Must try harder. Evaluating the role of effort in educational attainment*

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Abstract

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

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1 Introduction

This paper is based on the very simple idea that 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. They usually proxy students' effort with the amount of homework undertaken (Natriello and McDill (1986)). Empirical research in this area is however far from reaching clear conclusions. This is partly due to ambiguities in the interpretation of homework: it could be seen as an indicator of either students' effort, operating at the individual level, or of 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. Several dimensions of parental effort have 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. 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 attainment also hinders economists. For example, Hanushek (1992) proxies parental effort with measures of family socio-economic status (parents' permanent income and 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] Bonesrønning (1998; 2004) and Cooley (2004) are among the very few authors in the economics literature who measure the effort exerted by students and parents and estimate its effects on examination results.

[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.

Theoretical analyses of the role of effort in the education process are also scarce.[2] Our paper attempts to fill these gaps, 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 them, and the effect of effort on educational attainment.

We test the theoretical model with the British National Child Development Study (NCDS; see CUSSRU (2000) and JCfLR (2003) for detailed descriptions). This dataset is well suited to the study of a structural model of the role of effort on educational achievement, as it contains a large number of variables which can be used as indicators of effort by students, parents, and schools. A student's effort is measured by her attitude, for example whether she thinks that school is a "waste of time", and by the teacher's views about the student's laziness. Other variables give the parents' interest in their children's education, how often 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. 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 negatively the effort exerted by that child's parents towards that child's education.

Our econometric model is a structural, not a reduced form model, and therefore it 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 that

[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 (2005)). 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)).

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]

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. 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 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 educational 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 posit, 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

[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 teenagers for staying on at school beyond the compulsory age (Dearden *et al.* (2003)).

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 educational 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 educational attainment; we capture this by means of a multidimensional variable, s^P.

Parents care about their children's qualification, and so they will exert effort e^P, which 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] if parents have n children, their payoff function is given by:

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

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. Since the marginal cost of effort is increasing, a testable prediction of our model is that, all other things equal, parental effort decreases in the number of children, as proposed in Becker's seminal contribution (1960).[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

[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 avoiding failure may take an opposite view; given this potential ambiguity, it seems a good approximation to take the average attainment as the objective function.

[5] We ignore the potential endogeneity of the number of children. Blake (1989) is a demographic analysis of the relationship between family size and achievement.

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

$$\pi_k\left(e^C, a; e^P, s^P; e^S, s^S\right), \tag{2}$$

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 teaching effort:

$$\sum_{k=1}^{m} q_k \sum_{h=1}^{H} \pi_k\left(e^C(h), a; e^P(h), s^P; e^S(h), s^S\right) \lambda_h - \psi_S\left(e^S\right). \tag{3}$$

(3) 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,

[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 (2006) suggests 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 (3).

or an indirect effect, via the effort level exerted by the participants in the education process. H is the number of all the possible combinations of 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 (2006) 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 there is a single student in a given school. This is obviously unrealistic, but the point here is to illustrate that, even with highly special simplifying assumptions, the interaction between the parties may turn out to be extremely complex (De Fraja and Landeras (2006) study the game-theoretic interaction among the several students in the school, and their analysis has the same insights as our own). We capture this interaction with the game theoretic concept of Nash equilibrium: each party chooses their effort in order to maximise their utility, taking as given the choice of effort of the other parties. To establish existence and to characterise the Nash equilibrium, we impose natural bounds on the effort levels and a constraint on the shape of the function giving the probability of achievement.

Assumption 1 *Let* $E^X = \left[\underline{e}^X, \overline{e}^X\right]$, $X = C, P, S$, *and let the effort functions satisfy* $\lim_{e^X \to \underline{e}^X} \psi'_X\left(e^X\right) = 0$ *and* $\lim_{e^X \to \overline{e}^X} \psi'_X\left(e^X\right) = +\infty$, $X = C, P, S$; *moreover, let the achievement function* π *satisfy* $\frac{\partial^2 \pi_k(\cdot)}{\left(\partial e^X\right)^2} > 0$, *for* $k = 1, ..., m-1$, *and* $X = C, P, S$.

In words, the sets E^C, E^P, and E^S are closed intervals of $\mathbb{R}$, increasing (decreasing) effort is costless (infinitely beneficial) when effort is at its possible minimum (maximum), and, loosely speaking, effort is more effective in reducing the probability of lower qualifications than in increasing the probability of higher ones.

Proposition 1 *Let Assumption 1 hold. A Nash equilibrium exists and is given by the set of values e^C, e^P, and e^S, satisfying the first order conditions*

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

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

$$\sum_{k=1}^{m} q_k \frac{\partial \pi_k\left(e^C, a; e^P, s^P; e^S, s^S\right)}{\partial e^S} - \psi'_S\left(e^S\right) = 0. \tag{6}$$

Proof. Each player has a compact and convex strategy space, and therefore a Nash equilibrium exists (Fudenberg and Tirole 1991, p. 34). Differentiation of the LHS of (4) with respect to e^C, using the fact that $\sum_{k=1}^{m} q_k = 1$, gives: $\sum_{k=1}^{m-1}\left(u\left(q_k\right) - u\left(q_m\right)\right)\frac{\partial^2 \pi_k(\cdot)}{(\partial e^C)^2} - \psi''_C\left(e^C\right)$. Since u is increasing in q, and $\psi''_C\left(e^C\right) > 0$, the child's payoff function is quasi-concave; it is also continuous and therefore the first order condition characterises the best response. Analogously for the parents and the school. ■

The conditions imposed in Assumption 1, as is usually the case in these situations, are sufficent, but not necessary, and could therefore be relaxed at the expense of increased algebraic complexity. In addition, it should be noted that the equilibrium is not necessarily unique. (4)-(6) implicitly define the best reply function[8] of each of the three agents: their intersections in the space $E^C \times E^P \times E^S$ identify the Nash equilibria. This is best illustrated with a graphical analysis in two dimensions only: let the parental effort be fixed, at e^P. Total differentiation of (4) and (6) gives the slope of the best reply function

[8] Mathematically, for the student, 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).

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 student's payoff, and analogously for $U_S''\left(\cdot\right)$. From the above:

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

$$\left.\frac{de^S}{de^C}\right|_{\substack{\text{school} \\ BRF}} = \frac{\sum_{k=1}^{m} q_k \frac{\partial^2 \pi_k(\cdot)}{\partial e^C \partial e^S}}{-U_S''\left(\cdot\right)}. \tag{8}$$

The signs of the best reply functions depend in general on the sign of the cross derivatives $\frac{\partial^2 \pi_k(\cdot)}{\partial e^C \partial e^S}$, that is, on the effect of a small change in school's (child's) effort on the marginal effect of the child's (school's) effort. In plainer words, on whether the children's and the school's efforts are complements or substitutes. In general, there is no compelling theoretical reason to believe that one is more likely than the other, and therefore both (7) and (8) can have either sign at their intersection. Notice moreover that, in the plausible case where $u\left(q\right)$ is not linear, implying that children and schools attribute different importance to relative changes in qualification, they could have opposite signs:[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 (7) and (8) 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 student's 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 student's effort. For example, the dashed lines may represent the best reply functions of the student 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

[9] Vice versa, in this special case of one student per school, while the school's and the student's best reply functions can have different signs at their intersection, the parents' and the school's best reply functions have necessarily the same sign.

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.

[insert figure 1 approximately here]

Consider panel (b), however. It differs from panel (a) only in that the best reply functions meet at a point where the student's best reply function is negatively sloped. Again the dashed lines are the best reply functions associated with higher effort levels, *ceteris paribus*, both for the school and for the student, with shifts of similar magnitude as in panel (a). In the case depicted in panel (b), the different values in the exogenous parameters h are associated to a *lower* equilibrium effort exerted by the student. This is so even though the student's best reply function 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.* (1985)), and the student responds to the higher school's 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 the effects 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 the rest of the paper.

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 ability, socio-economic, demographic and other relevant factors. Formally, the academic achievement is specified as an educational production function (Hanushek (1986)):

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\beta}_1 + \beta_2 e_i^C + \beta_3 e_i^P + \beta_4 e_i^S + u_i, \qquad i = 1, ..., n, \tag{9}$$

where 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, derived in Section 5, $\mathbf{x}_i^Q$ are other control variables affecting the educational outcome, and u_i an error term. However, 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 simultaneously determine each other, and this in turn implies that effort levels are endogenous, which would make inconsistent estimates of the effort level parameters in (9) taken as a separate equation.

To deal with the endogeneity of the effort levels, we estimate the educational attainment equation (9) as part of a system also containing equations which determine the Nash equilibrium effort levels. These are (4)-(6), an empirical counterpart to which is obtained by taking their linear approximation around the Nash equilibrium:

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

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

$$e_i^S = \mathbf{x}_i^{S\prime}\boldsymbol{\gamma}_1^S + \gamma_2^S e_i^C + \gamma_3^S e_i^P + v_i^S, \qquad i = 1, ..., n, \tag{12}$$

where $\mathbf{x}_i^C$, $\mathbf{x}_i^P$ 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.

Our empirical strategy is the estimation of the system of simultaneous equations given by (9)-(12).

To ascertain whether the effort variables are indeed simultaneously determined, we use the Durbin-Wu-Hausman (DWH) augmented regression test suggested by Davidson and MacKinnon (1993). To perform this test, we obtain the residuals from a model of each endogenous right-hand side variable, e_i^C, e_i^P, e_i^S, as a function of all exogenous variables, and including these residuals in a regression of the educational attainment equation, (9). Thus, we first estimate by 3SLS the system

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

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

$$e_i^S = \widetilde{\mathbf{x}}_i^{S\prime}\boldsymbol{\delta}_1^S + \delta_2^S e_i^C + \delta_3^S e_i^P + r_i^S, \tag{15}$$

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 (10)-(12), with the variables which form the vector $\mathbf{x}_i^Q$ in equation (9) (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:

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\eta}_1 + \eta_2 e_i^C + \eta_3 e_i^P + \eta_4 e_i^S + \eta_5 \widehat{r}_i^C + \eta_6 \widehat{r}_i^P + \eta_7 \widehat{r}_i^S + \widetilde{u}_i, \qquad (16)$$

where $\widehat{r}_i^C$, $\widehat{r}_i^P$ and $\widehat{r}_i^S$ are the residuals obtained from the estimates of (13)-(15). According to Davidson and MacKinnon (1993), if the parameters η_5, η_6 and η_7 are significantly different from zero, then estimates of equation (9) 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, in Section 6, we find endogeneity of the effort variables. Therefore the four equations (9)-(12) should be estimated simultaneously. However, the dependent variable in the educational production function Q_i is discrete, and there are no direct methods to jointly estimate the full system (9)-(12). We therefore adapt the method regularly used to estimate systems of two simultaneous equations, one with a continuous dependant variable, the other with a discrete one (Lewis 1986). In our case, we have four equations, so we estimate the educational attainment equation using the *predicted* values $\widehat{e}_i^C$, $\widehat{e}_i^P$ and $\widehat{e}_i^S$ obtained from a 3SLS estimation[10] of equations (10)-(12) instead of the three original effort variables:[11]

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\beta}_1^* + \beta_2^* \widehat{e}_i^C + \beta_3^* \widehat{e}_i^P + \beta_4^* \widehat{e}_i^S + u_i^*, \qquad i = 1, ..., n. \qquad (17)$$

Equation (17) is estimated as an ordered probit, because the educational outcome variable Q_i is a discrete ordered variable, taking eleven possible values. Model specification is based on the general-to-specific procedure (Hendry, 1995). We start from the most general specification of equations (10)-(12) compatible with the order conditions for their identifiability. Our identification strategy relies on theoretical considerations, joint tests for exclusion restrictions, and an appropriate sensitivity analysis performed by including and excluding plausible variables in the three simultaneous equations. In order to improve the efficiency of our estimates, we proceed towards a more specific model, testing jointly for acceptable exclusion restrictions at each step. We then consider equation (17). Its initial general specification includes the predicted values of the three effort variables and all the available exogenous variables. A more parsimonious specification is obtained, again, on the grounds of joint tests

[10] We estimate (10)-(12) with 3SLS, because of the interdependent nature of the effort variables, and the possible dependence of the error terms across equations.

[11] For the sake of comparison, we also present the estimates of the same equation using the original effort variables, see Table 6.

for exclusion restrictions, general goodness of fit, and stability of the estimated parameters.

5 Data and variables

The National Child Development Study (NCDS)[12] follows the cohort of individuals born in Great Britain 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 individuals were 7, 11, and 16. We also use data from the Public Examinations Survey, also a part of the NCDS, which gives the 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

The NCDS dataset contains many variables that capture aspects of the effort levels e_i^C, e_i^P and e_i^S. Described in detail in Table 1, these take the form of categorical variables, which have different scales and are in general non-comparable. We therefore use factor analysis[13] to construct a single[14] aggregate continuous index for each of the three effort levels. To account for the ordinal nature of our original variables, we perform factor analysis from a matrix of polychoric correlations (Kolenikov and Angeles (2004)).[15] Table 1 contains the scoring coefficients for the child's, the parents' and the school's effort indicators (all the results are reported separately for the samples of girls and boys, see

[12] 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).

[13] 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 also 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.

[14] We retain one factor for all three effort indices on the basis of scree tests and the structure of item loadings (Costello and Osborne, 2005).

[15] The STATA routine which estimates polychoric correlations can be downloaded from www.unc.edu/∼skolenik/stata/.

footnote 21 for details). The scoring coefficients are the weights assigned to each effort indicator in the construction of the effort indices. To reduce the loss of information due to non-response, we run an imputation method to obtain factor scores when we have observations with missing data: if some of the variables in Table 1 are missing for an observation, then the effort variable for that observation is replaced by the predicted value from a linear regression with the non-missing variables as explanatory variables. Using this method we have imputed 7%, 13.1% and 6.5% of the child's, the parents' and the school's effort information, respectively.

The 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).[16] This information is complemented by the teacher's assessment of the child's effort when she is 16 (the last row in the top part of Table 1). For the children, the variable with the highest weight is whether the child wishes she could have left school at 15, while that with the lowest weight is the frequency of reading in the child's spare time.

[insert table 1 approximately here]

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 parents read to their children. As mentioned in the Section 2, we use information available in three waves of the NCDS, to capture the long term nature of the beneficial effects of parental and school's effort. From the middle 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 hand, whether the parents provide substantial help for school at age 7 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 bottom 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 her parents, the presence of a parent-teacher association in the school, whether students receive career

[16] 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.

guidance in the school, and so on. We also include the practice of grouping children of similar ability (streaming): we do so on the grounds that this practice has a cost for the school both because of the additional administration and paperwork, and because some teachers may dislike it. Finally, we include information on disciplinary methods used, the idea being that activities such as detention or additional homework require also additional work on the teachers' part. The variables with the greatest weight are some disciplinary methods (special reports, reports to parents, and detention) and the practice of streaming in mathematics at age 16. Figure 2 illustrates the density of the effort variables we have constructed.

[insert figures 2 and 3 approximately here]

5.1.2 Examinations

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 (Steedman (1983a; 1983b)) paying special attention to particular problems such as different timing, grade equivalence, retakes and double entries (see Galindo-Rueda and Vignoles (2003, p. 10) for a exhaustive 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.[17] The educational outcome Q_i in equation (17) is a categorical variable ranging 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 who 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.

[17] We put together, in "Q9", observations of "Two A-levels at 9 or 10 points" and "Three A-levels at 8 points or less", since 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 only 70 observations of the former.

Ability 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)). Just as with the effort measures, the ability scale is arbitrary. We include birth weight in ounces following some of the literature on lifetime attainment (Conley *et al.* (2003); Fryer and Levitt (2004)). It may be argued that ability measured at age 11, and more so at age 16, is a measure of educational achievement, rather than an exogenous individual characteristic, despite the endeavour of the test designers. To address this possible pitfall, we repeat all our estimations measuring ability by the ability score at age 7 only: results change little, see Tables 4 and 6.

[insert table 2 approximately here]

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,[18] and the household socio-economic status is measured by the father's (or the father figure's) social class at age 11. We have also included the percentage of total income not earned by the father figure, whether the household's accommodation is owned by the household, whether any child in the household receives free school meals, and whether the household experiences serious financial hardship. Other variables are parental educational attainment and the frequency of reading *by* 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 several measures of class size, at the three different ages, and their square, to capture possible non-linearities in class size.

An important aspect of a school's quality is the "peer group effect" that is,

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

the characteristics of its students.[19] To capture this, we consider both academic and social indicators: the percentage of boys and girls in the school attended at age 16 who are studying for O-levels, whether pupils from the school attended subsequently enrolled into higher education (both indicate a more "academic" peer group), and the proportion of class-mates whose father has a non-manual occupation.

The final rows of Table 2 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 (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).

Dummies for missing values are used for each of the variables to capture possible non-randomness in non-response.[20]

6 Results

Our theoretical foundation is that the effort of the three groups of 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 (16).[21] We can reject, at conventional significance levels, the null hypothesis that the residuals of the

[19] 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.* (2003) 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.

[20] These are the unlabelled 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 observations in the sample did not report the value of this variable. All estimations include these dummy variables, but we do not report their coefficients to make the reading of the tables easier.

[21] We have also 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 likelihood-ratio test. The test statistic for this test is $\chi^2(96) = 299.13$ (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 explanatory variables would make the interpretation of the coefficients very difficult.

effort equations do not affect examination results,[22] 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 Nash equilibrium solution in the theoretical model. This is further confirmed by the results reported in Table 3 for our 3SLS estimates of equations (10)-(12). Starting from the general model, which includes the child's birth weight (and its dummy for missing values) only in equation (10) and the school size variables only in equation (12), we have arrived at the more specific model of Table 3, by subsequently excluding groups of variables after performing a series of Wald tests to ensure that each exclusion restriction is acceptable: for each group of variables we have tested for their joint significance in a particular equation, both for the sample of girls and for the sample of boys, and stopped when this procedure did not permit us to exclude any other group of variables.[23]

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 and of the school effort on parental effort. 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, at point E_1 in panel (a) in Figure 1).

[insert tables 3 and 4 approximately here]

Table 3 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 but not that

[22] The test statistics of the likelihood-ratio tests of the null hypothesis are $\chi^2(3) = 20.76$ (p-value 0.0001) for the sample of girls, $\chi^2(3) = 19.34$ (p-value 0.0002) for the sample of boys.

[23] Intermediate results and the data to obtain them are available on request. At the end of the general-to-specific process we tested for the joint significance of all the excluded variables (both equation by equation, and in the model as a whole). These further Wald tests confirm the acceptability of our exclusion restrictions. We also tested the specific model for the system of equations (10)-(12) for misspecification. The Hausman test statistics are $\chi^2(92) = 48.98$ (p-value 0.9999) for the sample of girls, and $\chi^2(94) = 52.40$ (p-value 0.9998) for the sample of boys.

exerted by parents. Conversely, schools respond positively to children's effort, but not to parents' effort.

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 children's 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 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 receives (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, but possibly in unexpected ways: the percentage of household income not earned by the father figure has a clear negative influence on parents' effort, and the effect of the mother being in work is negative when the child is 7, positive, for boys only, when the child is 16. Household income and socio-economic status, on the other hand, do affect positively parental effort; measures of deprivation (financial hardship and receiving free school meals) affect it negatively. The peer group of their child appears to affect boys' parents' effort more than it does girls'.

The school's effort is unaffected by the parents' education or income, but peer group is statistically significant: schools work harder which have a larger proportion of children from higher socio-economic groups. It is also higher in larger schools at age 16. Conversely, school effort increases with class size at age 7 and at age 11; at age 16 it increases with class size up to 24-25, though the coefficients are not statistically significant for girls in Maths. The increase in effort with class size may provide an explanation for the "wrong" sign of the relationship between class size and achievement which is often found in studies that use this dataset (Levacic and Vignoles (2002)). With regard to the school type variables, the "single-sex" variable has a negative coefficient.

Private schools exert an effort level not significantly different from state schools (except, at most, for boys at age 16), and secondary modern schools exert less effort than comprehensive schools, in line with the perception of the British educational system at the time. The composition of the peer group, which, from the school's viewpoint is the social background of its pupils, also affects the school's effort. As Table 4 shows, measuring ability using only the test scores at age 7 does not affect the relative size of each of the effort variables in the three effort equations. With these measures, that ability does not have a significant effect on childŠs effort.

Table 5 presents the results for our ordered probit estimates of equation (17). As we expect, effort strongly improves educational attainment, see the first three rows.

Table 6 shows that the effect of effort is robust to different measures of ability and econometric approaches. It compares the uppermost part of Table 5 (on the top-left of Table 6), with the coefficients obtained by replacing the measure of ability used above (obtained from the results of the questionnaire at all the three ages) with the equivalent measure using only the results of the tests administered at age 7 (on the bottom left of Table 6), and using the original effort variables, rather than the predicted values from the 3SLS system (on the righ hand side of Table 6). As Table 6 shows, there is no qualitative difference between the two measures of ability, whereas difference in the coefficients obtained using the original measures of effort indicate the interdependence between the effort levels and the children's qualification, and are a further indication that our econometric approach is warranted.

[insert tables 5 and 6 approximately here]

Table 7 quantifies these findings in more detail reporting the marginal effects of changes in effort on examination outcomes derived from the ordered probit estimation. The values in each column are the marginal changes in the probability of the eleven possible outcomes due to 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 parents' effort is the most effective in affecting educational outcomes.

[insert table 7 and figure 4 approximately here]

Table 7 is presented graphically in Figure 4. An increase in effort pushes the mean ability children into the group of individuals who have at least one

to four O-levels. 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 children's educational attainment.

Table 5 shows that children's ability and family composition also have, again as one would expect, a strong independent positive effect on their examination results. Family background variables, such as social class, the parents' education, and their taste for reading 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)). Similarly for income variables, which are not statistically significant in the equation. These results have, in our view, a natural interpretation: family background influences school achievement indirectly, via parental effort, rather than directly. Other variables, such as ability, influence achievement both directly and indirectly via effort: given two children who exert the same effort, the abler obtains a higher school qualification. We can present this formally within the theoretical model developed in Section 2, where (2) gives the probability $\pi_k(\cdot)$ of a child obtaining qualification k. At the Nash equilibrium, e^C, e^P and e^S are themselves functions of the control variables, and we can write the probability of a child obtaining qualification k as $\pi_k\left(e^C(\cdot), a; e^P(\cdot), s^P; e^S(\cdot), s^S\right)$, where the $(\cdot)$ includes all the variables in corresponding column in Table 2. A change in one of these variables, say x, causes a change in $\pi_k(\cdot)$ given by[24]

$$\frac{d\pi_k(\cdot)}{dx} = \frac{\partial \pi_k(\cdot)}{\partial e^C}\frac{\partial e^C(\cdot)}{\partial x} + \frac{\partial \pi_k(\cdot)}{\partial e^P}\frac{\partial e^P(\cdot)}{\partial x} + \frac{\partial \pi_k(\cdot)}{\partial e^S}\frac{\partial e^S(\cdot)}{\partial x} + \frac{\partial \pi_k(\cdot)}{\partial x}. \quad (18)$$

The reduced form measure of the probability of qualification k, say $\widetilde{\pi}_k(\cdot)$, is a function of the control variables only: $\widetilde{\pi}_k(\cdot) = \pi_k\left(e^C(\cdot), a; e^P(\cdot), s^P; e^S(\cdot), s^S\right)$ Table 8 decomposes the total effect according to (18) for two of the control variables, ability and the dummy for whether the father reads books regularly. The same technique can of course be used to calculate the corresponding effects for any of the control variables. These two variables differ qualitatively: ability affects positively both exam results (that is it increases the likelihood of high qualifications and reduces the likelihood of low qualifications) and effort, whereas whether the father reads books regularly appears to reduce the direct positive effect on qualification (see the third, fifth and seventh column in the

[24] Note the symbol d on the LHS, denoting the total effect of a change dx in variable x, and the symbol ∂ on the last term on the RHS, denoting the direct effect of a change in x only, that is the effects that a change in x would have on the probability π_k keeping the values of the effort constant.

table, and the ninth). The total effect (the tenth column) is positive for both these variables. It is instructive to compare the total effect obtained with this decomposition with the effect which is obtained from a standard reduced form oprobit estimation, the equivalent of (17) without the effort variables:

$$Q_i = \mathbf{x}_i^{Q\prime}\boldsymbol{\beta} + u_i, \qquad i = 1, ..., n. \tag{19}$$

Column [2] reports the marginal effects estimated from the β coefficients in (19) denoted as the partial derivatives of the reduced form probabilities $\widetilde{\pi}_k(\cdot)$. The last column reports the ratio between the coefficients estimated from the reduced form (column [2]) and the total effect from the structural system (column [10]). Loosely speaking (as we are not calculating confidence intervals) a coefficient near 1 indicates that the two procedures give similar results; note also that at the extremes of the distribution of the qualification the gap between the two procedures widens, indicating, again loosely, the lower accuracy of the estimation at the extremes due to lower number of observations.

[insert table 8 approximately here]

To conclude the discussion of Table 5, of the "school" variables, being in a private school at age 16 affects positively the results for boys, but not for girls, and both a grammar school and a secondary modern affect positively boys' results. The academic peer group effect appears very strong: interestingly, it operates within genders, girls are influenced only by girls, and boys only by boys. This makes perfect sense, and we take it as a further indication that our model specification is plausible. Of the census variables listed in Table 2, we include in Table 5 only those that are statistically significant: the percentage of unemployed or sick in the census enumeration district for girls, and the proportion of owner occupied houses, the proportion of council tenants, and the average number of persons per room for boys. These variables have a negative effect on examination results. With regard to regional dummies, the reference group is London, which appears to have a direct negative effect on results.

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 parents' effort is more important than the school's and the children's effort is not necessarily intuitive, though it can be rationalised ex-post. 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, understanding which fundamental factors affect the behaviour of the agents at the heart of the educational 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.

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Table 1: Factor analysis for effort measures

Child's effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
School is not a waste of time	1-5	4.3012	0.0928	4.1513	0.0955
I get on with classwork	1-5	3.4051	0.0565	3.2500	0.0607
Homework is not boring	1-5	2.6703	0.0810	2.4712	0.0866
It is not difficult to keep my mind on work	1-5	3.3017	0.0780	3.2406	0.0748
I take work seriously	1-5	4.1110	0.1215	4.0319	0.1118
I like school	1-5	3.4974	0.1155	3.3705	0.1273
There is a point in planning for the future	1-5	4.0111	0.0286	4.0911	0.0261
I am always ready to help my teacher	1-5	3.6489	0.0351	3.3033	0.0301
I often read in my spare time	1-4	3.0814	0.0205	2.8330	0.0260
Age I am likely to leave school	1-4	1.9331	0.0990	1.9019	0.1081
I wish I could have left school at 15	1-3	2.4167	0.2091	2.2849	0.1894
Teacher thinks child is lazy or hardworking	1-5	3.4141	0.0624	3.0669	0.0637
Parents' effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
Mother's interest in child's education at age 7	1-5	3.9961	0.0869	3.9084	0.0827
Father's interest in child's education at age 7	1-5	2.9653	0.0432	3.0107	0.0521
Mother reads to child at age 7	1-4	3.3173	0.0319	3.3036	0.0325
Father reads to child at age 7	1-4	3.0037	0.0437	2.9855	0.0503
Father's role in management of child at age 7	1-4	3.3706	0.0221	3.4238	0.0251
Parents' initiative to discuss child with teacher at age 7	1-2	1.5618	0.0413	1.5675	0.0446
Substantial help from parents for school at age 7	1-2	1.5221	0.0091	1.5218	0.0117
Mother's interest in child's education at age 11	1-5	3.8553	0.0867	3.7575	0.0673
Father's interest in child's education at age 11	1-5	3.2903	0.0811	3.3346	0.0807
Father's role in management of child at age 11	1-4	3.3715	0.0162	3.4558	0.0176
Parents' initiative to discuss child with teacher at age 11	1-4	2.0493	0.0598	2.1055	0.0595
Parental hopes about child's school leaving age at age 11	1-3	2.6965	0.0697	2.7152	0.0982
Parents want further education for child at age 11	1-3	2.7718	0.0570	2.8222	0.0476
Mother's interest in child's education at age 16	1-5	3.7779	0.1267	3.6504	0.1017
Father's interest in child's education at age 16	1-5	3.5026	0.1060	3.4932	0.1093
Parents and teacher discuss child at age 16	1-4	2.0653	0.0404	2.1613	0.0460
Parents' anxiety over child's school achievement at age 16	1-5	3.3967	0.0196	3.6154	0.0220
Parents wish child goes to higher education at age 16	1-2	1.3278	0.0584	1.3323	0.0511
School's effort		Girls		Boys	
Variable	Range	Mean	Scoring Coefficient	Mean	Scoring Coefficient
Parent-teacher association in school at age 7	1-2	1.1670	0.0542	1.1667	0.0229
Parent-teacher educational meetings arranged at age 7	1-2	1.5997	0.0501	1.5918	0.0347
Social functions arranged for parents at age 7	1-2	1.5029	0.0179	1.5013	0.0106
Teachers' initiative to discuss child at age 7	1-2	1.2314	0.0145	1.2658	0.0146
Teachers' initiative to discuss child at age 11	1-2	1.4291	0.0103	1.4293	0.0110
Parent-teacher association in school at age 16	1-2	1.6295	0.0670	1.6456	0.0797
Parent-teacher meetings, discussion at age 16	1-4	3.0225	0.0273	3.0151	0.0474
Parents are shown teaching methods at age 16	1-4	1.5598	0.0527	1.5794	0.0557
Paid career guidance given by teachers at age 16	1-2	1.7349	0.0346	1.7495	0.0398
English class streamed at age 16	1-2	1.7270	0.0624	1.7425	0.0359
Mathematics class streamed at age 16	1-2	1.8672	0.1468	1.8532	0.2108
Disciplinary methods - suspension at age 16	1-3	1.9414	0.0534	1.9979	0.0493
Disciplinary methods - physical/manual activities at age 16	1-3	1.3619	0.0467	1.4755	0.0326
Disciplinary methods - extra school work at age 16	1-3	2.6245	0.0543	2.6986	0.0340
Disciplinary methods - detention at age 16	1-3	2.4252	0.0746	2.4601	0.1030
Disciplinary methods - report to parents at age 16	1-3	2.9216	0.0960	2.9087	0.1022
Disciplinary methods - special reports at age 16	1-3	2.6270	0.1374	2.6890	0.1158

Table 2 - Descriptive statistics

Variable	Girls		Boys		Child's effort equation	Parents' effort equation	School's effort equation	Exam result equation
	Mean	Std. Dev.	Mean	Std. Dev.				
Exam result	3.716	2.771	3.542	2.918	-	-	-	-
Child's effort	-0.018	0.855	-0.018	0.859	-	*	*	*
Parents' effort	0.010	0.791	0.006	0.793	*	-	*	*
School's effort	-0.001	0.764	0.001	0.775	*	*	-	*
Ability measured at 7, 11 and 16	-0.132	2.243	-0.147	2.259	*	*		*
‡	0.006		0.006		*	*		*
Ability measured at 7	0.000	1.148	0.000	1.158				
‡	0.119		0.126					
Weight at birth (ounces)	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		*	*		*
Unclassifiable§§	0.002		0.005		*	*		*
‡	0.178		0.185		*	*		*
House owner	0.403		0.394		*	*	*	*
‡	0.202		0.213		*	*	*	*
Total household income (£ per week)	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	*	*	*	*
Free school meals in school age 11	0.085		0.080		*	*	*	*
‡	0.163		0.170		*	*	*	*
Financial hardship at 11	0.110		0.103		*	*	*	*
‡	0.161		0.165		*	*	*	*
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 3 - Three-stage least squares estimates of effort equations

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	0.291	0.159	0.291	0.246	0.086	0.084	-0.062	0.087	-4.666 **	0.254	-5.057 **	0.234
Child's effort					0.319 **	0.068	0.307 **	0.066	0.184 *	0.092	0.168 *	0.071
Parents' effort	0.882 **	0.169	0.740 **	0.138					0.027	0.093	0.067	0.083
School's effort	-0.162 **	0.038	-0.124 **	0.035	-0.046	0.032	-0.042	0.027				
Ability	0.043 *	0.021	0.067 **	0.016	0.072 **	0.012	0.067 **	0.012				
Weight at birth (ounces)	-0.001 *	0.000	-0.002 **	0.000								
Older brothers	0.008	0.017	0.005	0.014	-0.042 **	0.011	-0.036 **	0.010				
Younger brothers	-0.002	0.015	0.007	0.013	-0.030 **	0.011	-0.010	0.010				
Older sisters	0.024	0.019	0.001	0.016	-0.066 **	0.011	-0.051 **	0.011				
Younger sisters	0.029	0.016	0.028	0.015	-0.045 **	0.011	-0.040 **	0.011				
Mother in work age 16	-0.025	0.028	-0.011	0.027	0.031	0.021	0.056 **	0.021				
Mother in work age 7	0.013	0.026	0.023	0.024	-0.047 *	0.019	-0.046 *	0.019				
Houseowner	0.001	0.036	-0.052	0.033	0.102 **	0.023	0.127 **	0.021	0.036	0.025	0.001	0.025
Total household income (£ per week)	0.000	0.001	-0.002 **	0.001	0.000	0.001	0.002 **	0.001	0.001	0.001	0.001	0.001
% of income not from father	0.038	0.046	0.032	0.044	-0.079 *	0.033	-0.111 **	0.033	0.116 **	0.035	-0.009	0.034
Free school meals in school age 11	0.045	0.045	0.047	0.047	-0.078 *	0.033	-0.143 **	0.033	-0.041	0.037	-0.045	0.037
Financial hardship at 11	0.080	0.041	0.019	0.036	-0.108 **	0.029	-0.066 *	0.028	-0.026	0.034	0.036	0.031
Father has higher education	-0.064	0.049	0.108 *	0.045	0.056	0.037	-0.001	0.037	-0.042	0.041	-0.051	0.039
Father has secondary education	0.000	0.029	-0.015	0.028	0.008	0.022	0.022	0.022	-0.052 *	0.025	0.018	0.024
Mother has higher education	-0.044	0.061	-0.125 *	0.058	0.133 **	0.043	0.128 **	0.044	0.004	0.047	-0.016	0.049
Mother has secondary education	-0.054	0.030	-0.027	0.026	0.070 **	0.021	0.016	0.021	0.038	0.024	-0.037	0.022
Father reads books regularly	-0.110 *	0.045	-0.049	0.038	0.185 **	0.023	0.160 **	0.023	0.006	0.029	-0.065 *	0.027
Father reads books occasionally	-0.079	0.041	-0.036	0.034	0.134 **	0.026	0.077 **	0.026	0.048	0.030	-0.040	0.028
Mother reads books regularly	-0.060	0.033	-0.077 *	0.033	0.094 **	0.022	0.135 **	0.022	-0.041	0.025	0.014	0.026
Mother reads books occasionally	-0.027	0.032	-0.045	0.032	0.055 *	0.023	0.091 **	0.023	-0.043	0.026	-0.028	0.026
Intermediate§§	-0.029	0.056	0.003	0.051	-0.040	0.042	-0.018	0.041				
Skilled non-manual§§	0.006	0.066	-0.020	0.058	-0.108 *	0.048	-0.063	0.046				
Skilled manual§§	0.088	0.075	0.020	0.063	-0.251 **	0.044	-0.221 **	0.043				
Semiskilled non-manual§§	0.027	0.098	0.065	0.096	-0.170 *	0.071	-0.228 **	0.072				
Semiskilled manual§§	0.056	0.074	-0.006	0.067	-0.210 **	0.048	-0.212 **	0.048				
Unskilled§§	0.115	0.097	-0.005	0.083	-0.324 **	0.059	-0.295 **	0.057				
English class size age 16	0.011	0.009	0.004	0.009					0.052 **	0.010	0.053 **	0.009
(English class size age 16)^2	0.000	0.000	0.000	0.000					-0.001 **	0.000	-0.001 **	0.000
Maths class size age 16	0.004	0.008	-0.006	0.009					0.006	0.009	0.029 **	0.009
(Maths class size age 16)^2	0.000	0.000	0.000	0.000					0.000	0.000	-0.001 **	0.000
No. children in child's present class age 7	0.006	0.007	0.004	0.006					0.004	0.008	0.017 *	0.007
(No. children in child's present class age 7)^2	0.000	0.000	0.000	0.000					0.000	0.000	0.000 *	0.000
No. children in child's present class age 11	-0.007	0.007	-0.003	0.005					0.013	0.007	0.014 **	0.005
(No. children in child's present class age 11)^2	0.000	0.000	0.000	0.000					0.000	0.000	0.000 *	0.000
Log of school size age 16									0.554 **	0.021	0.529 **	0.019
Log of school size age 11									-0.022	0.023	0.031	0.022
Log of school size age 7									0.041 *	0.021	0.005	0.020
Single sex school age 16	-0.101	0.062	-0.020	0.051	0.062	0.048	-0.015	0.041	-0.178 **	0.053	-0.095 *	0.044
Grammar school age 16	-0.090 *	0.043	0.048	0.043	0.040	0.033	-0.032	0.035	0.010	0.037	0.041	0.038
Secondary modern age 16	-0.020	0.036	-0.059	0.032	-0.065 *	0.026	-0.029	0.025	-0.068 *	0.026	-0.055 *	0.025
Private school age 16	-0.073	0.078	0.078	0.070	0.113 *	0.057	0.035	0.056	0.038	0.065	0.142 *	0.061
Private school age 11	-0.022	0.076	-0.102	0.071	-0.051	0.058	0.123 *	0.054	-0.097	0.065	0.115	0.061
Private school age 7	-0.037	0.074	0.027	0.073	0.035	0.056	-0.034	0.057	0.051	0.065	-0.120	0.064
Pupils from school go to university	0.017	0.031	0.006	0.029	0.042	0.023	-0.003	0.023	0.071 **	0.025	0.099 **	0.025
% of girls studying for O-levels	-0.002 **	0.001	0.000	0.001	0.001	0.001	0.000	0.001	-0.005 **	0.001	-0.001 *	0.001
% of boys studying for O-levels	0.001 *	0.001	-0.001 *	0.001	-0.001	0.001	0.001 *	0.000	0.002 **	0.001	-0.003 **	0.000
10%-19%§	-0.017	0.044	-0.091 *	0.040	0.031	0.034	0.067 *	0.033	0.131 **	0.038	0.124 **	0.036
20%-29%§	-0.095 *	0.046	-0.109 **	0.042	0.092 **	0.034	0.090 **	0.033	0.126 **	0.039	0.209 **	0.037
30%-39%§	-0.051	0.049	-0.189 **	0.044	0.050	0.037	0.115 **	0.036	0.114 **	0.042	0.149 **	0.040
40%-49%§	-0.002	0.055	-0.202 **	0.050	0.029	0.043	0.116 **	0.041	0.189 **	0.047	0.227 **	0.045
50%-59%§	-0.040	0.055	-0.141 **	0.053	0.027	0.042	0.091 *	0.043	0.186 **	0.047	0.321 **	0.046
60%-69%§	-0.114	0.059	-0.198 **	0.057	0.104 *	0.045	0.154 **	0.044	0.242 **	0.051	0.225 **	0.050
70%-79%§	-0.042	0.075	-0.171 *	0.071	0.066	0.058	0.225 **	0.052	0.268 **	0.064	0.220 **	0.059
80%-100%§	-0.062	0.065	-0.083	0.068	0.018	0.050	0.128 *	0.053	0.150 **	0.055	0.280 **	0.057
% of new Commonwealth immigrants †	0.004 *	0.002	0.007 **	0.002					-0.001	0.002	-0.001	0.002
Northwest age 11					0.010	0.027	-0.032	0.028	-0.087 *	0.038	-0.068	0.037
North age 11					-0.081 *	0.035	-0.097 **	0.035	-0.364 **	0.048	-0.315 **	0.044
East-west Riding age 11					-0.048	0.031	-0.078 *	0.030	-0.160 **	0.043	-0.103 **	0.040
North Midlands age 11					-0.055	0.031	-0.057	0.032	-0.179 **	0.043	-0.207 **	0.041
South age 11					0.005	0.032	-0.025	0.033	0.137 **	0.045	0.000	0.043
Midlands age 11					-0.040	0.029	-0.079 *	0.031	-0.131 **	0.041	-0.103 **	0.038
Wales age 11					-0.085 *	0.037	-0.096 **	0.037	-0.425 **	0.051	-0.379 **	0.045
Scotland age 11					-0.169 **	0.041	-0.267 **	0.045	-0.525 **	0.050	-0.487 **	0.048
Number of observations	5611		5860		5611		5860		5611		5860	
R^2	0.1346		0.2292		0.4615		0.4489		0.2887		0.3309	
chi^2	2089.26**		2489.2**		4781.51**		4690.17**		2578.45**		3170.25**	

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% level. Other variables included in the model and not reported are: father's socio-economic status unclassifiable, wether mother was married at birth, % of comprehensive schools in LEA other census variables and regional dummies. † Enumeration district-level variables from 1971 Census Small Area Statistics

Table 4 - Three-stage least squares estimates of effort equations with age 7 ability only

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	-0.345	0.230	-0.104	0.226	0.038	0.086	-0.113	0.088	-4.661 **	0.253	-5.016 **	0.232
Child's effort					0.429 **	0.053	0.444 **	0.049	0.146	0.130	0.103	0.088
Parents' effort	0.977 **	0.157	0.809 **	0.129					0.047	0.101	0.145	0.078
School's effort	-0.158 **	0.038	-0.127 **	0.034	0.002	0.030	-0.005	0.026				
Ability	-0.010	0.025	0.007	0.020	0.085 **	0.012	0.085 **	0.012				
Number of observations	5611		5860		5611		5860		5611		5860	
R^2	0.0729		0.1831		0.4213		0.4073		0.3000		0.3408	
chi^2	1657.1**		1946.01**		4105.10**		4052.79**		2597.87**		3187.54**	

Table 5 - Ordered probit estimates of exam results equation

	Girls		Boys	
Variable	Coef.	Std. Err.	Coef.	Std. Err.
Child's effort	0.210 **	0.028	0.186 **	0.033
Parents' effort	1.650 **	0.077	1.972 **	0.077
School's effort	0.311 **	0.069	0.375 **	0.061
Ability	0.295 **	0.013	0.247 **	0.012
Older brothers	0.089 **	0.021	0.052 *	0.020
Younger brothers	0.094 **	0.020	-0.026	0.019
Older sisters	0.078 **	0.021	0.058 **	0.021
Younger sisters	0.033	0.021	0.067 **	0.022
Mother in work age 16	-0.063	0.038	-0.132 **	0.038
Mother in work age 7	0.054	0.036	0.056	0.036
Houseowner	-0.066	0.041	-0.202 **	0.039
Total household income (£ per week)	0.000	0.001	-0.001	0.001
% of income not from father	0.176 **	0.063	0.081	0.062
Free school meals in school age 11	-0.049	0.064	0.170 *	0.067
Financial hardship at 11	0.086	0.056	0.134 *	0.056
Father has higher education	0.034	0.070	0.147 *	0.064
Father has secondary education	-0.004	0.040	-0.036	0.040
Mother has higher education	0.091	0.080	-0.155	0.083
Mother has secondary education	-0.136 **	0.038	-0.006	0.038
Father reads books regularly	-0.266 **	0.044	-0.258 **	0.043
Father reads books occasionally	-0.230 **	0.047	-0.065	0.049
Mother reads books regularly	-0.082 *	0.041	-0.246 **	0.040
Mother reads books occasionally	-0.070	0.044	-0.191 **	0.043
Intermediate[§§]	-0.113	0.077	-0.232 **	0.074
Skilled non-manual[§§]	-0.086	0.087	-0.134	0.081
Skilled manual[§§]	0.101	0.080	0.145	0.076
Semiskilled non-manual[§§]	-0.045	0.135	-0.011	0.142
Semiskilled manual[§§]	-0.015	0.088	0.020	0.085
Unskilled[§§]	0.044	0.113	0.207 *	0.106
English class size age 16	0.027	0.019	-0.009	0.018
(English class size age 16)^2	0.000	0.000	0.000	0.000
Maths class size age 16	-0.001	0.016	-0.001	0.017
(Maths class size age 16)^2	0.000	0.000	0.000	0.000
No. children in child's present class age 7	-0.011	0.014	-0.019	0.011
(No. children in child's present class age 7)^2	0.000	0.000	0.000	0.000
No. children in child's present class age 11	0.003	0.011	-0.009	0.009
(No. children in child's present class age 11)^2	0.000	0.000	0.000	0.000
Single sex school age 16	0.042	0.098	-0.006	0.075
Grammar school age 16	-0.024	0.061	0.151 *	0.062
Secondary modern age 16	0.038	0.046	0.106 *	0.046
Private school age 16	-0.176	0.115	0.363 **	0.104
Private school age 11	0.121	0.107	-0.273 *	0.106
Private school age 7	-0.268 *	0.117	-0.035	0.103
Pupils from school go to university	-0.049	0.044	0.089 *	0.043
% of girls studying for O-levels	0.003 **	0.001	-0.001	0.001
% of boys studying for O-levels	0.001	0.001	0.003 **	0.001
10%-19%[§]	0.068	0.067	-0.078	0.065
20%-29%[§]	-0.037	0.066	-0.103	0.065
30%-39%[§]	0.020	0.073	-0.113	0.068
40%-49%[§]	0.104	0.080	-0.103	0.075
50%-59%[§]	0.135	0.080	-0.121	0.082
60%-69%[§]	-0.043	0.086	-0.108	0.083

70%-79%§	0.150	0.107	-0.276 **	0.096
80%-100%§	0.407 **	0.093	0.111	0.100
% of unemployed or sick†	-0.008 **	0.003	-0.003	0.003
% of owner occupied households†	-0.002	0.001	-0.004 **	0.001
% of council tenants†	-0.001	0.001	-0.002 *	0.001
Average no. persons per room†	-0.200	0.195	-0.485 **	0.184
North West age 11	0.038	0.060	0.153 *	0.064
North age 11	0.314 **	0.078	0.480 **	0.077
East and West Riding age 11	0.260 **	0.068	0.362 **	0.063
North Midlands age 11	0.204 **	0.068	0.275 **	0.064
Eastern age 11	0.158 *	0.064	0.208 **	0.061
South West age 11	0.102	0.064	0.221 **	0.068
Midlands age 11	0.337 **	0.062	0.271 **	0.063
Wales age 11	0.280 **	0.087	0.151	0.080
Scotland age 11	0.528 **	0.092	0.820 **	0.093
% of comprehensive schools in LEA	-0.040	0.072	-0.134	0.071
μ_1 : boundary between Q0 and Q1	-1.564	0.453	-2.592	0.432
μ_2 : boundary between Q1 and Q2	-1.049	0.453	-2.061	0.432
μ_3 : boundary between Q2 and Q3	-0.513	0.454	-1.609	0.432
μ_4 : boundary between Q3 and Q4	0.137	0.454	-0.878	0.432
μ_5 : boundary between Q4 and Q5	1.594	0.453	0.424	0.433
μ_6 : boundary between Q5 and Q6	2.000	0.454	0.720	0.433
μ_7 : boundary between Q6 and Q7	2.346	0.454	1.025	0.434
μ_8 : boundary between Q7 and Q8	2.625	0.454	1.289	0.434
μ_9 : boundary between Q8 and Q9	3.065	0.454	1.703	0.435
μ_{10} : boundary between Q9 and Q10	3.655	0.454	2.269	0.437
Number of observations	5611		5860	
Pseudo R^2	0.2742		0.2737	
Wald $chi^2(90)$	4267.98**		4354.62**	
Log-Likelihood	-8866.7941		-9235.0072	

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% level. † Enumeration district-level variables from 1971 Census Small Area Statistics. Other variables included in the model and not reported are: father's socio-economic status unclassifiable, wether mother was married at birth, other census variables, and other regional dummies.

Table 6

Ordered probit estimates of exam results equation with ability 7-16

	Using predicted effort variables				Using original effort variables			
	Girls		Boys		Girls		Boys	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Child's effort	0.210 **	0.028	0.186 **	0.033	0.599 **	0.022	0.688 **	0.022
Parents' effort	1.650 **	0.077	1.972 **	0.077	0.223 **	0.025	0.184 **	0.025
School's effort	0.311 **	0.069	0.375 **	0.061	0.073 **	0.022	0.118 **	0.023
Ability	0.295 **	0.013	0.247 **	0.012	0.415 **	0.011	0.383 **	0.011

Ordered probit estimates of exam results equation with ability 7 only

	Using predicted effort variables				Using original effort variables			
	Girls		Boys		Girls		Boys	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Child's effort	0.321 **	0.025	0.273 **	0.031	0.674 **	0.021	0.770 **	0.022
Parents' effort	1.494 **	0.054	1.665 **	0.051	0.350 **	0.025	0.287 **	0.024
School's effort	0.257 **	0.070	0.327 **	0.063	0.111 **	0.022	0.145 **	0.023
Ability	0.238 **	0.019	0.223 **	0.019	0.358 **	0.019	0.357 **	0.019

Table 7 - Marginal effects

	Girls			Boys		
	Child's effort	Parents' effort	School's effort	Child's effort	Parents' effort	School's effort
Q0	-0.013	-0.099	-0.019	-0.018	-0.192	-0.037
Q1	-0.017	-0.137	-0.026	-0.020	-0.215	-0.041
Q2	-0.026	-0.205	-0.039	-0.020	-0.211	-0.040
Q3	-0.025	-0.198	-0.037	-0.016	-0.169	-0.032
Q4	0.041	0.323	0.061	0.044	0.464	0.088
Q5	0.017	0.138	0.026	0.011	0.115	0.022
Q6	0.010	0.082	0.015	0.008	0.087	0.017
Q7	0.005	0.042	0.008	0.005	0.051	0.010
Q8	0.004	0.035	0.007	0.004	0.044	0.008
Q9	0.002	0.015	0.003	0.002	0.021	0.004
Q10	0.000	0.003	0.001	0.000	0.005	0.001

Table 8 - Decomposition of Marginal Effects

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Q	$\frac{d\tilde{\pi}_k(\cdot)}{dx}$	$\frac{\partial \pi_k(\cdot)}{\partial e^C}$	$\frac{\partial e^C(\cdot)}{\partial x}$	$\frac{\partial \pi_k(\cdot)}{\partial e^P}$	$\frac{\partial e^P(\cdot)}{\partial x}$	$\frac{\partial \pi_k(\cdot)}{\partial e^S}$	$\frac{\partial e^S(\cdot)}{\partial x}$	$\frac{\partial \pi_k(\cdot)}{\partial x}$	$\frac{d\pi_k(\cdot)}{dx}$	$\frac{\frac{d\tilde{\pi}_k(\cdot)}{dx}}{\frac{d\tilde{\pi}_k(\cdot)}{dx}}$
Ability - Girls										
Q0	-0.042	-0.013		-0.099		-0.019		-0.018	-0.025	1.644
Q1	-0.044	-0.017		-0.137		-0.026		-0.025	-0.025	1.240
Q2	-0.054	-0.026		-0.205		-0.039		-0.037	-0.037	1.028
Q3	-0.047	-0.025		-0.198		-0.037		-0.035	-0.035	0.921
Q4	0.081	0.041		0.323		0.061		0.058	0.058	0.977
Q5	0.039	0.017	0.043	0.138	0.072	0.026	0.000	0.025	0.025	1.098
Q6	0.026	0.010		0.082		0.015		0.015	0.015	1.244
Q7	0.015	0.005		0.042		0.008		0.008	0.008	1.410
Q8	0.015	0.004		0.035		0.007		0.006	0.006	1.638
Q9	0.008	0.002		0.015		0.003		0.003	0.003	2.049
Q10	0.002	0.000		0.003		0.001		0.001	0.001	2.832
Father reads books regularly - Girls										
Q0	-0.007	-0.013		-0.099		-0.019		0.017	0.000	22.878
Q1	-0.008	-0.017		-0.137		-0.026		0.023	-0.001	7.438
Q2	-0.010	-0.026		-0.205		-0.039		0.033	-0.002	4.369
Q3	-0.008	-0.025		-0.198		-0.037		0.031	-0.003	2.686
Q4	0.014	0.041		0.323		0.061		-0.053	0.002	6.539
Q5	0.007	0.017	-0.110	0.138	0.185	0.026	0.006	-0.022	0.002	3.757
Q6	0.005	0.010		0.082		0.015		-0.013	0.001	3.963
Q7	0.003	0.005		0.042		0.008		-0.007	0.001	4.309
Q8	0.003	0.004		0.035		0.007		-0.006	0.001	4.856
Q9	0.001	0.002		0.015		0.003		-0.002	0.000	5.918
Q10	0.000	0.000		0.003		0.001		0.000	0.000	8.123
Ability - Boys										
Q0	-0.061	-0.018		-0.192		-0.037		-0.024	-0.038	1.598
Q1	-0.049	-0.020		-0.215		-0.041		-0.027	-0.027	1.145
Q2	-0.040	-0.020		-0.211		-0.040		-0.026	-0.026	0.964
Q3	-0.029	-0.016		-0.169		-0.032		-0.021	-0.021	0.851
Q4	0.088	0.044		0.464		0.088		0.058	0.058	0.956
Q5	0.026	0.011	0.067	0.115	0.067	0.022	0.000	0.014	0.014	1.122
Q6	0.022	0.008		0.087		0.017		0.011	0.011	1.279
Q7	0.015	0.005		0.051		0.010		0.006	0.006	1.476
Q8	0.015	0.004		0.044		0.008		0.005	0.005	1.767
Q9	0.009	0.002		0.021		0.004		0.003	0.003	2.288
Q10	0.003	0.000		0.005		0.001		0.001	0.001	3.248
Father reads books regularly - Boys										
Q0	-0.014	-0.018		-0.192		-0.037		0.026	-0.001	11.103
Q1	-0.011	-0.020		-0.215		-0.041		0.028	-0.002	5.085
Q2	-0.009	-0.020		-0.211		-0.040		0.027	-0.003	3.427
Q3	-0.007	-0.016		-0.169		-0.032		0.021	-0.003	2.027
Q4	0.020	0.044		0.464		0.088		-0.061	0.005	4.239
Q5	0.006	0.011	-0.049	0.115	0.160	0.022	-0.065	-0.015	0.002	3.685
Q6	0.005	0.008		0.087		0.017		-0.011	0.001	4.016
Q7	0.003	0.005		0.051		0.010		-0.006	0.001	4.484
Q8	0.004	0.004		0.044		0.008		-0.006	0.001	5.227
Q9	0.002	0.002		0.021		0.004		-0.003	0.000	6.601
Q10	0.001	0.000		0.005		0.001		-0.001	0.000	9.244

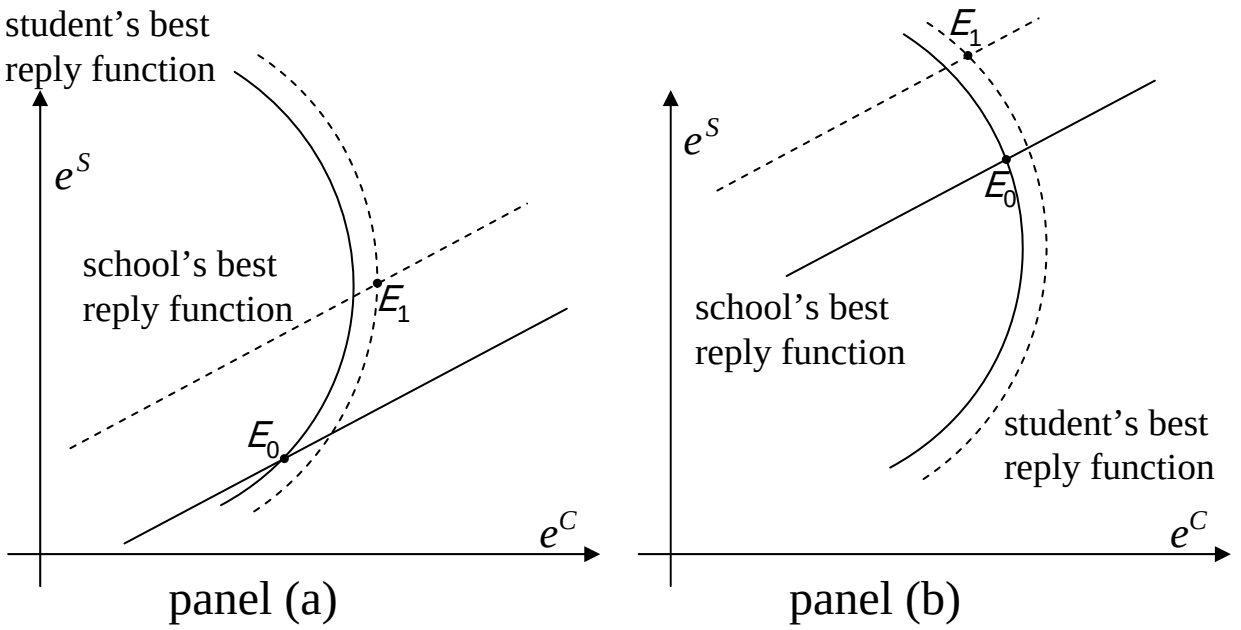


Figure 1: Best reply functions of the representative student and of the school.

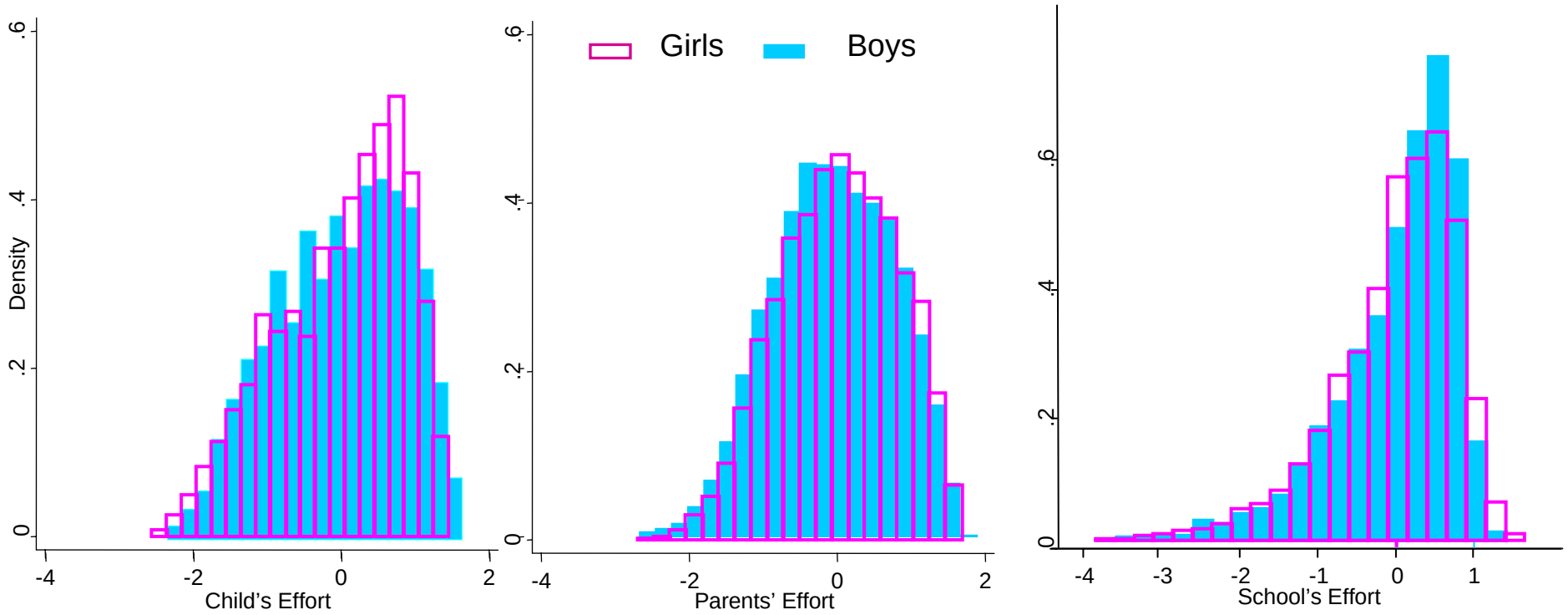
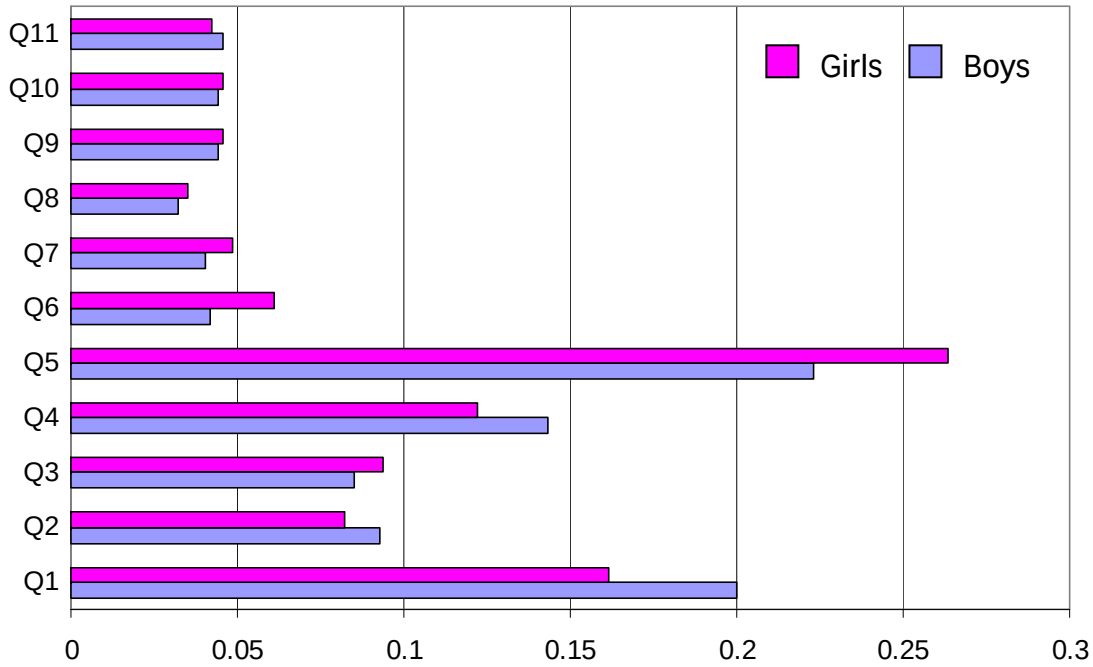


Figure 2: Density of effort for child, parents, and schools.



Q11	Three or more A-levels at 9 or 10 points, or three or more Scottish Highers at 9 or more points
Q10	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
Q9	Two A-levels or Scottish Highers at 8 points or less
Q8	One A-level or Scottish Higher
Q7	Seven or more GCE O-levels or CSE at grade 1, or seven or more Scottish O-levels
Q6	Five or six GCE O-levels or CSE at grade 1, or five or six Scottish O-levels at A-C grade
Q5	One to four GCE O-levels or CSE at grade 1, or one to four Scottish O-levels at A-C grade
Q4	Five or more CSE at grade 2-5, or five or six or more Scottish O-levels
Q3	One or more CSE at grade 2-3, or three or four Scottish O-levels
Q2	One or more O-levels or CSE at grade 4-5, or one or two Scottish O-levels
Q1	No formal qualification

Figure 3: Frequency of examination qualifications

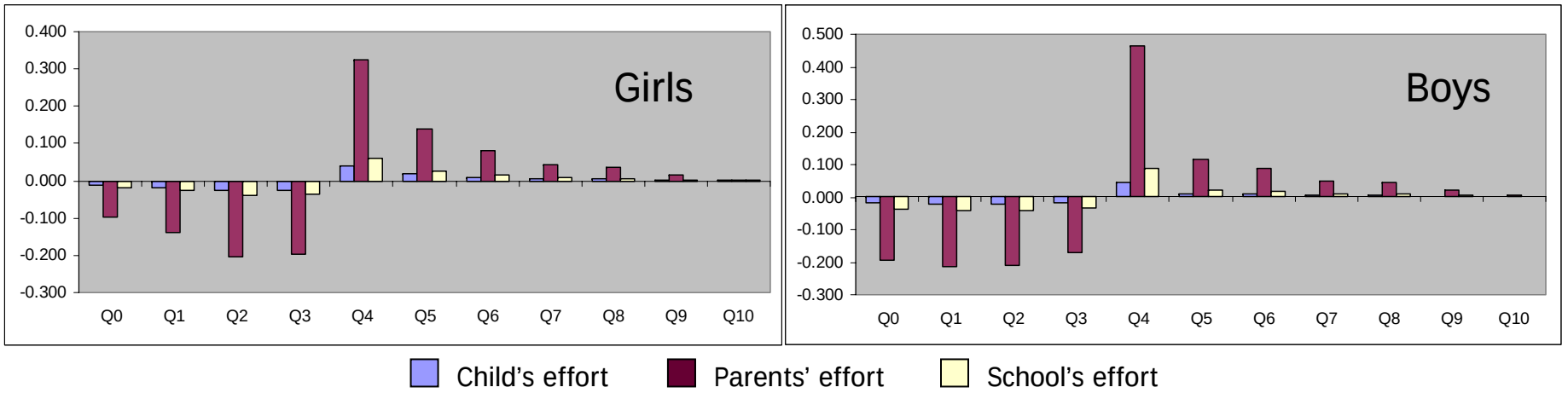


Figure 4: Changes in probabilities of qualification Q0-Q10