers are not statutorily required to perform, for example, whether teachers take the initiative to discuss a student's progress with his or her parents, the presence of a parent-teacher association in the school, whether students receive career guidance in the school, and the practice of grouping children of similar ability (streaming) in the school. We also include information on disciplinary methods used, on the grounds that activities such as detention or additional homework require also additional work on the teachers' part. Note also that the child's and the parents' effort indices are constructed with similar scoring coefficients for both boys and girls. This is not so for the school's effort analysis. For girls, the variables with the bigger weight are the disciplinary ones, while for boys, parents' and teachers' activities are also important. This may well reflect a difference in the schools' behaviour towards boys and girls in this period. The construction of the school's effort index is less satisfactory than for parents and children, as shown by the smaller proportion of explained variance. Figure 2 illustrates the density of the effort variables we have constructed.

5.1.2 Examinations



Q10	Three or more A-levels at 9 or 10 points, or three or more Scottish Highers at 9 or more points
Q9	Two A-levels at 9 or 10 points or three A-levels at 8 points or less, or three Scottish Highers at 8 points or less
Q8	Two A-levels or Scottish Highers at 8 points or less
Q7	One A-level or Scottish Higher
Q6	Seven or more GCE O-levels or CSE at grade 1, or seven or more Scottish O-levels
Q5	Five or six GCE O-levels or CSE at grade 1, or five or six Scottish O-levels at A-C grade
Q4	One to four GCE O-levels or CSE at grade 1, or one to four Scottish O-levels at A-C grade
Q3	Five or more CSE at grade 2-5, or five or six or more Scottish O-levels
Q2	One or more CSE at grade 2-3, or three or four Scottish O-levels
Q1	One or more O-levels or CSE at grade 4-5, or one or two Scottish O-levels
Q0	No formal qualification

Figure 3: Frequency of examination results

As well as an extremely detailed list of all the examinations taken by each student (obtained in 1978 by writing to schools), the dataset also includes a summary measure of the examination performance. This was created paying special attention to particular problems such as time and place constraints, grade equivalence, retakes and double entries (Steedman (1983a ;1983b); see Galindo-Rueda and Vignoles, 2003, p 10 for a more detailed discussion of the British education system in the early '70s). We have taken this measure modifying it only slightly, to allow inclusion in the sample of the Scottish students.[14] The educational outcome Q_i in equation (16) is a categorical variable ranging

[14] We put together, in "Q9", observations of "Two A-levels at 9 or 10 points" and "Three A-levels at 8 points or less"; there are only 27 observations of the former. Similarly, we have put together, in "Q1", "One or more O-levels at grade 4-5" and "One or more CSE at grade 4-5"; there are 70 observations of the former.

from 0, indicating no formal qualification, to 10, reflecting 3 or more A-levels at 9 to 10 points. Figure 3 shows the distribution of examination results for boys and girls in the samples used. The proportion of boys that have at least one A-level result is slightly higher, 17.37 against 16.66 for girls. The mode of both distributions is "up to four O-levels or CSE with grade 1".

5.2 Explanatory variables

The summary statistics for the background explanatory variables are reported in Table 2: individual characteristics first, then family characteristics, followed by school, peer group and geographical variables.

The main individual characteristic is ability. This is measured at ages 7, 11, and 16 by administered tests that are independent of educational qualifications. At 7 there is information on arithmetic and reading scores, at 11 and 16 the individuals were tested on their reading and mathematical ability, and at 11 they also completed a general ability test. Following the literature on cognitive ability and students' attainment, we combine the tests undertaken at the different points in time and on different subjects using the principal components method (see, for example, Galindo-Rueda and Vignoles (2003)). We include birth weight following some of the literature on lifetime attainments (Conley *et al.* (2003); Fryer and Levitt (2002)).

The vector of family background variables includes the number of older and younger brothers and sisters, and indicators of the mother's position in the labour market. Parental income is measured when the individuals were 16, and the household socio-economic status is measured by the father's (or the father figure's) social class at age 11.[15] We have also included the percentage of total income not earned by the father figure, and whether the household's accommodation is owned by the household. Other variables are parental education attainment and the frequency of reading of both parents, as distinct from the variable measuring the frequency of parents reading *to* their children, which enters the measure of parental effort.

The school characteristics we use are its size, measured by the log of the number of pupils, and its type: state or private at ages 7, 11, and 16, and single-sex, comprehensive, secondary modern or grammar at age 16. We also include class size, and to capture possible non-linearities in class and school

[15] We manipulated all income information using the procedure developed for this dataset (Micklewright (1986)).

Variable	Girls Mean	Girls Std. Dev.	Boys Mean	Boys Std. Dev.	Child's effort equation	Parents' effort equation	School's effort equation	Exam result equation
Exam result	3.716	2.771	3.542	2.918	-	-	-	-
Child's effort	-0.063	0.913	-0.075	0.918	-	*	*	*
Parents' effort	-0.125	0.891	-0.127	0.887	*	-	*	*
School's effort	-0.015	0.796	-0.026	0.793	*	*	-	*
Ability	-0.132	2.243	-0.147	2.259	*	*		*
‡	0.006		0.006		*	*		*
Weight at birth	104.763	37.049	108.448	39.713	*			
‡	0.089		0.097		*			
Older brothers	0.489		0.483			*		
‡	0.209		0.222			*		
Younger brothers	0.513		0.504			*		
‡	0.212		0.223			*		
Older sisters	0.447		0.449			*		
‡	0.211		0.222			*		
Younger sisters	0.478		0.476			*		
‡	0.212		0.224			*		
Mother in work age 16	0.512		0.513			*		
‡	0.215		0.222			*		
Mother in work age 7	0.251		0.235			*		
‡	0.137		0.147			*		
Mother married age 0	0.903		0.907			*	*	
‡	0.063		0.063			*	*	
Intermediate§§	0.159		0.144		*	*		*
Skilled non-manual§§	0.079		0.080		*	*		*
Skilled manual§§	0.346		0.345		*	*		*
Semiskilled non-manual§§	0.018		0.017		*	*		*
Semiskilled manual§§	0.127		0.125		*	*		*
Unskilled§§	0.046		0.051		*	*		*
‡	0.178		0.185		*	*		*
House owner	0.403		0.394			*		*
‡	0.202		0.213			*		*
Total household income	32.031	27.038	31.399	26.494		*		*
‡	0.286		0.293			*		*
% of income not from father	0.290	0.336	0.289	0.334		*		*
Father has higher education	0.075		0.077			*		*
Father has secondary education	0.257		0.245			*		*
‡	0.230		0.237			*		*
Mother has higher education	0.055		0.046			*		*
Mother has secondary education	0.363		0.359			*		*
‡	0.213		0.226			*		*
Father reads books regularly	0.427		0.423			*		*
Father reads books occasionally	0.169		0.166			*		*
‡	0.134		0.140			*		*
Mother reads books regularly	0.301		0.291			*		*
Mother reads books occasionally	0.188		0.185			*		*
‡	0.135		0.141			*		*
English class size age 16	24.710	7.947	24.043	8.050				*
(English class size age 16)^2	673.728	321.876	642.881	316.650				*
‡	0.050		0.051					*
Maths class size age 16	23.832	8.373	23.765	8.207				*
(Maths class size age 16)^2	638.054	332.037	632.104	326.054				*
‡	0.056		0.052					*
No. children in child's present class age 7	31.254	13.309	30.700	13.688				*
(No. children in child's present class age 7)^2	1153.894	610.691	1129.817	624.551				*
‡	0.116		0.125					*
No. children in child's present class age 11	29.129	14.278	28.748	14.443				*
(No. children in child's present class age 11)^2	1052.319	625.554	1035.040	651.123				*
‡	0.157		0.159					*

Log of school size age 16	6.554	1.098	6.578	1.023		*	*
‡	0.021		0.016			*	*
Log of school size age 11	4.773	2.175	4.755	2.179		*	*
‡	0.163		0.164			*	*
Log of school size age 7	4.650	1.994	4.615	2.010		*	*
‡	0.143		0.147			*	*
Private school age 11	0.032		0.034			*	*
‡	0.135		0.139			*	*
Private school age 7	0.029		0.026			*	*
‡	0.113		0.122			*	*
Grammar school age 16	0.123		0.098			*	*
Private school age 16	0.034		0.040			*	*
Secondary modern age 16	0.204		0.205			*	*
‡	0.000		0.000			*	*
Single sex school age 16	0.262		0.235			*	*
‡	0.012		0.010			*	*
Pupils from school go to university	0.534		0.542		*		*
‡	0.163		0.146		*		*
% of girls studying for O-levels	24.958	33.225	13.895	26.088	*		*
‡	0.065		0.295		*		*
% of boys studying for O-levels	14.119	26.478	24.928	33.994	*		*
‡	0.313		0.063		*		*
10%-19%§	0.174		0.163		*	*	
20%-29%§	0.174		0.170		*	*	
30%-39%§	0.109		0.123		*	*	
40%-49%§	0.069		0.079		*	*	
50%-59%§	0.075		0.071		*	*	
60%-69%§	0.062		0.057		*	*	
70%-79%§	0.027		0.035		*	*	
80%-100%§	0.073		0.069		*	*	
‡	0.155		0.137		*	*	
% of unemployed or sick †	3.975	5.818	3.879	6.138			*
% of professionals or managers †	10.493	13.183	9.827	12.943			*
% of non-manual workers †	22.527	17.300	21.287	17.724			*
% of skilled manual workers †	22.763	16.796	21.446	17.284			*
% of semi-skilled manual workers †	15.079	12.866	14.434	13.131			*
% of unskilled manual workers †	5.917	7.676	5.746	7.604			*
% of owner occupied households †	35.854	35.914	33.397	35.262			*
% of council tenants †	30.667	38.803	29.006	38.229			*
Average no. persons per room †	0.506	0.290	0.476	0.300			*
% of households lacking inside WC †	7.133	14.047	7.191	14.155			*
% of new Commonwealth immigrants †	1.286	5.091	1.278	5.033			*
‡	0.205		0.247				*
North West age 11	0.097		0.088				*
North age 11	0.057		0.060				*
East and West Riding age 11	0.072		0.081				*
North Midlands age 11	0.067		0.067				*
Eastern age 11	0.077		0.077				*
Southern age 11	0.055		0.054				*
South West age 11	0.062		0.056				*
Midlands age 11	0.079		0.080				*
Wales age 11	0.048		0.054				*
Scotland age 11	0.108		0.104				*
‡	0.134		0.139				*
% of comprehensive schools in LEA	0.641	0.299	0.649	0.297			*
‡	0.061		0.058				*

Notes: Standard deviations are not reported for 0/1 dummy variables. * Included as an explanatory variable in the corresponding equation
‡ Dummy for missing values of the variable(s) listed above. § Percentage of the child's classmates with a non-manual father, at age 16.
§§ Father's socio-economic status, at age 11. † Enumeration district-level variables from 1971 Census Small Area Statistics

Table 2: Descriptive statistics

size (implying, for example that an increase in size may be a good thing for small size, and a bad thing for larger size) we include the square of the size.

An important influence on the school's quality are the characteristics of the students in the school, that is the "peer group effect".[16] To capture it, we consider both academic and social indicators. The former are the percentage of boys and girls in the school attended at age 16 who are studying for O-levels and the proportion who subsequently enrolled into a higher education course (both indicate a more "academic" peer group). The social peer group is captured by the proportion of children in the individual's school class whose father has a non-manual occupation.

The last rows of the Table report some geographical characteristics. As well as regional dummies, we include the proportion of comprehensive schools in the area, and some social indicators of the enumeration district (this is a small geographical area comprising around 200 households) where the child was living at age 16. These variables are taken from the 1971 census, and correspond to those used by Dearden *et al.* (2002).

The last four columns in the Table illustrate the model specification we have chosen: an asterisk in a column indicates that the variable in the row was used as a regressor for the equation indicated by that column. Dummies for missing values are used for each of the other variables to capture possible non-randomness in non-response: these are the unnamed variables in the table, after each variable or group of variables; for example the 0.089 in the line below "Weight at birth" indicates that 8.9% of the data in the sample did not report the value of this variable. All estimations include these dummy variables, but we do not report their coefficients or standard errors in the results to make the interpretation and the reading of the tables easier.

6 Results

Our theoretical foundation is that the effort of the three agents is simultaneously determined at the Nash equilibrium. Econometrically, the effort variables should be endogenous. To ascertain this, we perform the DWH test described in Section 4 on the parameters of equation (15). We can reject, at conven-

[16] This is a well documented phenomenon; see Moreland and Levine (1992) for a survey from a psychology/education viewpoint, Summers and Wolfe (1977), Henderson *et al.* (1978) for early economic empirical studies, and Epple *et al.* (2002) and Zimmer and Toma (2000) for more recent ones. The theoretical analyses of Arnott and Rowse (1987) and de Bartolome (1990) were among the first to take the peer group effect explicitly into account.

tional significance levels, the null hypothesis that the residuals of the effort equations do not affect examination results,[17] and we therefore conclude that educational attainment and the effort levels exerted by children, their parents and their school are indeed simultaneously determined, as posited by the theoretical model.

All the results are reported separately for the samples of girls and boys. We have tested, and found support for, the hypothesis that girls and boys differ significantly. We have done so by estimating a more general specification of the entire model with a gender dummy interacting with each of the explanatory variables, and testing the joint statistical significance of the parameters of these interaction terms in the educational attainment equation, using a log-likelihood ratio test.[18]

In Table 3 we report the results for our three-stage least squares estimates of equations (9)-(11).[19] In each of the three effort equations, the effort level exerted by the other two groups of agents is significant, with the exception of parental effort on the school effort for girls. This confirms our assumption of simultaneous endogenous determination of effort levels as a Nash equilibrium. Also note that a 0 coefficient does not necessary falsify the Nash equilibrium hypothesis, because the intersection of the relevant best reply functions could happen close to a stationary point of one of them (as, for example, in point E_1 in panel (a) in Figure 1). The table suggests that parental and the child's efforts are strategic complements: by exerting more effort, parents induce their child to exert more effort, and, vice versa, parents respond positively to their children exerting more effort. In other words, there is a "multiplier" effect, suggesting, for example, that policies aimed at affecting directly the effort exerted by children and parents may prove very effective. On the other hand, the role of the school effort is less clear-cut: it affects negatively the effort exerted by children and by girls' parents, and positively the effort of boys' parents. Conversely, schools respond positively to girls' effort, and negatively to boys',

[17] The test statistics of the likelihood-ratio tests of the null hypothesis are $\chi^2(3) = 7.86$ (p-value 0.0491) for the sample of girls, $\chi^2(3) = 14.49$ (p-value 0.0023) for the sample of boys, and $\chi^2(3) = 21.71$ (p-value 0.0001) for the combined sample of girls and boys.

[18] The test statistic of this likelihood-ratio test is $\chi^2(88) = 172.89$ (p-value 0.0000). We prefer to report separate samples, rather than the more general model with the interaction terms because its very large number of regressors would make the interpretation of coefficients very difficult.

[19] We have tried several alternative specifications, and we present here only the most parsimonious, having tested at various stages for linear restrictions on non-significant coefficients. Other intermediate results and the data to obtain them are available on request.

but positively to boys' parents' effort. Anecdotal evidence does confirm the possibility of differential attitude of schools and parents towards boys and girls in the '60s and early '70s.

The striking feature of the children's effort equation is the paucity of statistically significant explanatory variables: only the other effort levels and their own ability and birth weight seem to affect their effort. Clearly, our results are tentative, constrained by the limitations of the dataset, but a possible interpretation for this finding is that children from different backgrounds or in different peer groups do not differ significantly in their propensity to exert effort. If confirmed by more targeted studies, this may have policy implications for the type of incentives to provide to pupils in schools.

The parents' effort equation indicates that the presence of (older or younger) siblings reduces parental effort. This is an interesting result, which also indicates that the variables we have used to measure effort do indeed capture relevant features of parental effort: theoretical considerations suggest that parents face a trade-off between the number of their children and the attention each of them receive (Becker (1960); Hanushek (1992)). Social class also appears relevant. Parental taste for education, as reflected by their education and the frequency of their reading, does positively influence their own effort. There is also some indication that the mother's position in the labour market may have some effect on parental effort: the effect of the mother being in work is rather ambiguous, but the percentage of household income not earned by the father figure has a clear negative influence on parents' effort. This confirms the intuition that parents' effort is not fully captured by their socio-economic status. Household income, on the other hand, affects parental effort only for boys.

The school's effort is higher in larger schools, for both boys and girls. The effects of school type variables are generally stronger for girls than for boys. It is interesting to note the different effect of the "single-sex" variable in the two subsamples: it suggests that girls' only schools exert less effort, and boys' only schools more effort than co-educational schools; this is in line with our perception of the British educational system at the time. Note that for younger children (age 7 and 11), private schools exert effort level either not significantly different or lower than state schools. At age 16, their effort level is not significantly different from the base school type, the state comprehensive. The effect of the peer group is statistically significant, especially for boys: schools work harder which have a larger proportion of children from higher socio-economic

Dependent variable	Child's Effort				Parents' Effort				School's Effort			
	Girls		Boys		Girls		Boys		Girls		Boys	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Constant	0.205 *	0.092	0.238 **	0.085	-0.032	0.072	-0.147 *	0.074	-3.455 **	0.165	-3.695 **	0.144
Child's effort					0.363 **	0.102	0.669 **	0.080	0.186 **	0.065	-0.114 *	0.051
Parents' effort	0.521 **	0.042	0.418 **	0.042					-0.063	0.053	0.279 **	0.044
School's effort	-0.094 **	0.039	-0.199 **	0.035	-0.121 **	0.024	0.133 **	0.026				
Ability	0.083 **	0.009	0.111 **	0.008	0.088 **	0.016	0.018	0.014				
Weight at birth	-0.002 **	0.001	-0.002 **	0.001								
Older brothers					-0.052 **	0.011	-0.033 **	0.010				
Younger brothers					-0.049 **	0.011	-0.020	0.010				
Older sisters					-0.074 **	0.012	-0.054 **	0.011				
Younger sisters					-0.049 **	0.010	-0.044 **	0.011				
Mother in work age 16					0.036	0.020	0.051 *	0.020				
Mother in work age 7					-0.066 **	0.020	-0.036	0.019				
Houseowner					0.163 **	0.026	0.148 **	0.022				
Total household income					0.000	0.001	0.002 **	0.001				
% of income not from father					-0.146 **	0.033	-0.131 **	0.033				
Father has higher education					0.049	0.037	0.009	0.037				
Father has secondary education					0.015	0.022	0.011	0.022				
Mother has higher education					0.145 **	0.043	0.138 **	0.043				
Mother has secondary education					0.063 **	0.021	0.020	0.021				
Father reads books regularly					0.197 **	0.023	0.170 **	0.023				
Father reads books occasionally					0.144 **	0.025	0.088 **	0.025				
Mother reads books regularly					0.098 **	0.022	0.119 **	0.022				
Mother reads books occasionally					0.066 **	0.023	0.079 **	0.023				
Intermediate§§	-0.031	0.058	-0.011	0.054	-0.055 *	0.048	-0.025	0.047				
Skilled non-manual§§	-0.012	0.065	-0.056	0.060	-0.140 **	0.055	-0.053	0.053				
Skilled manual§§	0.022	0.060	-0.078	0.055	-0.316 **	0.051	-0.216 **	0.050				
Semiskilled non-manual§§	-0.013	0.098	-0.038	0.095	-0.243 **	0.082	-0.232 **	0.083				
Semiskilled manual§§	0.011	0.065	-0.100	0.062	-0.276 **	0.055	-0.206 **	0.056				
Unskilled§§	0.016	0.082	-0.139	0.074	-0.422 **	0.068	-0.271 **	0.067				
Log of school size age 16									0.544 **	0.021	0.499 **	0.018
Single sex school age 16									-0.250 **	0.025	0.117 **	0.025
Grammar school age 16									-0.151 **	0.035	0.073 *	0.037
Secondary modern age 16									0.096 **	0.026	0.032	0.024
Private school age 16									0.082	0.068	-0.017	0.065
Private school age 11									-0.159 *	0.069	0.048	0.064
Private school age 7									-0.015	0.068	-0.154 *	0.068
Pupils from school go to university	0.051 *	0.025	0.009	0.026								
% of girls studying for O-levels	-0.001 *	0.001	-0.001	0.001								
% of boys studying for O-levels	0.000	0.001	0.000	0.000								
10%-19%§	-0.013	0.040	-0.021	0.037					0.108 **	0.040	0.157 **	0.038
20%-29%§	-0.032	0.041	-0.009	0.038					0.066	0.041	0.223 **	0.039
30%-39%§	-0.031	0.044	-0.054	0.040					0.033	0.045	0.167 **	0.042
40%-49%§	0.007	0.051	-0.046	0.046					0.175 **	0.050	0.265 **	0.047
50%-59%§	-0.061	0.050	-0.022	0.049					0.124 *	0.050	0.414 **	0.049
60%-69%§	-0.066	0.054	-0.009	0.051					0.129 *	0.054	0.277 **	0.052
70%-79%§	-0.013	0.068	0.066	0.061					0.089	0.068	0.331 **	0.062
80%-100%§	-0.091	0.055	0.082	0.055					-0.140 *	0.058	0.406 **	0.060
Number of observations	5611		5860		5611		5860		5611		5860	
R^2	0.2261		0.2477		0.4199		0.2397		0.1891		0.1852	
chi^2	1740.60**		2020.47**		4370.00**		3902.05**		1607.82**		1526.93**	

Notes: § Percentage of the child's classmates with a non-manual father, at age 16. §§ Father's socio-economic status, at age 11. * Significant at the 5% level. ** Significant at the 1% levi
Other variables included in the regression and not reported are: the absence of a father figure, whether the mother works at birth, the log of the school size at age 7 and 11.

Table 3: Three-stage least squares estimates of effort equations

groups.

Table 4 presents the result of our ordered probit estimates. As it should, effort strongly improves results. Ability also has, again as one would expect, a strong independent positive effect on results. Family background variables, such as the parents' education, their taste for reading and their social class have however a less definite effect than they had on effort, and they appear to have a weaker influence than much of the literature suggests (Ermisch and Francesconi (2001), Dearden *et al.* (2002)); for example, income is statistically not significant. Whether the mother (the father) has higher education affect positively girls' (boys') results, but otherwise parental education is not statistically significant. Book reading has, if anything, a negative effect on attainment, and the social class is overall less significant than in the effort equation. A natural interpretation of these results is that family background influences school examination's results indirectly, via parental effort, rather than directly.

With regard to the variables describing the school, we find that being in a private school has a direct positive effect for boys but not for girls; on the other hand, for girls, a state grammar has a direct positive effect, while a secondary modern has a direct negative effect. Girls in single-sex schools obtain, *ceteris paribus*, a better qualification. School size matters only at age 16, and only for girls, with a negative sign. These variables have the opposite sign in the school's effort equation: in Table 3, last columns, single-sex has a negative sign, and the school size a positive sign. We have included several measures of class size, at the three different ages, and their square, to account for possible non-linearities: of these only the English class size at age 16, for girls, is statistically significant.[20] The academic peer group effect appears very strong: interestingly, it operates within genders: girls are not influenced by boys and vice versa. This makes sense, and we take it as a further indication that our model specification is plausible.

We do not include in Table 4 the census variables, listed in Table 2. Among them, only the percentage of unemployed or sick in the census enumeration district are statistically significant for girls, and only the proportion of owner occupied houses, the proportion of council tenants, and the average number of persons per room are statistically significant for boys. These variables have

[20] The estimated coefficients suggest that exam results improve with class size up to 29 and decreases for class size larger than 30. Though the specific appealing value of the "optimal" class size may well be a fluke, it is interesting to note that the relationship between class size and achievement in this dataset has often the "wrong" sign (Levacic and Vignoles 2002)

	Girls			Boys		
Variable	Coef.		Std. Err.	Coef.		Std. Err.
Child's effort	0.439	**	0.046	0.164	*	0.073
Parents' effort	0.739	**	0.085	0.977	**	0.033
School's effort	1.076	**	0.162	0.333	**	0.104
Ability	0.331	**	0.014	0.357	**	0.014
Houseowner	0.001		0.043	-0.109	**	0.038
Total household income	0.000		0.001	0.000		0.001
% of income not from father	0.179	**	0.060	-0.028		0.058
Father has higher education	0.071		0.070	0.161	*	0.063
Father has secondary education	-0.014		0.040	-0.001		0.040
Mother has higher education	0.213	**	0.080	-0.063		0.082
Mother has secondary education	-0.067		0.038	-0.010		0.037
Father reads books regularly	-0.119	**	0.045	-0.146	**	0.042
Father reads books occasionally	-0.122	**	0.048	-0.025		0.048
Mother reads books regularly	-0.023		0.041	-0.109	**	0.039
Mother reads books occasionally	-0.048		0.043	-0.105	*	0.043
Intermediate[§§]	-0.151		0.078	-0.230	**	0.073
Skilled non-manual[§§]	-0.190	*	0.088	-0.211	**	0.080
Skilled manual[§§]	-0.111		0.082	-0.065		0.074
Semiskilled non-manual[§§]	-0.155		0.138	-0.226		0.143
Semiskilled manual[§§]	-0.187	*	0.089	-0.180	*	0.083
Unskilled[§§]	-0.232	*	0.117	-0.093		0.102
English class size at 16	0.046	*	0.018	0.000		0.018
(English class size at 16)^2	-0.001	*	0.000	0.000		0.000
Maths class size at 16	0.001		0.016	0.008		0.016
(Maths class size at 16)^2	0.000		0.000	0.000		0.000
Log of school size age 16	-0.434	**	0.102	-0.084		0.070
Single sex school age 16	0.353	**	0.103	-0.093		0.074
Grammar school age 16	0.211	**	0.066	0.083		0.063
Secondary modern age 16	-0.223	**	0.049	0.018		0.045
Private school age 16	0.193		0.112	0.617	**	0.096
Private school age 11	0.217		0.115	-0.002		0.105
Private school age 7	-0.125		0.120	-0.055		0.103
Pupils from school go to university	0.035		0.042	0.108	**	0.041
% of girls studying for O-levels	0.005	**	0.001	-0.002		0.001
% of boys studying for O-levels	0.000		0.001	0.005	**	0.001
% of comprehensive schools in LEA	-0.141	*	0.071	-0.071		0.070
μ_1 : boundary between Q0 and Q1	-4.352		0.759	-2.956		0.610
μ_2 : boundary between Q1 and Q2	-3.843		0.758	-2.421		0.610
μ_3 : boundary between Q2 and Q3	-3.315		0.757	-1.966		0.610
μ_4 : boundary between Q3 and Q4	-2.678		0.756	-1.235		0.609
μ_5 : boundary between Q4 and Q5	-1.248		0.755	0.059		0.608
μ_6 : boundary between Q5 and Q6	-0.850		0.754	0.355		0.607
μ_7 : boundary between Q6 and Q7	-0.509		0.754	0.660		0.607
μ_8 : boundary between Q7 and Q8	-0.234		0.753	0.924		0.607
μ_9 : boundary between Q8 and Q9	0.202		0.753	1.338		0.607
μ_{10} : boundary between Q9 and Q10	0.782		0.754	1.904		0.607
Number of observations	5611			5860		
Pseudo R^2	0.2677			0.2744		
Wald chi^2(90)	4166.01**			4192.97**		
Log-Likelihood	-8945.4208			-9226.7		

Notes: §§ Father's socio-economic status, at age 11. * Significant at the 5% level. ** Significant at the 1% level. Other variables included in the regression and not reported are: whether the mother is married at birth, the absence of a father figure, the log of school size at age 7 and 11, census variables, and regional dummies.

Table 4: Ordered probit estimates of exam results equation

	Girls			Boys		
	Child's effort	Parents' effort	School's effort	Child's effort	Parents' effort	School's effort
Q0	-0.028	-0.047	-0.069	-0.016	-0.095	-0.033
Q1	-0.037	-0.063	-0.091	-0.018	-0.107	-0.037
Q2	-0.054	-0.091	-0.132	-0.018	-0.105	-0.036
Q3	-0.051	-0.086	-0.125	-0.014	-0.082	-0.028
Q4	0.084	0.141	0.206	0.039	0.230	0.078
Q5	0.037	0.062	0.090	0.010	0.057	0.019
Q6	0.022	0.038	0.055	0.007	0.043	0.015
Q7	0.012	0.020	0.029	0.004	0.025	0.009
Q8	0.010	0.017	0.025	0.004	0.022	0.007
Q9	0.004	0.007	0.011	0.002	0.010	0.004
Q10	0.001	0.002	0.002	0.000	0.002	0.001

Table 5: Marginal effects

a negative effect on examination results. With regard to regional dummies (at age 11), "south" and "midlands" are positively significant for girls, and "north", "east and west riding" and "Scotland" for boys.[21]

Table 5 presents the marginal effects of changes in effort on examination outcomes derived from the probit estimation. The values in each column are the marginal changes in the probability of the eleven possible outcomes due a marginal change in effort of the various agents, evaluated at the means for all variables. The table suggests that both for girls and for boys, the child's effort is the least capable of affecting education outcomes. Where boys and girls differ is in the relative importance of parental and school effort: the latter is more important for girls, and parental effort for boys.

We analyse further the interaction between ability and effort, by determining the effect of marginal changes in effort at high (the top 5%), median and low (the bottom 5%) ability levels. Figure 4 illustrates this. The relative importance of effort levels by the three groups of agents is the same at the three ability levels. There are different effects for different ability individuals: the bottom two diagrams suggest that effort is effective in ensuring that low ability children obtain at least some qualification. Effort pushes the median ability children into the group of individuals who have one to four O-levels, and – as shown by the top two diagrams– moves high ability children out of this group into higher qualification classes. Clearly it is premature to draw policy prescription from our estimates, but these results would suggest that policies aimed at improving parental effort directly may be an effective way of influencing the results of low achieving boys, whereas schools may be more capable of improving

[21] The size of the coefficient for "Scotland" is similar to that of the other regions.

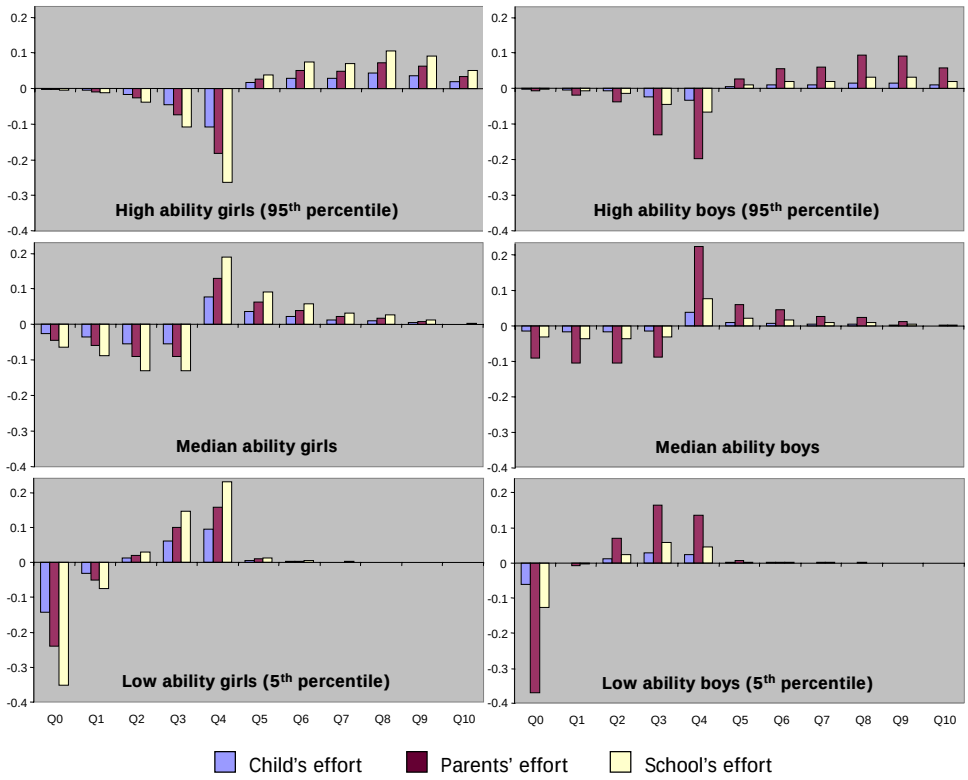


Figure 4: Changes in probabilities of qualification Q0-Q10

the educational attainment of low achieving girls. Our results may therefore be seen as an explanation of the relatively stronger improvement in educational attainment for girls than for boys experienced in the UK in the past few years, which has coincided with a definite strengthening of the incentives placed upon schools and teachers: if schools respond to incentives by putting in more effort, and if our conclusion regarding the relative importance of the school effort for boys and girls are correct, the schools' increased effort enhances their female pupils' attainment more than their male pupils'.

7 Concluding remarks

Intuition suggests that if children, their parents, and their teachers exert more effort, the academic performance of the children improves. Our paper confirms this intuition and qualifies it. At a theoretical level, it illustrates the consequences of the strategic interaction among the participants in the education

process: as a simple example shows, if effort levels are strategic substitutes, then an increase in effort by the school may cause a *reduction* in effort by the students. The model is tested empirically, with interesting results: for example our finding that the school's effort is more important for girls and the parents' effort is more important for boys is not necessarily intuitive, even though it can be rationalised ex-post. The same can be said of the findings that the children's effort seem to be less effective than both the parents' and the school's. The next step is to understand what motivates children, their parents and their teachers to exert effort. This can allow policy makers to design policies aimed at stimulating effort: it may be easier and more effective to stimulate effort in households with a low socioeconomic background, rather than wait for their economic conditions to change.

The environment where schools operate has clearly changed radically, both in term of the incentive system operating within schools and of the competitive climate between schools. Nevertheless, understand which fundamental factors affect the behaviour of the agents at the heart of the education production process is important both to be able to evaluate the effects of the changing environment and to predict the possible effects of proposed policy changes.

References

Arnott, R. and J. Rowse (1987). Peer group effects and educational attainment. *Journal of Public Economics 32*, 287–305.

Becker, G. S. (1960). An economic analysis of fertility. In *Demographic and economic change in developed countries*. NBER - Princeton University Press, Princeton, no 11.

Becker, G. S. and N. Tomes (1976). Child endowments and the quantity and quality of children. *Journal of Political Economy 84*, S143–62.

Blake, J. (1989). *Familiy size and achievement*. University of California Press, Berkeley.

Bonesrønning, H. (1998). The importance of student effort in education production. empirical evidence from Norway. Department of Economics. Norwegian University of Science and Technology.

Bonesrønning, H. (2004). The determinants of parental effort in education production: do parents respond to changes in class size? *Economics of Education Review 23*, 1–9.

Bulow, J. I., J. D. Geanakoplos, and P. D. Klemperer (1985). Multimarket oligopoly: Strategic substitutes and complements. *Journal of Political Economy 93*, 488–511.

Cappelli, P. and K. Chauvin (1991). An interplant test of the efficiency wage hypothesis. *Quarterly Journal of Economics 106*, 769–787.

Carneiro, P. and J. Heckman (2003). Human capital policy. In J. Heckman and A. Krueger (Eds.), *Inequality in America: What Role for Human Capital Policies*. MIT Press, Cambridge MA.

Conley, D., K. Strully, and N. G. Bennett (2003). A pound of flesh or just proxy? Using twin differences to estimate the effect of birth weight on life chances. Technical Report 9901, NBER Working Paper Series.

Connolly, S., J. Micklewright, and S. Nickell (1992). The occupational success of young men who left school at sixteen. *Oxford Economic Papers 44*, 460–79.

Cooley, J. (2004). Equilibrium achievement under conformity effects. Department of Economics, Duke University.

CUSSRU (2000). National child development study composite file including selected perinatal data and sweeps one to five, 1958-1991, 2nd edition. Technical report, City University Social Statistics Research Unit, National Birthday Trust Fund, National Children's Bureau, City University Social Statistics Research Unit, Colchester, Essex.

Davidson, R. and J. G. MacKinnon (1993). *Estimation and inference in econometrics*. Oxford University Press, New York.

de Bartolome, C. (1990). Equilibrium and inefficiency in a community model with peer group effects. *Journal of Political Economy 98*, 110–133.

De Fraja, G. and P. Landeras (2005). Could do better: The effectiveness of incentives and competition in schools. *Journal of Public Economics forthcoming.*

Dearden, L., C. Emmerson, C. Frayne, and C. Meghir (2003). The impact of financial incentives on education choice. Presented at the CEPR meeting, The Economics of Education, Paris.

Dearden, L., J. Ferri, and C. Meghir (2002). The effect of school quality on educational attainment and wages. *Review of Economics and Statistics 84*, 1–20.

Epple, D., R. E. Romano, and H. Sieg (2003). Peer effects financial aid and selection of students to colleges and universities: An empirical analysis. *Journal of Applied Econometrics 18*, 501–525.

Ermisch, J. and M. Francesconi (2001). Family matters: Impacts of family background on educational attainments. *Economica 68*, 137–156.

Everitt, B. S. and G. Dunn (2001). *Applied multivariate data analysis. Second edition.* Arnold, London.

Falk, A. and A. Ichino (2003). Clean evidence on peer pressure. European University Institute, Florence.

Fan, X. and M. Chen (2001). Parental involvement and students' academic achievement: A meta-analysis. *Educational Psychology Review 13*, 1–22.

Fryer, R. G. and S. D. Levitt (2004). Understanding the black-while test score gap in the first two years of school. *Review of Economics and Statistics 86*, 447–464.

Fudenberg, D. and J. Tirole (1991). *Game theory.* MIT Press, Cambridge, Massachusetts.

Galindo-Rueda, F. and A. Vignoles (2003). Class ridden or meritocratic? an economic analysis of recent changes in Britain. Technical Report 32, Centre for the Economics of Education, London School of Economics.

Galizzi, M. and K. Lang (1998). Relative wages, wage growth, and quit behavior. *Journal of Labor Economics 16*, 367–391.

Hanushek, E. A. (1986). The economics of schooling: Production and efficiency in public schools. *Journal of Economic Literature 23*, 1141–77.

Hanushek, E. A. (1992). The trade-off between child quantity and quality. *Journal of Political Economy 100*, 84–117.

Harman, H. H. (1976). *Modern factor analysis. Third edition.* University of Chicago Press, Chicago.

Henderson, V., P. Mieszkowski, and Y. Sauvageau (1978). Peer group effects in educational production function. *Journal of Public Economics 10*, 97–106.

Holmstrom, B. R. and J. Tirole (1989). The theory of the firm. In R. Schmalensee and R. D. Willig (Eds.), *Handbook of industrial organization. Volume 1*, pp. 61–133. North-Holland, Amsterdam,.

Hoover-Dempsey, K. V., A. C. Battiato, J. M. T. Walker, R. P. Reed, J. M. DeJong, and K. P. Jones (2001). Parental involvement in homework. *Educational Psychologist 36*, 195–209.

Ichino, A. and G. Maggi (2000). Work environment and individual background: Explaining regional shirking differentials in a large Italian firm. *Quarterly Journal of Economics 115*, 1057–1090.

Ichino, A. and R. Riphahn (2005). The effect of employment protection on worker effort: Absenteeism during and after probation. *Journal of the European Economic Association 3*, 120–143.

JCfLR (2001). National child development study and 1970 British cohort study (BCS70) follow-ups, 1999-2000. Technical report, Joint Centre for Longitudinal Research, UK Data Archive, Colchester, Essex.

Levacic, R. C. and A. Vignoles (2002). Researching the links between school resources and student outcomes in the UK: A review of issues and evidence. *Education Economics 10*, 313–331.

Micklewright, J. (1986). A note on household income data in NCDS3. Technical Report 18, NCDS User Support Group, Social Statistics Research Unit, City University, London.

Micklewright, J. (1989). Choice at sixteen. *Economica 56*, 25–39.

Moreland, R. L. and J. M. Levine (1992). The composition of small groups. In E. J. Lawler, B. Markovsky, C. Ridgeway, and H. Walker (Eds.), *Advances in group processes, Vol 9*, pp. 237–80. JAI Press, Greenwich, CT.

Natriello, G. and E. L. McDill (1986). Performance standards, student effort on homework, and academic achievement. *Sociology of Education 59*, 18–31.

Shapiro, C. and J. E. Stiglitz (1984). Equilibrium unemployment as a worker discipline device. *American Economic Review 74*, 433–444.

Steedman, J. (1983a). *Examination results in selective and non-selective schools: Findings from the National Child Development Study.* National Children's Bureau, London.

Steedman, J. (1983b). *Examination results in selective and non-selective schools: Findings from the National Child Development Study. Volume 2 – Appendices.* National Children's Bureau, London.

Summers, A. A. and B. L. Wolfe (1977). Do schools make a difference? *American Economic Review 67*, 639–652.

Trautwein, U. and O. Köller (2003). The relationship between homework and achievement: Still much of a mystery. *Educational Psychology Review 15*, 115–45.

Zimmer, R. W. and E. F. Toma (2000). Peer effects in private and public schools across countries. *Journal of Policy Analysis and Management 19*, 75–92.