ASSESSING THE IMPACT OF ICT USE ON PISA SCORES

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The aim of this paper is to assess whether the use of ICT has an impact on student performances. We did find a positive and significant effect of computer use on student performance. This effect, however, is not the same for all students. For a same level of computer use, male students with more educational resources and with wealthy, white-collar parents tend to get higher performance. This finding suggests that complementary skills are necessary to reach the full benefits from computer use. It also implies that policies to promote ICT use among students will be effective if they are supported by measures to improve complementary skills among low-performance students.

1. Introduction

1. The simplest way to assess the impact of ICT use on student performance is to group students according to their frequency of ICT use and to compare the average performances of each group. For instance, if one observed that computer users have better performances than non-users, one could argue that computer use has a positive effect on student performances.

2. The above conclusion, however, would be misleading for two reasons. The first reason is that students with different characteristics would get different benefits from a same frequency of computer use. Skills, interests and attitudes determine what students do on a computer and how well. Some students would benefit more from computer because they know how to use it as a tool for learning. Some others benefit less because they lack the skills necessary to use the computer for educational purposes. In the same way, students interested in school are likely to use the computer on activities related to school. Students with little interest in school would spend more time on computer activities that are not related to school. As a result, we need to account for differences in the skills, interests and attitudes of students.

3. The second reason why a simple comparison between computer users and non-users would be misleading is that some factors that affect computer use also have an impact on student performances. For instance, students from wealthy families tend to have easier access to computers than students from disadvantaged families. At the same time, students from wealthy families also tend to have better performances at school. As a consequence, the group of computer users may show better performance because it is mostly composed of students from wealthy families. In this case, computer use would simply capture the effect of family background but it would not provide any information on its effects on student performance. To avoid this problem, one needs to control for factors that affect both computer use and student performance.

4. In the following three sections, we will look at the factors that affect the frequency of computer use by students (Section 2); then, we will identify the factors that influence student performances (Section 3); finally, we will assess the impact of computer use after having controlled for both sects of factors (Section 4). Further considerations will be developed in Section 5. Section 6 will discuss the main policy implications of the analysis.

2. What explains ICT use?

5. ICT use can be measured in several ways. The simplest measure is whether a student uses a computer or not. More interesting indicators are the frequency of ICT use – eg: once a week – and the time spent using ICT – eg: one hour a day. Finally, there are measures related to the specific use of ICT, from broader use, eg: Internet, to more precise activities, eg: searching the Internet for school-related work. In order to assess the impact of ICT use, one would need a measure of both the specific activities carried out through ICT and the time spent in each activity. However, this information is difficult to collect and rarely available from statistical surveys.

6. The PISA 2006 survey includes questions about the location and frequency of student computer use. The survey asks students to rate their frequency of computer use at three locations: home, school, and other places. Computer use is rated according to five frequencies: "never", "once a month or less", "a few times a month", "once or twice a week" and "almost every day".

7. Several studies have pointed out that simple measures of ICT use, such as physical access or frequency of use, are not sufficient to assess to impact of ICT on student performances (Wenglinsky, 1998). What really matters is the degree of "engagement" with ICT. Engagement refers to a situation where the user exerts a degree of control and choice over the technology, thus leading to a 'meaningful use of ICT' (Bonfadelli, 2002; Silverstone, 1996). Engagement, therefore, is about how people develop relationships with ICT in a way that its use is useful, fruitful and relevant to them (Garnham, 1997; Jung et al., 2001).

8. Individuals' engagement with ICTs is based around a complex mixture of social, psychological, economic and pragmatic factors. Some of these factors are related to the family and social environment of students; some others on the personal way each individual interacts with this environment.

9. Several authors (Selwyn 2004, Murdock et al., 1996) have suggested that these factors can be regarded as the result of four different forms of "capital" (Bordieu, 1997): economic, cultural, social and technological capital.

10. Economic capital is probably the most immediate form of capital underlying individuals' engagement with ICT. Material resources and economic capacity play a central role in determining whether people use ICTs, and then the nature and subsequent patterns of that use. As Murdock et al. (1996) cite the example of the difficulties of using a word processor without a printer or an adequate monitor.

11. Not only does economic capital imply easier access to computer at home but it has also an indirect effect through ICT use at school. Students from wealthier family have a higher probability to attend schools with better resources, where access to computer is easier and teachers are more "engaged" with ICT.

12. Economic capital cannot account for all stages and levels of engagement to ICT (Murdock, 2002). What an individual can do with ICT is also intertwined with his level of cultural capital. Following Bordieu (1993), cultural capital denotes the extent to which individuals have absorbed - often unconsciously - or have been socialized into the dominant culture over time. Therefore, cultural capital can be embodied (in the form of knowledge), objectified (in the form of books, paintings, instruments and other artefacts) and institutionalized (in the form of qualifications).

13. The family represents one of the main channels of the transmission of cultural capital. The educational level, the profession, the cultural orientation and the interests of parents have an

important impact on students' cultural capital. School is the other main channel not only for its vocation to transmit codified knowledge but also as a milieu for the diffusion of cultural attitudes.

14. The success of many people's engagement with ICT is also influenced by their social capital (Di Maggio and Hargittai, 2001; Fountain, 1997, Jung et al., 2001). This can be regarded as social obligations or connections between an individual and networks of other individuals (family members, friends), organizations and institutions. As Murdock et al. (1996) have shown, people's ability to foster, maintain and draw upon social capital in terms of networks of friends, relatives, neighbours was a critical factor in the diffusion of home computing in the UK.

15. Again, family and school provide a powerful channel of socialisation for students. Networks tend to be stronger among families with similar economic and cultural values, through the relationships that their members establish at work, in the neighbourhood and in social activities. As a result, students tend to socialise with other students from a similar economic and cultural endowment, because they are the children's of their parents' friends, they live in the same neighbourhood and they go to the same schools.

16. Finally, some authors have pointed out the fundamental importance of technological capital as complementary to cultural, economic and social capital in the information age (Hesketh and Selwyn, 1999; Howard, 1992). ICT skills and 'know-how' as well as the access to local sources of technological expertise and material resourcing (eg: 'borrowing' equipment or 'sharing/copying' software) play a key role in people's engagement with ICT use.

Table 1 Different Forms of Capital

Economic capital	Economic capacity to purchase ICT hardware and software, domestic space of ICT use, material exchanges and resources
Cultural capital	Self-improvement of ICT skills, knowledge and competencies Participation in ICT education and training
Social capital	Socialization into technology use and 'techno-culture' via cultural goods, family, peers and other agents of socialization
Technological capital	Networks of 'technological contacts' and support

Source: adapted from Selwyn, 2004

Table 2. Determinants of computer use

	HEDRES	WEALTH	immigration	whiteblue	gender	COMPWEB	RATCOMP	SCHSIZE(*100)	STRATIO(*100)	SCMATEDU	F	N
Australia	0.189	0.415	-0.247	0.106			0.741	0.015			58.98	12300
	0.018	0.031	0.046	0.044			0.196	0.000				
Austria	0.123	0.316	-0.591	0.237	0.170		0.303				40.99	4287
	0.022	0.029	0.091	0.053	0.066		0.137					
Belgium	0.215	0.476			0.193			0.001	0.003		88.95	7513
	0.024	0.038			0.040		0.000	0.000	0.000			
Canada	0.186	0.462	-0.310		0.176		0.902				49.84	16802
	0.023	0.040	0.060		0.039		0.169					
Switzerland	0.107	0.450	-0.321	0.153	0.179						73.29	10197
	0.020	0.028	0.060	0.049	0.036							
Czech	0.407	0.376		0.160	0.456				0.003		71.99	4695
	0.033	0.043		0.067	0.057				0.000			
Germany	0.194	0.440	-0.353	0.249	0.483				0.005		81.85	3738
	0.026	0.036	0.068	0.067	0.045				0.000			
Denmark		0.290			0.489					0.101	39.77	2766
		0.037			0.062					0.049		
Spain	0.327	0.442			0.185	0.002				0.053	166.08	16134
	0.019	0.024			0.041	0.000				0.019		
Finland	0.168	0.393			0.358			0.030			66.52	4163
	0.027	0.034			0.048			0.000				
Greece	0.249	0.420	-0.253		0.513	0.005					137.8	4129
	0.026	0.027	0.068		0.043	0.000						
Hungary	0.321	0.371		0.106	0.278		0.658	0.002			89.85	3955
	0.027	0.030		0.050	0.050		0.142	0.000				
Ireland	0.236	0.431	-0.284								117.64	2935
	0.023	0.034	0.113									
Iceland	0.139	0.242			0.411				0.053		17.37	3367
	0.040	0.048			0.069				0.021			
Italy	0.302	0.259			0.393		0.758				226.84	18133
	[illegible]	[illegible]			[illegible]		[illegible]					
Netherlands	0.123	0.322						0.013			25.68	4102
	0.045	0.052						0.000				
Japan	0.203	0.168		-0.098	-0.099				0.010		262.66	4272
	[illegible]	[illegible]		[illegible]	[illegible]				[illegible]			
Norway	0.179	0.247		0.252	0.291		0.936				25.95	3554

	0.042	0.042		0.094	0.061		0.345				
Poland	0.665	0.407			0.455					357.82	4772
	0.028	0.036			0.041						
Portugal	0.362	0.441			0.260					205.4	4374
	0.025	0.029			0.052						
Sweden	0.145	0.269			0.396					51.58	3457
	0.048	0.053			0.064						
Turkey	0.515	0.142	-0.743		0.181		3.130			83.34	2833
	0.032	0.042	0.220		0.069		1.275				
Bulgaria	0.659	0.549			0.276					166.06	3529
	0.037	0.045			0.063						
Chili	0.541	0.434					3.953			357.61	3511
	0.027	0.029					1.136				
Croatia	0.456	0.263			0.443		1.528			119.33	4162
	0.030	0.028			0.048		0.652				
Latvia	0.562	0.423						0.034	0.110	145.46	3956
	0.034	0.039						0.000	0.040		
Lithuania	0.521	0.494		0.131	0.436	0.311				161.87	4130
	0.035	0.038		0.055	0.052	0.117					
Macao, China	-0.177	0.334			0.309					83.56	4206
	0.031	0.031			0.050						
Serbia	0.532	0.292		0.237	0.350					217.69	4018
	0.027	0.035		0.043	0.044						
Slovenia	0.257	0.335	-0.472	0.161	0.362			0.023		41.52	5564
	0.038	0.038	0.101	0.063	0.046			0.000			
Thailand	0.393	0.275		0.105	0.149		1.323			90.25	4984
	0.030	0.029		0.048	0.053		0.421				

Note: Standard errors in brackets. All estimates significant at 1% except: significant at 5%; significant at 10%; n*on significant.*

17. This brief survey of the literature points out that the same frequency of ICT use can have different effects on student performances depending on their level of capital. It follows that, in order to assess the impact of ICT, we need to measure both the frequency of ICT use and the level of capital of each student.

18. By definition, students' capital cannot be observed. However, the above discussion has highlighted what factors play a role in the accumulation of capital: economic and cultural resources, personal characteristics, school resources and ICT access. Based on these indicators, we can therefore estimate the level of capital of each student.

19. We ran the same statistical model (Ordered Probit, see Statistical Annex for detail) in each of the 33 countries – 23 OECD and 10 partner countries - who filled out the ICT survey. The model produces two sets of results. First, it estimates the level of capital of each student based on a number of relevant indicators. Second, it estimates the frequency of computer use of each student as a function of his capital.

20. The PISA 2006 surveys contain several indicators that can be used as a proxy for the different type of "capital". We used these indicators to explain the determinants of computer use at home and at school. We did not consider computer use in other place both because it represents a pretty small percentage of all students, particularly in OECD countries, and because the type of use is likely to be more diverse than at home and at school and less related to education.

21. The frequency of computer use at home and at school tends to be closely connected. On the one hand, students from a family with a better endowment – in terms of any of the forms of capital considered above – tend to have a higher frequency of computer use at home and to attend better schools with higher ICT use. On the other hand, computer use at school is likely to increase students' interest and skills in ICT so that ICT use at home would also increase. For these reasons, computer use at home and at school would be analysed conjointly.

22. We begun with including all variables available in the PISA and that could be related to determinants of computer use based on previous studies: gender, immigration, computer possession, family wealth, educational attainments of the parents, etc. Then, we dropped variables that were not statistically significant one at the time, starting with the less significant one. The final results are reported in Table 2. We found out that one or more of the following variables affect computer use:

Household characteristics

- The wealth of the student's family;
- the educational resources available at a home;

Parents' characteristics

- the occupation of his/her parents;

Student's characteristics

- his/her immigration status;
- his/her gender;

School characteristics

- the number of teachers per student;
- the quality of educational resources;

- the size of the school;

ICT access in school

- the number of computers per student at school;

- the percentage of school computers connected to the Internet.

23. Family wealth, educational resources at home and gender appear to be significant determinants of computer use in a large majority of countries. Parents' occupation and immigration also tend to be relevant in a large number of cases. Educational resources and ICT equipment in school also appear to play a role, although their effect is captured by a different set of indicators in different countries.

24. The wealth of the student's family is measured by an index (WEALTH) that combines the answers about the number of cellular phones, televisions, cars, and other country specific wealth items a family possesses (Table 3). A wealth index was chosen over an income variable because previous studies have shown that household possessions are a more reliable indicator of family wealth. In all countries, the wealth index has a positive sign: the higher the wealth of the student's family, the more he would tend to use computer at home.

25. It is worth to notice that the items "computer" and "a link to Internet" are part of the wealth index. Interestingly enough, these two variables were not statistically significant, neither alone nor together. This suggests that possession of a computer and/or a link to Internet is not sufficient to make a difference about the frequency of computer use at home. They do have an effect only for students from wealthy family.

26. Home education resources are also measured by an index (HEDRES) composed of various school items such as a study room, calculator, books, a computer for school work and educational software (Table 3). The sign of the index is always positive: more educational resources tend to result in higher computer use. Again, neither the possession of a computer for school work nor the availability of educational software had a significant effect alone. These items seem to make a difference only together with a broader set of educational resources.

27. The occupational status of the parents has also a significant impact on the frequency of computer use at home. Students' families were classified into "white collars" and "blue collars", according to the highest occupational status of the two parents. The positive sign of this variable shows that children of white collar parents tend to use computers more frequently than the children of blue collar parents.

Table 3. Items included in PISA indexes: WEALTH, HEDRES and HOMEPOS

		Item is used to measure index		
	:	*WEALTH*	*HEDRES*	*HOMEPOS*
Q13	In your home, do you have			
ST13Q01	A desk to study at		X	X
ST13Q02	A room of your own	X		X
ST13Q03	A quiet place to study		X	X
ST13Q04	A computer you can use for school work		X	
ST13Q05	Educational software		X	X
ST13Q06	A link to the Internet	X		X
ST13Q07	Your own calculator		X	X
ST13Q08	Classic literature (e.g., <Shakespeare>)			X
ST13Q09	Books of poetry			X
ST13Q10	Works of art (e.g., paintings)			X
ST13Q11	Books to help with your school work		X	X
ST13Q12	A dictionary		X	X
ST13Q13	A dishwasher (country-specific)	X		X
ST13Q14	A <DVD or VCR> player (country-specific)	X		X
ST13Q15	<Country-specific wealth item 1>	X		X
ST13Q16	<Country-specific wealth item 2>	X		X
ST13Q17	<Country-specific wealth item 3>	X		X
Q14	How many of these are there at your home?			
ST14Q01	Cellular phones	X		X
ST14Q02	Televisions	X		X
ST14Q03	Computers	X		X
ST14Q04	Cars	X		X
Q15	How many books are there in your home			X

28. The variable immigration measures the difference in computer use between native and immigrants. Its negative sign indicates that first and second generation immigrants are more likely than natives to be higher computer users.

29. Lastly, the sign of the variable gender is also positive, indicating that males use computers at home more frequently than females.

30. The last group of variables measures the access to ICT and the educational resources in schools.

31. The number of teachers per student (STRATIO) and the quality of educational resources (SCMATEDU) provide a measure of educational resources at school. The latter is an index based on the self-evaluation of the school principal. Both indicators have a positive and significant effect, suggesting that schools with better educational resources tend to promote ICT use among their students.

32. The size of school (SCHSIZE) also turned out to have a positive and significant impact on computer use. This may be an indication that large schools are proportionally better equipped in ICT than small ones – eg: schools in urban versus rural areas – or it may be due to some "economy of scale" in computer access: as not all students use the computer at the same time, the larger the number of computers available in a school the higher the probability for a student to find a machine available.

33. Finally, both the number of computers per student (RATCOMP) and the number of computer connected to the Internet (COMPWEB) seem to increase computer use among students in some countries.

3. What explains student performance?

34. PISA assesses the extent to which students near the end of compulsory education have acquired the knowledge and skills essential in everyday life. Students are tested in the domains of reading, mathematical and scientific literacy and complete a background questionnaire. In this study, we will focus on the student performance in science. Nonetheless, the scores of the three tests are highly correlated, so that the results presented for science can be generalized, at least in their broad lines, to math and reading as well.

35. We ran the same statistical model (OLS, see Statistical Annex for detail) to explain science scores in each of the 33 countries – 23 OECD and 10 partner countries - who filled out both the general PISA survey and the ICT module. We begun with including all variables available in PISA and that, based on previous studies, could be related to determinants of science performance. In addition, we included the frequency of computer use and the measure of students' capital estimated in the previous section.

36. We dropped variables that were not statistically significant one at the time, starting with the less significant one. The final results are reported in Table 4. In most countries, the variables that affect PISA science scores are the following:

Students' characteristics

- Gender;
- Immigration status;
- Interest in science;
- Motivation to continue learning about science.

Parents' characteristics

- Science-related carrier;
- Educational attainments;
- Occupation.

Household characteristics

- Home possession;
- Educational resources;
- Number of books at home.

School characteristics

- Number of teachers per student;
- Size of the school;
- Quality of educational resources.

Frequency of computer use

- Associated to the “average” level of students’ capital;
- Associated to the “marginal” level of students’ capital.

37. The first set of factors is related to students’ characteristics. The variable gender measures the difference in science scores between males and females. The variable has a positive sign, showing that males tend to have higher scores than females, when controlling for all other differences.

38. The variable immigration measures the difference in science scores between native and immigrants. Its negative sign indicates that first and second generation immigrants tend to have lower science scores than natives.

39. We also added two science indexes to the model. The 2006 PISA dataset has nine science indexes related to attitudes and perceptions of science. The two that were significant - and positive - are an index measuring student interest in science (INTSCIE), and another measuring student motivation to continue learning about science or pursuing a science-related career in the future (*SCIEFUT)*. Therefore, students with a stronger interest in science will tend to have better scores in science.

40. The second set of variables is related to the characteristics of parents. A first variable measures whether either parent has a science-related career (PARSCI). Its positive sign indicates that students will have better science scores if one of their parents has a science-related career.

Table 4. Determinants of science scores

	gender	parsci	immigration	HOMEPOS	HEDRES	HISEI	PARED	INTSCIE	SCIEFUT	books	STRATIO	SCHSIZE	SCMATEDU	F	R2	N
Australia					10.892	1.002	3.245	10.834	17.890	37.060		0.012	6.966	255.89	0.25	12226
					1.434	0.068	0.553	1.159	1.132	1.652		0.004	1.664			
Austria	6.993		73.185			0.763		15.754	8.184	44.384		0.044		65.90	0.36	4328
	3.751		7.909			0.098		2.040	2.004	2.938		0.010				
Belgium	9.814	6.909	62.558	21.187	7.960	1.093		14.485	13.798	15.642	-0.006			135.94	0.30	7405
	3.651	2.581	5.452	5.472	2.044	0.084		2.047	1.448	3.112	0.001					
Canada	11.361	8.579	15.621		4.934	1.053		10.071	16.473	34.776		0.008		118.30	0.21	16698
	2.076	2.505	3.977		1.466	0.065		1.489	1.150	2.182		0.003				
Switzerland	15.962		40.737	20.355		0.921	2.887	21.212	9.646	25.515		0.017	8.107	128.96	0.36	10124
	2.814		4.175	4.328		0.085	0.491	1.540	1.413	2.873		0.005	2.138			
Czech Republic	20.151	12.373	39.240	8.941	20.864	1.699	12.678	4.728		37.036		0.034		55.92	0.24	4652
	6.647	3.631	11.712	4.842	4.450	0.143	1.979	2.069		4.237		0.016				
Germany	20.729	11.876	44.634	8.088	6.894	0.793	2.822	16.403	7.640	31.265	-0.001	0.041		71.29	0.32	3690
	4.842	3.158	6.117	3.715	1.883	0.104	0.474	2.068	1.589	3.178	0.000	0.008				
Denmark	26.954		51.428	17.546		0.716	1.950	19.059	8.206	26.775	-0.002			66.67	0.27	2714
	5.539		8.359	3.897		0.114	0.768	1.754	1.902	4.559	0.001					
Spain	26.135		34.127	27.991	24.784	0.787	1.811	10.663	12.378	20.704			6.272	139.46	0.25	15931
	2.917		5.792	4.553	2.098	0.080	0.344	1.186	1.242	2.670			1.994			
Finland	26.193	5.876	79.101	25.336		0.511	1.660	17.518	16.380	19.485		0.034		101.29	0.24	4122
	4.254	2.288	17.189	4.622		0.088	0.543	1.819	1.750	3.094		0.010				
Greece		7.967	26.673		23.993	0.773	3.341	15.449		21.824			6.751	45.96	0.25	4112
		3.579	8.197		2.412	0.120	0.596	1.374		2.632			3.222			
Hungary	13.244	6.394			17.134	0.838	6.717	14.707		35.824				69.69	0.28	3931
	3.339	2.999			2.578	0.126	0.756	2.053		3.057						
Ireland	11.891			20.053	8.933	0.829	1.843	13.224	15.288	30.610		0.032		56.03	0.26	2918
	3.817			4.979	2.782	0.109	0.714	1.954	1.984	4.000		0.010				
Iceland	51.939		72.096	20.577	18.876	0.662	3.520	13.089	17.490	21.176			6.130	67.44	0.27	3323
	10.491		12.931	5.888	2.571	0.103	0.530	1.965	2.306	3.883			1.549			
Italy	18.562		32.466		17.738	0.826	0.938	15.859		35.148		0.022		54.92	0.19	17712
	5.123		5.836		3.668	0.087	0.395	1.319		2.482		0.005				
Japan				14.199	14.855	0.552	7.628	20.185	13.799	9.886		0.034	6.006	56.95	0.24	4262

				3.764	3.436	0.124	0.831	1.779	1.951	3.360		0.008	2.827			
Netherlands	8.230	9.885	48.192	18.670	9.095	1.182		14.292	8.981	20.609	-0.004	0.041		115.14	0.33	3978
	2.946	3.026	6.738	4.727	1.976	0.115		1.756	1.826	3.781	0.002	0.006				
Norway	14.544	6.622	33.115		10.271	1.012		20.678	5.159	35.721				73.21	0.22	3499
	3.996	2.809	7.328		2.618	0.109		1.534	2.017	3.208						
Poland	44.738			31.426	58.852	0.627	7.382	12.997		17.946	-0.002	0.021		0.20	54.67	4751
	4.148			3.516	5.286	0.113	0.893	1.749		3.123	0.000	0.009				
Portugal	19.285	12.727	34.977	25.786	17.124	1.147		8.125	16.345	7.584		0.030		68.81	0.29	4320
	3.450	3.975	7.052	4.873	3.187	0.090		2.145	1.630	3.733		0.005				
Sweden	20.352		48.802		5.773	1.166		20.212	10.879	36.047		0.026		81.47	0.27	3407
	4.104		4.594		2.041	0.082		2.122	1.849	3.246		0.012				
Turkey					21.533	0.795		12.761	6.199	22.482				16.82	0.26	2818
					9.048	0.135		2.086	2.072	4.482						
Bulgaria	34.188	10.248		54.466	55.134	0.925	2.123	7.390		18.532	-0.003	0.073		27.74	0.33	3514
	4.791	4.222		5.884	4.727	0.125	0.812	1.783		4.258	0.001	0.011				
Chili	17.228	11.621	38.907			0.799	2.703	5.278	6.149	29.919			10.325	37.07	0.25	3446
	3.411	5.170	15.289			0.128	0.503	1.598	1.641	4.513			3.702			
Croatia	41.987	9.875	7.962	22.896	38.163	1.082		15.901		20.027		0.025		37.21	0.20	4095
	7.867	3.019	3.877	4.420	6.861	0.108		1.886		3.900		0.008				
Latvia				23.453	38.641	0.903			6.863	22.226		0.029		51.85	0.15	3940
				5.821	7.439	0.138			2.048	3.661		0.010				
Lithuania	20.000	8.265		26.928	39.070	0.884	1.424	16.618		25.296			7.587	36.16	0.23	4109
	6.055	3.409		5.587	5.511	0.101	0.612	2.007		3.409			3.346			
Macao, China	24.063		-13.576	18.709	20.613	0.391	0.990	19.406				-0.004	9.770	57.26	0.16	4148
	4.466		2.667	4.097	2.597	0.107	0.484	1.622				0.001	1.409			
Serbia	15.173	12.280	-13.784	14.338	26.724	1.175		6.991		22.889				36.82	0.16	3932
	5.965	3.522	4.641	3.759	6.134	0.095		1.593		3.606						
Slovenia	35.496	7.016		21.380	18.124	1.019	3.913	12.459	8.927	23.861	-0.005	0.100		95.18	0.34	5535
	3.708	3.477		2.826	2.651	0.114	0.788	1.860	1.586	3.930	0.003	0.004				
Thailand		26.395	66.778		14.093	0.437	1.189	15.949		11.928	-0.004	0.010	6.513	96.97	0.27	4892
		6.637	21.669		4.023	0.106	0.484	1.662		3.545	0.000	0.003	2.140			

Note: Standard errors in brackets. All estimates significant at 1% except: significant at 5%; significant at 10%; *non significant.*

41. Parental education is a second family background variable that is often used in the analysis of educational outcomes. It is measured by the highest number of year in education of either parent (PARED). Our findings show that longer the time parent spent in education, the higher the expected science scores of their children.

42. Parents' occupations are classified according to the level and specialization of the skills they required. The classification is based on the International Standard Classification of Occupations (ISCO-88). The higher the skills content of the occupation of either patent (HISEI), the higher the expected science scores of his/her children.

43. The third set of variables measures household characteristics. In PISA 2006, students reported the availability of 13 different household items at home (Table $). In addition, countries added three specific household items that were seen as appropriate measures of family wealth within the country's context. The index home possession (HOMEPOS) is based on the availability of these household items. Home possession has a positive impact on science scores, as shown by its positive sign.

44. Home education resources are measured by an index (HEDRES) composed of various school items such as a study room, calculator, books, a computer for school work and educational software (Table 2). The sign of the index is always positive: more educational resources tend to result in higher science scores.

45. PISA 2006 reports interesting information about the number of books in a household. We found that students from households with a large number of books (over 100) tend to achieve better scores in science. The role of this factor appears even stronger when one considers that the number of book also enter the home possession index.

46. The last set of variable looks at the characteristics of the school. The number of teachers per student (STRATIO) and the quality of educational resources (SCMATEDU) provide a measure of educational resources at school. The latter is an index based on the self-evaluation of the school principal. Both indicators have a positive and significant effect: students in schools with better educational resources tend to have higher scores in science.

47. The size of school (SCHSIZE) also turned out to have a positive and significant impact on science scores. As discussed above (section 2), this may be an indication that large schools are proportionally better endowed with physical and human resources – eg: schools in urban versus rural areas – or it may be due to some "economy of scale" in the use of educational resources: as not all students use libraries, laboratory, tutors, etc. at the same time, students in larger schools would benefit more of a same stock of educational resources per capita.

4. Does ICT use improve student performance?

48. The last two variables look at the impact of computer use on student performance in science. The first variable is the frequency of computer use, measured at the "average" level of students' capital. As the impact of computer use varies with capital and that students with the same frequency of use have different levels of capital, this variable permits to estimate the "average" impact for each frequency of use.

49. Columns 1 to 4 in Table 5 show the estimated increase in average science scores due to computer use. The first column shows the estimated increase from using computer once a month as compared to never. The second column shows the estimated increase from using computer a few times a month as compared to never. And so on.

Table 5 “Average” increase in science scores due to computer use

	Average				Differential
	Once a month or less	A few times a month	Once or twice a week	Almost every day	
Australia	*8*	51	76	105	-24.31
	37.02	16.17	17.37	18.20	3.56
Austria	50	63	60	79	*-4.37*
	17.70	13.41	13.80	13.87	5.32
Belgium	71	93	135	162	-38.19
	25.47	29.80	34.84	40.60	12.00
Canada	49	60	84	102	-17.06
	19.92	18.95	19.53	21.17	4.02
Switzerland	56	103	153	197	-54.32
	26.19	27.90	30.64	34.77	8.30
Czech Republic	*34*	57	104	131	-34.72
	28.99	22.97	27.74	34.34	12.49
Germany	*52*	44	59	99	-29.85
	37.97	12.68	16.27	22.93	8.90
Denmark	72	187	196	218	37.16
	36.70	39.09	41.22	45.00	9.09
Spain	121	202	259	327	-93.75
	14.19	21.79	26.56	32.18	9.60
Finland	112	175	218	270	-60.89
	26.15	31.40	35.13	42.19	10.22
Greece	35	38	44	56	-20.14
	11.98	13.30	14.72	17.64	4.96
Hungary	*27*	49	76	87	-17.09
	31.25	24.93	23.30	24.27	5.74
Ireland	89	149	182	239	-63.49
	19.17	26.05	31.13	38.45	10.17
Iceland	353	478	549	648	-157.17
	74.64	81.45	92.53	104.01	24.62
Italy	71	102	110	120	-23.10
	22.65	29.67	33.82	39.63	10.93
Japan	128	218	281	392	-90.38
	25.63	39.53	51.79	70.13	17.26
Netherlands	187	204	255	282	-64.51
	79.93	53.22	53.23	57.52	12.95
Norway	171	214	262	284	-38.19
	40.07	38.01	42.19	44.79	8.19
Poland	136	195	251	322	-91.34
	18.55	22.56	26.58	32.92	8.94
Portugal	107	161	207	244	-53.03
	20.98	27.85	31.15	37.38	9.81
Sweden	136	184	204	214	-36.30
	42.97	47.70	48.45	49.93	6.78
Turkey	*26*	*18*	*23*	*20*	*-14.02*
	21.63	*34.84*	*40.76*	*55.65*	*19.41*
Bulgaria	117	212	275	354	-95.95
	26.09	25.18	27.08	33.78	8.76
Chili	ns	ns	ns	ns	ns
Croatia	128	213	247	302	-86.43
	27.16	39.23	45.29	53.37	17.35
Latvia	99	162	219	264	-60.37
	28.15	38.20	47.15	58.25	14.69
Lithuania	97	148	198	250	-61.87
	23.92	31.45	35.34	44.65	12.68
Macao, China	83	236	292	356	-71.50
	30.05	33.04	40.52	47.58	11.62
Serbia	72	142	176	200	-42.68
	33.30	37.38	42.87	48.01	12.58
Slovenia	129	226	284	334	-80.21
	33.08	34.77	38.84	40.20	7.96
Thailand	21	18	25	25	*-2.08*
	10.55	9.20	8.05	8.15	*7.93*

Note: Standard errors in brackets. All estimates significant at 1% except: significant at 5%; significant at 10%; *non significant.*

50. For instance, the first row shows that, on average, Australian students would increase their science scores by 8 points using the computer once a month or less, by 51 using it a few times a month, by 76 if the use it once or twice a week and by 105 points if they use it almost every day.

51. We found out that higher frequency of computer use is associated to higher average science scores in all countries considered. Among OECD countries, the largest effect of using computer almost everyday was found in Iceland, Japan, Spain, Poland, Norway and the Netherlands. Among partner countries, the largest effect of using computer almost every day is found in Macao China, Bulgaria and Slovenia.

52. It is important to stress that these figures cannot be compared across countries. In fact, the effect of computer use is estimated for the average level of students' capital and this level is likely to vary across countries.

53. The second variable to measure the effects of ICT on science scores is the frequency of computer use associated to the level of capital of each student. As not all students with a given frequency of computer use have the same level of capital, this effect will differ among students. In particular, it would be higher the average if a student has a level of capital above the average and lower than the average if the student has a level of capital lower than the average. For each student, therefore, the increase in science score due to computer use would be the sum of two parts: the "average" increase plus the "differential" increase due to the difference from the "average" capital.

54. The last column of table 5 shows the estimated "differential" effect of computer use. This effect is positive in all countries: if a student uses the computer almost every day but he has a level of capital below the "average", the increase in his science score would be smaller than the "average" increase.

55. We can illustrate these results with the help of Figure 1. Science scores are plotted on the vertical axis while computer use on the horizontal axis. The red dots shows the "average" science score associated to the corresponding frequency of computer use, measured at the "average" level of students' capital. The line joining these dots shows the average increase in science score due to higher computer use.

56. The vertical dotted line in correspondence of each frequency of computer use show "differential" effect of computer use on science scores for a student with a level of capital above or below the "average" level. For instance, the points below the red dot in correspondence of "almost every day" show that, among all students using the computer almost every day, those with a lower capital have also lower science scores as compared to the "average". The contrary happens for student with higher capital than "average". For instance, the points above the red dot in correspondence of "never" show that, among all students not using the computer, those with a higher level of capital have also higher science scores.

5. School or home: does it make a difference?

57. One interesting question is whether the effects of ICT on student performance are different when ICT is used at home or at school. On the one hand, we may expect ICT use at school to be prepared by some ICT training, to be more closely related to educational activities and to benefit from the expertise of a teacher (Wenglinsky, 2002). On the contrary, ICT use at home may be more related to leisure activities and does not benefit from any formal training (Fuchs and Woessmann, 2004).

Table 6 "Average" increase in science scores due to computer use: at home and at school

	At home				At school			
	Once a month or less	**A few times a month**	**Once or twice a week**	**Almost every day**	**Once a month or less**	**A few times a month**	**Once or twice a week**	**Almost every day**
Australia	*ns*	63	**86**	109	*ns*	51	**61**	101
		20.017	17.140	18.157		17.753	17.715	17.608

Austria	**33**	56	52	76	78	59	50	79
	22.496	14.522	13.191	13.654	22.653	18.508	14.698	16.567
Belgium	114	119	162	**202**	66	110	148	**174**
	30.261	24.319	25.583	29.426	23.717	27.061	26.456	31.981
Canada	43	**91**	**92**	**106**	47	**43**	**66**	**92**
	20.998	19.652	19.944	21.394	23.281	19.437	20.559	23.178
Switzerland	*ns*	81	117	159	*ns*	57	106	142
		14.244	18.917	23.969		19.559	18.472	24.428
Czech	*ns*	52	108	138	*ns*	64	101	148
		22.703	28.919	35.996		23.858	27.976	34.508
Germany	**53**	**61**	**85**	**120**	*ns*	**32**	**56**	**84**
	14.152	16.418	17.813	24.389		17.150	18.884	33.573
Denmark		139	140	159		148	115	148
		44.200	30.089	31.960		37.978	33.548	36.269
Spain	**147**	**224**	**286**	**353**	**120**	**209**	**266**	**326**
	19.369	23.357	27.317	32.939	14.825	21.407	27.022	34.280
Finland	95	**209**	**251**	**303**	111	**179**	**225**	**251**
	36.249	34.205	33.812	40.695	28.988	30.717	36.238	42.770
Greece	*ns*	35	**45**	**50**	33	**32**	**28**	*ns*
		6.965	6.119	5.985	9.462	9.801	6.130	
Hungary	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Ireland	**119**	177	**216**	281	**74**	167	**197**	279
	20.671	26.327	31.327	38.330	20.282	29.898	30.694	39.662
Iceland	**390**	485	**567**	**671**	**246**	494	**531**	**618**
	69.892	80.306	90.645	100.139	74.433	80.580	90.162	106.816
Italy	61	105	106	**118**	68	96	98	**95**
	24.823	30.644	34.069	39.352	25.509	28.756	33.675	40.303
Japan	138	**231**	**302**	**410**	133	**218**	**286**	**385**
	28.342	44.764	58.709	79.211	29.495	43.869	57.998	78.535
Netherlands	**77**	210	**271**	289	**227**	221	**220**	273
	48.950	58.193	55.237	59.349	90.637	59.846	54.704	59.346
Norway	198	208	261	280	152	210	253	283
	33.520	43.336	42.512	45.126	46.472	38.595	44.241	46.605
Poland	160	231	**293**	**367**	146	217	**276**	**333**
	36.008	27.784	29.852	34.641	20.332	23.039	26.993	38.326
Portugal	**204**	218	**272**	**318**	**133**	199	**249**	**287**
	18.994	33.595	30.572	35.227	21.429	26.116	28.617	34.776
Sweden	118	181	211	215	129	203	185	221
	54.820	48.629	47.921	49.895	49.119	50.195	52.795	50.406
Turkey	3	12	15	14	27	13	20	10
	26.897	36.310	40.730	55.321	21.023	35.998	40.888	57.408
Bulgaria	*ns*	198	259	**358**	126	205	268	**327**
		29.620	29.366	33.409	21.532	23.381	25.699	35.298
Chili	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Croatia	159	**246**	**284**	**339**	147	**222**	**260**	**297**
	27.838	40.149	45.957	54.139	27.200	39.432	45.624	56.359
Latvia	**58**	158	208	261	**93**	154	209	249
	26.685	44.732	46.066	57.609	29.068	37.134	45.998	55.771
Lithuania	102	154	**225**	275	105	166	**209**	266
	38.816	31.998	38.670	46.750	23.801	32.341	35.906	46.002
Macao, China	*ns*	218	247	310	*ns*	181	235	318
		28.166	33.234	38.833		33.751	32.614	40.985
Serbia	*ns*	141	201	**225**	90	162	190	**167**
		48.669	40.008	42.830	32.247	32.688	37.876	49.177
Slovenia	121	222	268	333	154	225	284	336
	35.485	36.513	40.893	40.522	43.335	38.527	39.303	40.905
Thailand	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Note: **Difference between school and home statistical significant**

58. On the other hand, students using computer at home are likely to be more interested in ICT, have more scope for experiment and self-learning and can search and discover the resources – both in terms of software and web content - that are best suited to their needs (Ravitz, Mergendoller and Rush, 2002; Marsh, Pattie and BMRD, 2005; OECD, 2006).

59. We can further develop our analysis to explore this question. In Section 4 we have found out that higher frequency in computer use is associated with higher science scores. We can now distinguish whether computer use occurs at school or at home and test whether the effects on science scores vary with location.

60. As a same student may use computer both at home and at school, the location of computer use is defined according to the location of the highest frequency of use. For example, if a student uses the computer once a week at home and almost every day at school, he would be considered as using the computer at school.

61. Table 6 shows the estimated increase in "average" science scores due to computer use at home and at school. The findings are not as clear-cut as in the previous section but we can identify some patterns.

62. In a large majority of countries, the benefits from higher computer use tend to be larger at home than a school. Therefore, despite the better environment and support that schools are expected to provide, the use of computer tends to have a lower impact at school than at home.

63. These differences, however, are statistical significant only in some countries. In Canada, Germany, Spain, Finland, Iceland, Japan, Poland, Portugal and Croatia the higher effect of computer use at home is significant for almost all frequency of use. In Belgium, Greece, Italy, Bulgaria and Serbia, the difference is favour of home is significant only at high frequencies of computer use.

64. For the remaining countries, lack of statistical significant does not necessarily imply that differences between school and home are negligible. This may be due to the fact that use frequency hides a large variation in the actual use of ICT and to the relative small number of observations available when we split them by location. In addition, and as discussed above, other studies, based on different methodologies, have suggested that computer use at home matters more than a school. Finally, the larger effect of computer use at home appears too generalized to be simply dismissed as non significant. In sum, although we did not find a clear-cut answer to our question, there is evidence that the benefits of computer use at school, as compared to use at home, should not be taken for granted.

6. Lessons for educational policy: is ICT enough?

65. Our analysis has shown that computer use does increase student performance. This increase, however, is not the same for all students. Students with high capital would benefit more from an increase in computer use than students with low capital.

66. This finding has two interesting implications for policies. First, as the benefits from computer use depend on the characteristics of each student, policies to increase ICT use need to be tailored on students. This means that policy-makers should try to identify the relevant personal and socio-economic characteristics. The analysis presented in this chapter provides a tool to target students.

67. Second, the positive effects of computer use on student performance are the largest when they are supported by a sufficient level of capital. Skills, interests and attitudes affect the ICT engagement of students, what actives they carry out on the computer and how well. An increase in ICT use that is not supported by an increase in capital would have a lower impact on student performance.

68. This can be seen with the help of Figure 2. Suppose that a student increase his computer use from "never" to "almost every day" and that this increase is accompanied by an increase of his capital. His performance will increase along the red line. Suppose now the same student increased his computer use from "never" to "almost every day" but his level of capital remains unchanged. In this case, he would move along the green line, which is always below the red one. Therefore, any increase in computer use that is not supported by an improvement in capital would have a lower impact on student performance.

69. This finding implies that a policy to increases computer use among disadvantage students will be fully effective only is it is accompanied by other policies to increase their capital: improve their complementary skills, raise their interests and change their attitudes.

Figure 1. Increase in science scores due to computer use: average

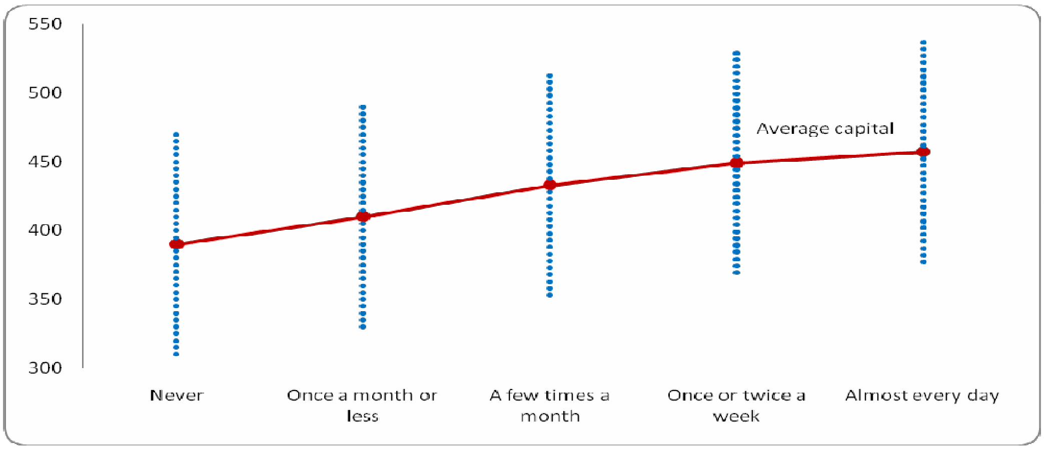
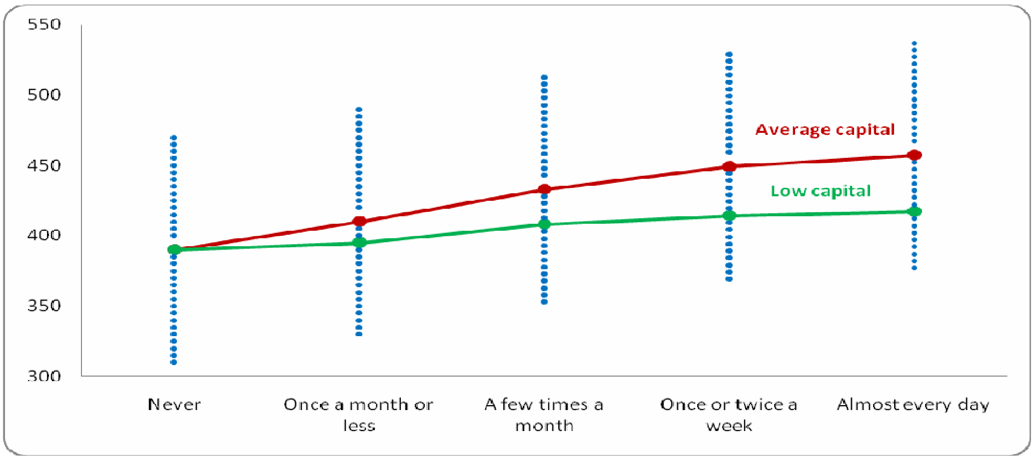


Figure 2. Increase in science scores due to computer use: average and differential



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Statistical Annex

Econometric model

Our aim is to assess whether computer use at home (*IT**) has an impact on science scores (*Science*) after having controlled for other observable student characteristics (*X*):

$$Science_i = \beta' X_i + \delta(IT_i^*) + e_i \qquad (1)$$

where the subscript *i =1…….N* indicate the students, X denotes observable individual characteristics; *e* is an individual idiosyncratic error terms which influence the student's science scores; β denotes unknown parameters; and δ is an unknown function which generates increases science scores through additional computer use.

We do not observe actual computer use IT* but only the variable IT (computer use frequency) with discrete values: 1 (never), 2 (once a month or less), 3 (a few times a month), 4 (once or twice a week) and 5 (almost every day). This means:

IT_i = 1 if $IT_i^* < \mu_1$; IT_i = 2 if $\mu_1 < IT_i^* \leq \mu_2$; IT_i = 3 if $\mu_2 < IT_i^* \leq \mu_3$; IT_i = 4 if $\mu_3 < IT_i^* \leq \mu_4$; IT_i = 5 if $\mu_4 < IT_i^*$.

We can write the observable computer use frequency as the following *j* dummy variables based on these discrete values:

$D_{ij} = 1 \; if \; IT_i = j$ and

$D_{ij} = 0 \; otherwise$

Therefore, equation (1) can be estimated through the following empirical model which comprises the reduced form representations of the student's science score and computer use:

$$Science_i = \beta' X_i + \sum_{j=1}^{5} \delta_j D_{ij} + e_i, \quad i=1.......N \qquad (2)$$

$$IT_i^* = \lambda' Z_i + v_i, \quad i=1.......N \qquad (3)$$

$$IT_i = h(IT_i^*), \quad i=1.......N \qquad (4)$$

where X_i and Z_i continue to denote vectors of exogenous characteristics, possibly overlapping; e_i and v_i are jointly normally distributed error terms with zero means, variances σ_e^2 and σ_v^2 and covariance σ_{ev}; *β*, *δ* and *λ* are vectors of parameters and the effects of computer use are captured by the δ's. The observed value of IT_i is obtained from the latent variable IT_i^* through the censoring function *h* in (4) which maps ranges of IT_i^* into ordinal discrete values represented by IT_i.

The primary difficulty in consistently estimating the parameters from (2) is the endogeneity of the computer use dummy variables. This is due to the potential for students to choose their frequency of computer use (*self-selection*). In general, therefore, $\sigma_{ev} \neq 0$, which implies that computer use choice is not weakly exogenous to the science score. We allow for this endogeneity by employing the procedures of Vella and Gregory (1996)[1].

Rewrite (2) conditioning on the observed value of IT_i and Z_i:

[1] Vella, F and R.G. Gregory (1996) Selection bias and human capital investment: Estimating the rates of return to education for young males. *Labour Economics 3*, pp. 197-219

$$E(Science_i|IT_i,Z_i) = \beta' X_i + E(e_i|IT_i,Z_i) \qquad (5)$$

Employing our assumption of joint normality, (5) becomes:

$$E(Science_i|IT_i,Z_i) = \beta' X_i + \theta E(v_i|IT_i,Z_i) \qquad (6)$$

where θ is equal to σ_{ev}/σ_{vv} .

Equation (6) can be estimated by least squares once we have an estimate of the conditional error $E(v_i|IT_i,Z_i)$. This is obtained in the following manner.

First, estimate the parameters from (3) and (4) by ordered probit. $E(v_i|IT_i,Z_i)$ is then computed as the value of the first derivative for each observation of the ordered probit likelihood function with respect to the intercept at the maximum likelihood estimates. This conditional error term from the computer use is a type of within sample prediction error. Accordingly, it can be interpreted as a measure of computer over- or under-use. Note that it also accounts for the selection bias induced by estimating the *β*'s over the various computer use frequency.

The coefficient *θ* captures the return or penalty to computer over-use. It reflects the covariance between the unobserved factors which affect science scores and the unobserved factors that affect computer use. Accordingly, it captures the process by which individuals self-select into computer use groups.

Computer use by location

We can test whether computer use has different effects at home and at school by rewriting equation (2) as follows:

$$Science_i = \beta' X_i + \sum_{j=1}^{5} \delta_j^h D_{ij}^h + \sum_{j=1}^{5} \delta_j^s D_{ij}^s + \sum_{j=1}^{5} \delta_j D_{ij} + e_i, \qquad i=1.......N \qquad (2bis)$$

where s and h denote at school and at home, respectively, the D’s are dummies for the frequency of computer use and the effects of computer use on science scores are captured by the δ's.

Ordered probit regression

The ordered probit regression of equations (3) and (4) is based on the hypothesis that actual computer use *IT** is normally distributed over (-∞;+∞). This hypothesis, however, is not realistic since the normal distribution is symmetric, whereas the distribution of *IT* tends to be skewed to the right, with a steep increase on the right and a long left tail. Moreover, with *IT** being normally distributed, negative frequency of computer use would become possible. To accommodate these features, we transformed equation (3) into (3’):

$$\ln(1/IT_i^*) = \lambda' Z_i + v_i \qquad (3')$$

If $\ln(1/IT_i^*)$ is normally distributed, then the distribution of IT_i^* has the desired features (positive, skewed to the right).

PISA plausible values

For each test and each student, PISA reports five plausible values. None of these values is the actual score of a student but they represent five random values drawn from the posterior distributions of the students’ scores[2]. This implies that, in order to obtain unbiased estimates, we had to run the same regression model five times, once for each plausible value of the science scores, and compute the unbiased estimates and their standard based on these five sets of estimates. However, the estimates

[2] OECD 2005 PISA 2003 Data Analysis Manual: SPSS® Users

generated by the five regressions and their standard errors turned out to be almost identical. For sake of simplicity, we have reported only the estimates for the first plausible value.

PISA replicate weights

As many international educational surveys, PISA 2006 uses a two-stage sample design. As a result, sampling variances have to be estimated through replication methods. These methods function by generating several subsamples, or replicate samples, from the whole sample. The statistic of interest is then estimated for each of these replicate samples and then compared to the whole sample estimate to provide an estimate of the sampling variance.

A replicate sample is formed simply through a transformation of the full sample weights according to an algorithm specific to the replication method. PISA 2006 uses the Fay's variant of the Balanced Repeated Replication with a Fay coefficient equal to 0.5 and 80 replicates[2]. This means that each regression was run 81 times, first by weighting the data with the student final weight and then by weighting the data with each of the 80 replicates.