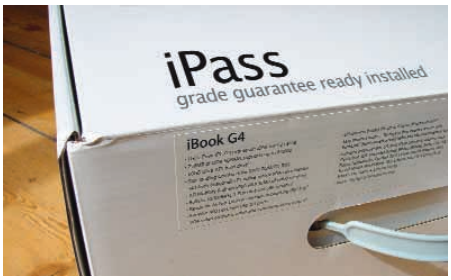
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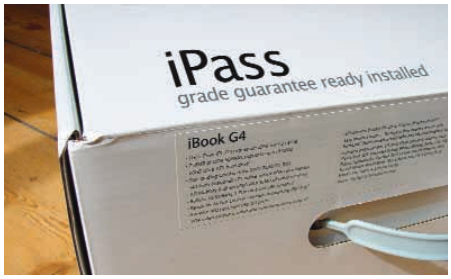
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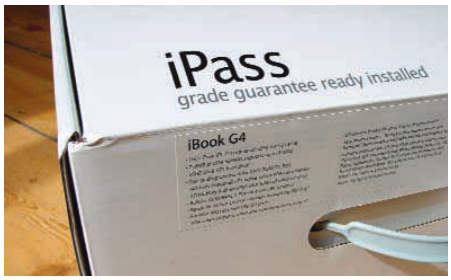
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Designed by Apple in California
Computer Assembled in Taiwan
Other Foreign Items as Marked Thereon
iBook G4 14-inch
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by John Schmitt and Jonathan Wadsworth

Computer assisted exam results

John Schmitt and Jonathan Wadsworth look at 10 years' data on GCSE and A level results and conclude that access to a PC at home has a significant impact on outcomes.

A large body of research has documented the "digital divide" in household ownership of personal computers (PCs) in the United States, Britain and elsewhere. PC ownership is concentrated in richer households and the ownership gap between rich and poor has widened over the last decade.

One important question is whether unequal access to computers matters in itself, or whether PC ownership inequality is just a manifestation of the widening income inequality that has pervaded the UK for the last 20 years. Research attempting to link PC ownership directly to economic or social outcomes has tended to focus on the effect on the earnings of adults. Our study is concerned as to whether there is any link between PC ownership and children's educational attainment.

Increased familiarity with a computer, increased frequency of Internet use and access to computer-based learning programs could all help to boost educational attainment and examination performance. A simple search of the World Wide Web, for example, shows that many commercial study guides specific to British school examinations are available in CD format in shops or can be downloaded directly from the Internet. Access to the many on-line exam preparation sites, which provide details and interactive tests, could also have a positive effect on examination performance. Many examinations now require coursework, which can be completed in a student's own time and are,

therefore, open to the influence of all the resources provided by ownership of a computer. The BBC, for example, has an on-line revision site for schools (http://www.bbc.co.uk/schools/revision/). In this way, home computers may complement any effects of PCs used in schools.

Our starting hypothesis was simple: if personal computers (PCs) are widely used to enhance learning and information gathering across a variety of subjects, then a computer at home might well be a way of enhancing educational attainment.

To test this notion, we used data on British youths from the British Household Panel Survey between 1991 and 2001. We found a significant positive association between PC ownership at home and both the number of GCSEs obtained and the probability of passing five or more GCSEs. Home computer ownership was also associated with a significant increase in the probability of passing at least one A level and of getting three A levels or more.

Our findings appear robust to a set of controls for individual, household and area characteristics, including household wealth proxies and, for A levels, prior educational attainment of the student. When we use the panel nature of the data set to control, additionally, for *future* ownership of a PC (as a proxy for unobservable household characteristics), the "PC" effects remain and are statistically significant (though reduced for the sample of A level results). These findings suggest that the observed PC effects may have a direct role for PCs in the educational "production function" for teenagers, though we would welcome further research on this issue.

GCSE (at age 16) and A level (at age 18) are the principal school examinations taken in Britain and getting five or more GCSE passes (at Grade C or higher) is an important gateway to A level courses, with three or more A level passes being the standard requirement for university admission. We used data from the British Household Panel Survey (BHPS) to compare the educational achievement of 16- and 18-year-olds living in households with and without a PC. The same data also allow for a large range of household and individual controls that are necessary to attempt to separate out any true "PC" effects from those simply

Our data

The BHPS is a longitudinal survey of all the occupants living in a sample of some 5,000 randomly selected, nationally representative British households. It is conducted each autumn, beginning in 1991 and currently available to 2001. It was designed originally as an annual survey of *each* adult (aged 16 and over) member of a household, a total of approximately 10,000 individual interviews in each wave. Individual adults who left their original households are followed and interviewed. Thus the sample should have remained broadly representative of the population as it changed. In addition to detailed information on each occupant aged 16 and over, including all examination results, each wave monitored the age and gender of any children in the household. Around 150 individuals turn 16 in each wave of the survey. We pooled all 16- and 18-year-olds across the last 10 waves of the survey to create our sample data sets. (Those in the first wave in 1991 were omitted, since there is no information for these individuals on their circumstances one year earlier.)

The data sets contain information for each individual on the number of GCSE passes at grade C and above (but not the actual grade obtained) and the number of any A levels passed (but not the grade). Since the level of educational attainment was asked in each year of the survey, we can identify those who took their GCSE exams at age 15 and at age 16. It is common for an individual getting a GCSE grade lower than C to repeat the examination the following year, particularly in the key subjects of Mathematics and English. These additional measures of examination success, while recorded in subsequent waves of the data, do not appear in our dependent variables. For most individuals in the data, therefore, we essentially observe a "one-off" experiment.

We used a similar method for 18-year-olds and their A levels. Because the data are longitudinal, about 70% of individuals appear in both our "16-year-old" and our "18-year-old" samples. (The data set contains no other information on children's ability, such as the nationally administered aptitude tests taken by all 14-year-olds in Britain.) Month of birth also determines in which third of the school year the child begins school. This influences the total amount of time spent in school and, potentially, future earnings. We, therefore, include relevant controls for month of birth.

The BHPS asks whether "the household owns or rents a personal computer, even if used only for games, but only if it has a keyboard". It includes in this definition computers used for business purposes by the self-employed, but excludes those provided by employers for work at home. We can, therefore, determine whether or not the household owned a personal computer in the year(s) before the child sat GCSE or A level examinations. This enabled us to construct dummy variables with the value 1 for households owning a computer in the year

correlated with PC ownership, such as household income or parental background, which could also influence the educational outcomes for children in the household.

We used our sample of youths from the BHPS to estimate the impact of PC ownership on six educational outcomes: (1) successful completion of any GCSE at grade C or higher; (2) the total number of GCSE passes; (3) successful completion of five or more GCSEs at grade C or higher; (4) successful completion of one or more A levels; (5) the number of A levels; and (6) successful completion of three or more A levels. The basic equation we considered is set out in our CEP Discussion Paper No. 625.

Table 1 provides a summary of the overall trends in educational attainment and PC ownership in our data set.

Table 1. Sample means of key variables, pooled sample

All	Sample of 16 year old individuals				Sample of 18-year-old individuals			
	% with PC	% with PC	% with GCSE A*-C	mean no. GCSEs A*-C passes	% with 5+ GCSEs A*-C	% with PC	% with A Level	mean no. A Level passes
Year								
1991	29.4	52.1	62.4	3.6	38.7	35.9	33.9	0.6
1994	34.4	52.3	64.2	4.1	45.1	46.3	48.8	1.1
1997	37.4	51.2	67.6	4.5	47.7	55.4	48.2	1.2
2001	57.1	73.2	76.9	5.2	56.1	66.7	48.5	1.3

Source: Authors' calculations using BHPS, 1991-2001. Individual PC count is percentage of individuals living in a household with a home computer present. Mean number of passes includes those coded as zero who did not take A level examination. Age cohort refers to first sample observation taken after examination.

before the relevant examination took place and 0 for the rest. (Since each BHPS wave asked about PC ownership, "recall bias" should not be a problem. If, though, a respondent wrongly claimed ownership of a PC at the time of a survey, for example, this would bias the results toward zero in the usual way.) The annual survey also tells us the age of the youth when the household first owned a PC and hence gives us a "years of PC ownership" variable, which could help to measure any effect of cumulative PC experience on subsequent performance.

Beginning with the fourth wave (1995), the BHPS also asked a separate set of questions of all 11- to 15-year-old household members. In 1997, this additional survey includes a specific question on the frequency of home computer use among 11- to15-year-olds, excluding time spent on computer games. We can match the answers to these questions at age 15 to around one third of our 16-year-old sample. For this sub-sample we constructed five dummy variables, splitting 16-year-olds according to whether they: (a) made no use of a PC in a household that had one; (b) used a PC 1-2 days a week; (c) 3-4 days a week; (d) most days; or (e) did not have a computer at age 15. We can then test whether frequency of use, as well as ownership, is associated with educational attainment. For this sub-sample, we also have information on individuals' attitude to school work and whether they were bullied at school at age 15, which we included as additional controls to try to account for some aspects of individual heterogeneity.

The potential control variables were measured for the year before the relevant examination took place and then mapped onto the individual. We matched information relating to household and local area characteristics to each child, using the household and local authority identifiers in the data. The survey allows us to follow any child leaving the parental home to his or her new household.

Since Scotland has its own examination system, which differs in important ways from that in England and Wales, we dropped all Scottish observations from the sample. When indicated, the regressions also contain a set of control variables for household and parental background, as well as for the characteristics of our 16- and 18-year-olds.

In all, we have around 1,450 observations with a full set of control variables on 16-year-olds, of which 78% come from different households and around 1,500 complete observations on 18-year-olds.

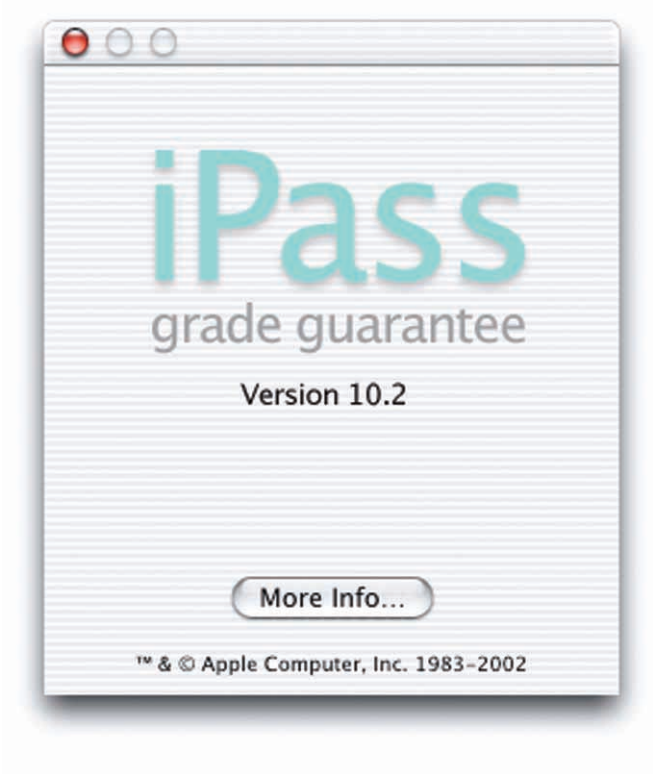
Over the 10-year sample period, PC ownership rates for the population as a whole virtually doubled, from about 29% of all individuals living in a household with a PC in 1991 to about 57% in 2001. In households containing 16-year-olds, the incidence of PC ownership is higher than in the rest of the population and ownership rates for this group of households also rose steadily, from just over half (52%) in 1991 to almost three fourths (73%) in 2001. PC ownership is slightly less common among households with an 18-year-old, but showed the same strong upward trend in ownership between 1991 and 2001. Over the same period, the overall level of GCSE and A-level attainment also rose. By 2001, over 75% of the sample of 16-year-olds had at least one GCSE at grade C or higher, over 55% had managed five or more GCSEs passes and just under 50% of the 18-year-olds had at least one A level.

Panel (a) of Table 2 presents our first set of results on the impact of PC ownership on obtaining any GCSEs at grade C or higher. Column 1 reports the marginal effects from a probit equation of GCSE attainment at age 16 conditional on PC ownership at age 15, with controls only for the wave of the BHPS in which the individual was observed at age 16. In this simple equation, PC ownership at 15 raises the likelihood of receiving GCSEs at 16 by 15.1 percentage points (statistically significant at the 1% level using robust standard errors). Column 2 adds a quadratic for real household income, equivalised by the square root of the number

Table 2. Effect of PC ownership at age 15 on educational attainment at age 16

	(1)	(2)	(3)	(4)	(5)	(6)
(a) Any GCSE grade A*-C						
PC at 15	0.151**	0.099**	0.029	0.034	0.032	0.018
Controls						
Panel wave	Yes	Yes	Yes	Yes	Yes	Yes
Income	No	Yes	Yes	Yes	Yes	Yes
Household	No	No	Yes	Yes	Yes	Yes
Individual	No	No	No	Yes	Yes	Yes
Area	No	No	No	No	Yes	Yes
Area 2	No	No	No	No	No	Yes
Pseudo R^2	0.032	0.069	0.139	0.172	0.237	0.252
N	1453	1453	1453	1453	1453	1305
(b) Number of GCSEs grade A*-C						
PC at 15	1.218**	0.981**	0.567**	0.667**	0.548*	0.536*
Controls						
Panel wave	Yes	Yes	Yes	Yes	Yes	Yes
Income	No	Yes	Yes	Yes	Yes	Yes
Household	No	No	Yes	Yes	Yes	Yes
Individual	No	No	No	Yes	Yes	Yes
Area	No	No	No	No	Yes	Yes
Area 2	No	No	No	No	No	Yes
Adjusted R^2	0.035	0.054	0.154	0.191	0.205	0.192
N	1005	1005	1005	1005	1005	887
(c) 5 + GCSEs grade A*-C						
PC at 15	0.151**	0.127**	0.084**	0.096**	0.086*	0.093*
Controls						
Panel wave	Yes	Yes	Yes	Yes	Yes	Yes
Income	No	Yes	Yes	Yes	Yes	Yes
Household	No	No	Yes	Yes	Yes	Yes
Individual	No	No	No	Yes	Yes	Yes
Area	No	No	No	No	Yes	Yes
Area 2	No	No	No	No	No	Yes
Pseudo R^2	0.025	0.033	0.099	0.136	0.167	0.172
N	1005	1005	1005	1005	1005	887

Source: BHPS 1991-2001. * = significant at 5%; ** = significant at 1%. Coefficients in panels (a) and (c) are marginal probabilities from probit equations. Coefficients in panel (b) are OLS estimates. Area 2 effects in Column 6 includes local authority level data and applies to England only.



of individuals in the household, which cuts the estimated PC effect to 9.9 percentage points. Column 3 adds other housing level controls, including additional possible household wealth proxies (number of rooms and housing tenure) and other controls for mother's and father's education, mother's and father's age, marital statues of parents, number of dependent children living in household, whether household had moved in past 12 months, parental involvement in school parent-teacher association, and the religious outlook of parents. These variables reduce the size of the estimated PC effect considerably and it is no longer statistically significant. Column 4 adds individual-level controls for the trimester in which the child began school, gender, ethnicity, sibling order of the child, and health status of the child. Column 5 adds area level variables for region, school type and parental perception about whether the neighbourhood is "bad". These additional controls have little further effect on the magnitude or statistical significance of PC ownership. (The Appendix to Discussion Paper No. 625 gives the full set of estimates from this regression.)

Panel (b) of Table 2 repeats the exercise in panel (a), now using the number of GCSEs as the dependent variable conditional on obtaining at least one GCSE (and using ordinary least squares, rather than probit, given the change in the nature of the dependent variable).

The results of the simple equation shown in Column 1 indicate that having access at home to a PC at age 15 increases the number of GCSEs achieved on average by over 1.2. Even after including the full set of individual, household and area controls (Column 5), PC ownership is associated with a positive, statistically significant increase in the number of GCSEs, equivalent to about half an additional GCSE. Adding variables to control for educational conditions in local authorities (Column 6), which lowers the sample size somewhat, has no impact on the size or significance of the estimate.

Panel (c) of Table 2 suggests that PC ownership may also have an important (and statistically significant) positive impact of 15.1 percentage points on the probability of attaining five or more GCSEs at grade C or higher, a current national educational goal. Adding successive levels of controls (Columns 2 to 5) reduces the economic impact to about 9 percentage points, but the effect remains statistically significant at the 5% level. Again, adding controls for local education authority characteristics (Column 6) does not alter the conclusions.

Even though the regressions in Column 5 of Table 2 control for a broad list of individual, household and local area characteristics, PC ownership may still simply be acting as a proxy for unobserved characteristics, such as household wealth, which may be positively correlated with both PC ownership and with higher educational attainment. So, as a robustness test, we substituted dishwasher, tumble drier and car ownership for the PC ownership variable. These alternative household durables may also proxy unobservable household effects, especially wealth effects that are not picked up in the comprehensive list of controls. At the same time, we might not expect these other consumer durables, in and of themselves, to be important inputs into an educational production function.

The results of these regressions are set out in detail in Discussion Paper No. 625. In summary, if you only apply basic controls, dishwasher or car ownership do indeed appear to have as large an impact on the number of GCSEs obtained as owning a PC, while owning a tumble drier appears only to have an insignificant negative impact. But, if you include our full set of controls, the apparent educational effects of dishwashers, driers and cars fall substantially and are no longer statistically significant. In fact with a regression that includes a full set of individual, household and area controls, together with all three of these other household assets and the original PC-ownership variable, PC ownership still raises the number of GCSE passes by an amount that is very close to the impact reported in Table 2, Column 5 (about half an extra GCSE, significant at the 1% level). Meanwhile, none of the other household durables is statistically significant.

The pattern of results for the attainment of five or more GCSE passes is similar. The inclusion of cars and the other household durables in the regression does not eliminate the large, well-defined effect of PC ownership at age 15. When the full set of individual, household and area controls is

Over the 10 years to 2001 students living in a household with a PC almost doubled to 57%

Table 3. Effect of PC ownership at age 17 on educational attainment at age 18

	any A Levels	any A levels / 5+ GCSEs	No. of A levels / has A level	3+ A Levels / has A level
Panel A				
PC at 17	0.123**	0.109*	0.278*	0.149**
Pseudo R^2 / Adj. R^2	0.189	0.221	0.154	0.233
N	1512	513	471	471
Panel B				
PC at 17	0.083*	0.081	0.229*	0.161**
Pseudo R^2 / Adj. R^2	0.302	0.253	0.328	0.233
N	1364	497	428	428

Source: BHPS 1991-2001.
* = significant at 5%;
** = significant at 1%.
Estimates in Columns 1, 2 and 4 are marginal probabilities from probit equations. Estimates in Column 3 are OLS regression coefficients. Sample size in Columns 3 and 4 are less than that in Column 2 because of missing values on dependent variable. Panel B is sub-set of panel with information on number of GCSE qualifications, which is included as an extra conditioning variable.

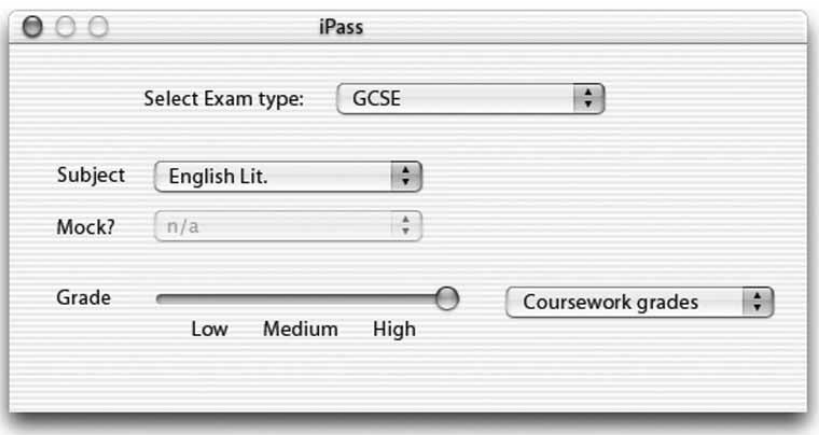
included, PC ownership is associated with about a 9 percentage point increase in the probability of obtaining five or more GCSEs, very close to the 9.3 points estimated effect shown in Column 6 of Table 2. All this strongly suggests that the "PC" effect is not simply acting as a proxy for unobserved household wealth.

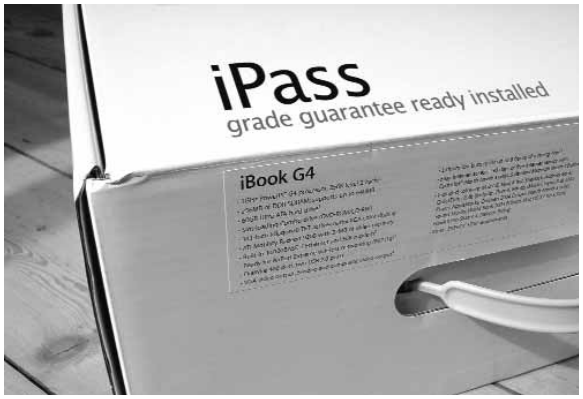
We performed one other test to try to distinguish between a true PC effect on educational outcomes and a spurious effect based on PC ownership acting as a proxy for unobserved household characteristics. Implicit in the analysis so far is the assumption the PC ownership is a good proxy for actual use of computers, which is presumably the channel through which computer ownership improves educational outcomes. Since 1997, the BHPS has asked all 15-year-olds about how many days each week they used a home computer, if one is present in the household. This gives us one way to test the effect of computer use at the intensive margin. Another way is to count the number of years of PC ownership, using the information in the data set.

We found that, while positive, the "years of experience" variable was not significant when added to any of our regressions. However, the intensity of computer use does appear to track educational outcomes closely. Children who live in houses with computers, but who never use them, are actually less likely (by about 20 percentage points) to complete at least one GCSE than children in houses without a computer; those who use computers "once or twice a week" have about the same probability as those in houses without a computer; children who report using a computer three to four times a week have a 10 percentage point advantage; and those who say they use computers "most days" a 13 percentage point advantage.

The results are not quite as clear cut for our other two educational outcomes (the number of GCSEs at grade C and above and five or more GCSEs at grade C and above) and sample size for those with at least one GCSE for whom we had the "frequency of use" variable is smaller. Nevertheless, the results still suggest that more frequent PC use is associated with better educational outcomes. Taken together, the results in all three cases provide some support for the view that, *within* households that have computers, children who use computers more fare better. To the extent that this is true, these results, therefore, reinforce the findings PC ownership is *not* simply acting as a proxy for unobserved household characteristics.

The BHPS data also allow us to look separately at the impact of PC ownership at age 17 on the attainment of A levels, typically at age 18. Table 3 reports results for the ownership of a PC at age 17 on the probability of getting at least one A level, on the number of A levels obtained, and on the probability of gaining three more A levels. Again





applying all our previous controls for 16-year-olds, including household ownership of cars, VCRs and dishwashers, Column 1 shows a strong, statistically significant, impact. PC ownership at age 17 raises the likelihood of attaining an A level pass among all 18-year-olds in our data set by just over 12 percentage points. For the smaller subset of youths (Column 2) who, in principle, are eligible to take A levels (i.e. those with five or more GCSEs) the PC effect falls to around 11 points, but remains significant. Among the third of 18-year-olds with at least one A level pass, household PC ownership at age 17 seems to be associated with around one quarter of an extra A level (Column 3). The probability for those in this sub-set of passing three or more A levels is estimated to be up almost 15 percentage points as a result of the PC effect (Column 4).

Data from household surveys are not ideal for measuring the impact of PCs on educational attainment, because unobservable factors at the household (and possibly even at the individual) level may cause problems. Random assignment of individuals to control and treatment groups could help to control for unobserved effects explicitly, though this is unlikely ever to happen in the nationally important examinations we study here. Moreover, the "one-off" nature of the examinations we study means that even an experiment would struggle to control for individual unobservable effects. So, until there is evidence to the contrary, the results here suggest that PC ownership may have important effects on significant educational outcomes.

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This article is an edited version of their CEP Discussion Paper No. 625, which can be downloaded from http://cep.lse.ac.uk/pubs

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