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# BROADBAND IN SCHOOLS: DOES IT HELP OR HURT STUDENT PERFORMANCE?

*Completed Research Paper*

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## **Abstract**

*This paper provides empirical evidence on the effects of broadband Internet usage in schools on student performance in terms of national exams scores. We use a rich panel of data that has information on test scores, as well as broadband usage for all schools in Portugal, allowing us to control for school-specific effects. Additionally we use an instrument to account for possible unobserved time-varying effects. For 9th grade students, our estimates indicate that a higher use of broadband Internet is detrimental for students' test scores, despite this effect seeming to be wearing off with time. We find that the adverse effect tends to be reinforced for boys and weakened for girls, compared to the pooled estimates. We also find that schools with worse performance right before the introduction of broadband Internet in schools suffered the most.*

*Our results suggest that introduction of broadband Internet in schools is not enough to improve students' performance. Broadband deployment in schools needs to be accompanied by complementary measures that support the use of the technology in productive ways.*

**Keywords:** IT Adoption, ICT, Internet Use, IS Education

## **Introduction**

There is a generalized consensus that education plays an important role in the economic performance of countries as well as on the success of firms and of individuals in the labor market. Research has shown that higher levels of education are associated with both higher productivity at the country level (e.g., Mankiw et al., 1992), and higher wages at the individual level (e.g., Card, 1999). There is also a general belief that providing more resources to schools contributes to a higher quality of education, to better student performance, and consequently to higher levels of productivity both at the individual and at the aggregate level.

However, researchers have hardly reached a consensus regarding the latter topic. For a long time research on the impact of resources in education has produced mixed results. A review of such studies provided by Hanushek (1986) suggested that there is “no strong or systematic relationship between school expenditures and student performance”. Most of the early studies suffered from endogeneity issues, which might have led to biased findings. More recent studies that control for endogeneity show that some types of resources (e.g., class size, school hours) have a consistent positive impact on students’ performance, but others do not, such as Information and Communications Technologies (ICTs) (Webbink, 2005).

ICTs are perceived by many as potential powerful tools to improve the quality of education, by widening access to information and by fostering new learning methods that promote more interaction and feedback, ultimately increasing students’ interest and performance (e.g., Underwood et al., 2005). According to this line of thought, broadband is likely to help students and teachers to be more effective in the classroom by providing real time access to information and a more hands-on experience. Still, it is also quite likely that teachers may find it hard to effectively use ICTs as part of the curriculum. Moreover, students may predominantly use broadband to play games or to chat, which can ultimately hurt the learning experience.

This paper provides empirical evidence on the impact of *actual usage* (as opposed to investment) of broadband Internet in schools in Portugal on students’ performance. The latter is measured by scores obtained in national exams. We collect a panel data on broadband usage and school performance for more than 900 schools. We then use a first differences model to account for school-specific effects and an instrument to account for the endogeneity of broadband use. We take advantage of a technical specificity of ADSL technology and use school Internet connection’s quality as an instrument for broadband Internet use. This measure has some unique and desirable properties of a good instrument for broadband use.

For 9<sup>th</sup> grade students, our estimates indicate that more broadband Internet use is detrimental for students’ test scores. The test score decline by about 9% for schools using high level of broadband. We provide additional support for this finding by evaluating the impact of Internet use on boys and girls separately. A survey administered to a sample of students in Portugal shows that a higher percentage of boys engage in distracting activities and, conversely, a higher percentage of girls use the Internet for learning purposes. We find that the adverse effect of broadband Internet use in schools tends to be reinforced for boys and weakened for girls, compared to the pooled estimates. We also find that schools with worse performance right before the introduction of broadband Internet in schools suffered the most. Schools in the lower quartile seem to have a harder time to counter the disruptive effect that the introduction of broadband Internet in schools might entail.

## **Related Work**

### ***School Resources and Students’ Performance***

There is a vast literature on the impact of class size, school hours, teacher training, computer use and peer group effects on students’ performance. One of the first studies is Coleman’s report (Coleman, 1966), which concludes that higher levels of school resources do not necessarily translate into improved test scores. A series of subsequent works have also been inconclusive in this respect. In his influential meta-analyses, Hanushek (Hanushek, 1986; Hanushek

et al., 1996) also concludes that there is no systematic relationship between school expenditures and student performance.

These early results have been highly questioned<sup>1</sup>, due to unobserved effects driving some of the conclusions. Worries of endogeneity casts doubts on the causality of the relationship between education inputs and students performance (see Webbink, 2005, for a detailed explanation of the endogeneity problem in these studies).

Some of the more recent studies that overcome the endogeneity problem find a positive impact of class size, school hours and peer group effects (e.g., Krueger, 1999). The impact of other characteristics, such as teacher training and computer use, either remains non-significant or exhibits mixed results (e.g., Angrist and Lavy, 2002; Webbink, 2005; Barrera-Osorio and Linden, 2009).

### ***ICT Investments and Students' Performance***

Research on the contribution of ICTs to students' performance has also produced mixed results. Early studies on the use of computers in the classroom report positive effects on students' performance, but are often criticized either because they fail to account for endogeneity or because they report effects with small magnitudes (Cuban and Kirkpatrick, 1998; Webbink, 2005).

More recent work overcomes the endogeneity problem by exploiting exogenous sources of variation in computer use. Angrist and Lavy (2002) present the first study along these lines. They exploit a randomization (determined by a lottery) in the timing of school computerization in Israel. They find no effect on students' performance, except for a negative effect in math exam scores for 8<sup>th</sup> graders. Goolsbee and Guryan (2006) study the impact of subsidizing schools' Internet access and find no evidence that more classrooms with Internet access has an impact on students' performance, as measured by the Stanford Assessment Test (SAT). Leuven et al. (2007) exploit a discontinuity in a subsidy given to schools in the Netherlands. In 2000, Dutch schools in which more than 70% of the students were considered disadvantaged were eligible to receive a subsidy to acquire computers. Using a differences-in-differences framework, they find that this subsidy had a negative impact on students' performance, especially on girls. Malamud and Pop-Eleches (2010) exploit a discontinuity in a subsidy provided in Romania in 2008. This subsidy would allow low-income families to acquire a home computer. They find that the students of families that used this subsidy (households that indeed bought a home computer) had significant lower school grades in Math, English and Romanian. They also find that these students had higher scores in tests of computer skills and in self-assessment tests in computer fluency.

An exception to this recent trend of non-significant or negative results is provided by Machin et al. (2007). The authors exploit a 2001 policy change in the rules governing ICT investment in different regions in the UK. This change created a quasi-experiment setting with winners and losers among the regions. They find evidence of a positive effect of ICT investment in elementary schools.

A few studies show positive effects of computer-aided learning on students' performance (e.g., Rouse and Krueger, 2004; Banerjee et al., 2007; Barrow et al., 2009). Rouse and Krueger (2004) study the results of a randomized experiment on the use of a specific software (FastForWord) designed to improve language or reading skills. Their results suggest that the use of this software improves some aspects of students' language skills, but this does not necessarily translate into better language acquisition and reading skills.

Banerjee et al. (2007) report the results of randomized experiments in schools in urban India aimed at improving the test scores of students lagging behind. One of such projects consisted in using a computer-assisted program aimed at improving math scores. They find that math scores increased by 0.47 of a standard deviation, but this result fades to 0.1 of a standard deviation one year after the end of the project. These results did not seem to spillover to other subjects.

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<sup>1</sup> For example, Krueger (2003) challenges Hanushek (1986)'s methodology.

Barrow et al. (2009) find that students randomly assigned to a computer-aided instruction program scored significantly higher in an algebra and pre-algebra test, than those that were not assigned to the program. They ran the experiments between 2003 and 2005 in 17 schools (146 classes) in the U.S. The authors also hypothesize that this effect comes from the increased individualized instruction, based on the evidence that the computer-aided instruction was more effective in larger classes.

In summary, studies that properly account for endogeneity issues still lack. The few that do so report mixed results. In any case, most studies published so far look at the impact of investment in ICTs on student's performance and not at the impact of actual ICTs usage on the latter. Moreover, most of these studies pertain to the availability of ICTs in general. They do not look at the impact of a specific technology. This paper looks at the impact of *actual* broadband use on a real school environment.

### ***Measuring Education Outcomes***

There have been two main approaches on how to evaluate the effects of education inputs on students' performance (see Card and Krueger, 1996b, for a review on school resources and student outcomes). One is to look at how school resources determine school attainment and posterior earnings (e.g., Guryan, 2003; Card, 1993; Card and Krueger, 1996a). This approach provides a good measure of productivity, but it is hard to implement. First, students' wages need to be observed several years after they have been subject to a given set of educational inputs. Second, different regions may offer different rewards to skills, which complicates the analysis by requiring region-specific controls. . Therefore, despite offering a good measure to assess the true impact of resources in education, only a few studies manage to pursue this line of research.

The most common approach is to look at how school resources determine test scores (e.g., Angrist and Lavy, 2002; Goolsbee and Guryan, 2006; Leuven et al., 2007; Machin et al., 2007). However, test scores may not reflect all the skills acquired by the students while in school and thus will not reflect well how students will perform in a work environment. In fact, there is evidence that test scores explain very little on wage equations (Murnane et al., 1995). Nevertheless, most of the studies use test scores as a measure of student performance mainly because they are easy to obtain and provide a standard way to do so<sup>2</sup>.

## **Broadband in Portuguese Schools**

### ***Broadband Internet Provision to Schools***

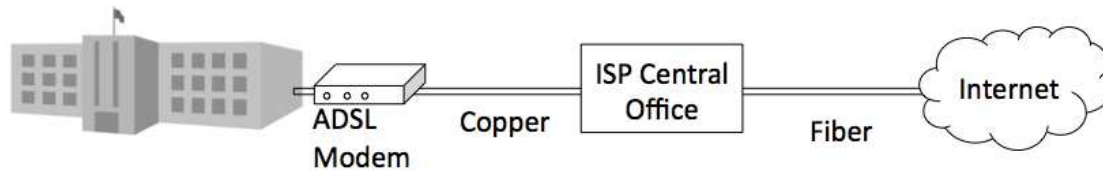
In Portugal most of the schools are public schools, funded either by the Central or the Local Government, with limited autonomy on how to manage their resources. The provisioning of Internet to schools has been managed by FCCN - the Portuguese National Foundation for Scientific Computation. FCCN is a private foundation, under the tutelage of the Ministry of Science, Technology and Higher Education, that runs the National Research and Education Network (NREN). The NREN connects all schools, institutions of higher education and research labs in the country. The same institutional model is followed by a number of other European countries, each having its own NREN. NRENs interconnect forming a trans-European NREN, called the GÉANT network.

In the European context, Portugal has been in the forefront of Internet provisioning to schools. Since 1997, Portugal has launched different programs to connect its schools with either dial-up and later with ISDN connections. In 2004, the same Ministry launched another major initiative, this time aimed connecting all school with broadband ADSL. Monthly connectivity costs were supported by City Halls and the Central Government as before. This project was completed by January 2006, despite the fact that only less than 15% of the schools had migrated to ADSL before

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<sup>2</sup> Also, typically students have incentives to perform well in tests because test scores often determine whether students can continue their studies or need/must drop from school.

July 2005<sup>3</sup> (UMIC, 2007). Most schools (>95%) received a DSL modem from FCCN and an ADSL connection of at least 1 Mbps over the copper line that connects them to the ISP's Central Office (COs) from which FCCN buys connectivity to the Internet backbone (Figure 1). The remainder of the schools, where this speed could not be offered, got a symmetric 256K ISDN connection to the Internet.



**Figure 1: Broadband schools' connection to the Internet. Schools connect through a copper line to the ISP's central office. From there, the ISP ensures connectivity to the Internet backbone through fiber.**

### *Internet Use at School*

We conducted a number of informal interviews with teachers in 8 different schools in order to learn more about how Internet is used in schools. We found that students and teachers use broadband Internet in different ways and intensities across schools. Some teachers are comfortable with using ICTs in the classroom and consider the Internet as a good tool to capture the students' interest and to improve the learning process<sup>4</sup>. Other teachers look at the Internet as just another resource that students can use but were critical about it<sup>5</sup>. Differences in skills and in the attitude of teachers towards the Internet translate into significant differences on how students get to use the Internet in the classroom.

School-specific Internet access policies may also explain part of the differences in the pattern of Internet usage across schools. While some schools provide an open wireless network that can be accessed by any computer, such as students' laptops, other schools have their wireless network closed to all but the school computers. Some schools block only a restricted set of web sites (mainly adult content sites), while other schools block a whole range of sites considered inappropriate in a school context<sup>6</sup>. These factors influence how students use the Internet at school and, consequently, their incentive to bring their laptop to school. Students of some schools bring their laptops several days a week to school and use them pervasively, while in other schools students seldom make use of their own laptops at school.

Finally, the time that students spend at school after classes is yet another aspect that might explain variations in Internet use across schools. In some schools students usually stay at school after class time, while in other schools

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<sup>3</sup> No data are available on the number of schools that had already purchased broadband Internet from the market by the time this intervention took place. However, there are reasons to believe that only a small fraction of schools did so. First, schools had tight budgetary constraints. Second, FCCN strongly encouraged schools to use the broadband connection provided by the Government. Furthermore, traffic over the broadband connection provided by FCCN is free of charge to schools, so even if some schools had bought a DSL connection before, they had a strong incentive to shut it down and use only the former one. Therefore, the broadband usage over the Internet connection provided by FCCN seems to be a good proxy for the school's overall broadband usage.

<sup>4</sup> Some of the teachers interviewed referred that students engage more in discussions and are more motivated when Internet is used in class.

<sup>5</sup> One of the teachers interviewed pointed out that he had difficulty in explaining to students that Wikipedia is not a reliable source of information and that they should always check their sources.

<sup>6</sup> Video, chat, social network and adult content sites are among the categories most often blocked.

most students leave school right after classes. Students that stay at school after hours often do so to use the school's computers and their Internet connectivity, most likely, in some unsupervised way. All in all, there is a wide variation across schools on how students use broadband Internet. Teacher knowledge and attitude towards the use of ICTs in the classroom, school's Internet and wireless network access policies, time spent at school after classes, and the number of students that access the Internet out of school, are some of the factors that contribute to such a variation.

## Data

School traffic data were obtained from the monitoring tools set up by FCCN. For the ISDN project, we obtained data for all ISDN sessions between November 2002 and January 2005 for all schools in the country. For the ADSL project we obtained monthly reports were available. These reports include download and upload traffic per school between November 2005 and June 2009. School traffic is measured at the school's edge router and consists of all traffic exchanged between the school and the Internet. For our measure of school Internet usage, we average out the total monthly traffic (upload plus download) over the entire academic period<sup>7</sup>.

Internet usage in schools grew significantly since the introduction of ADSL in late 2005. Before that, it has been pretty small (see Figure 2), probably because the ISDN connections could not support more traffic. Inbound traffic is the major contributor for this increase; outbound traffic remains relatively little. Internet use per student displays high variability across schools. Figure 3 depicts a histogram across schools for 2009. The reasons for such a high variability are explained in the previous section.

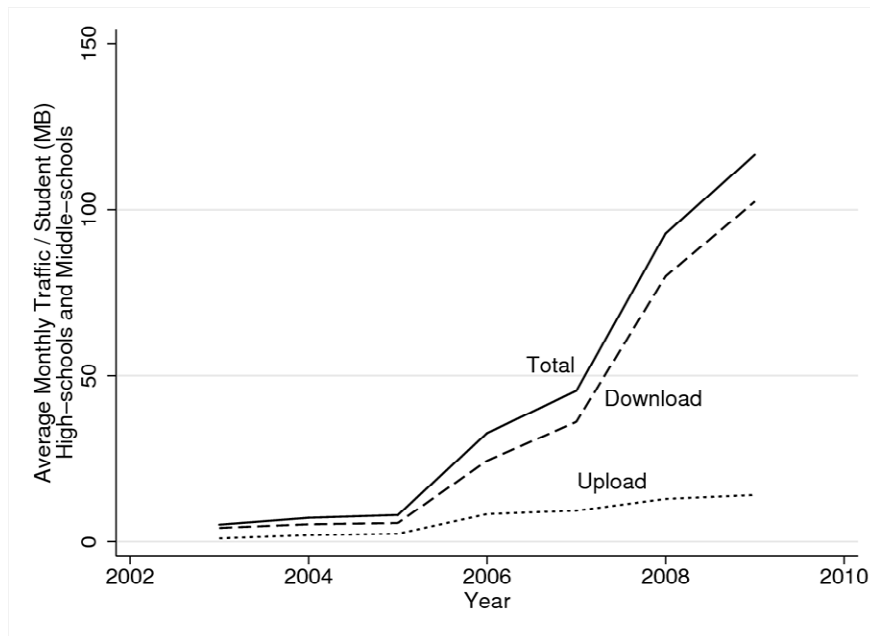
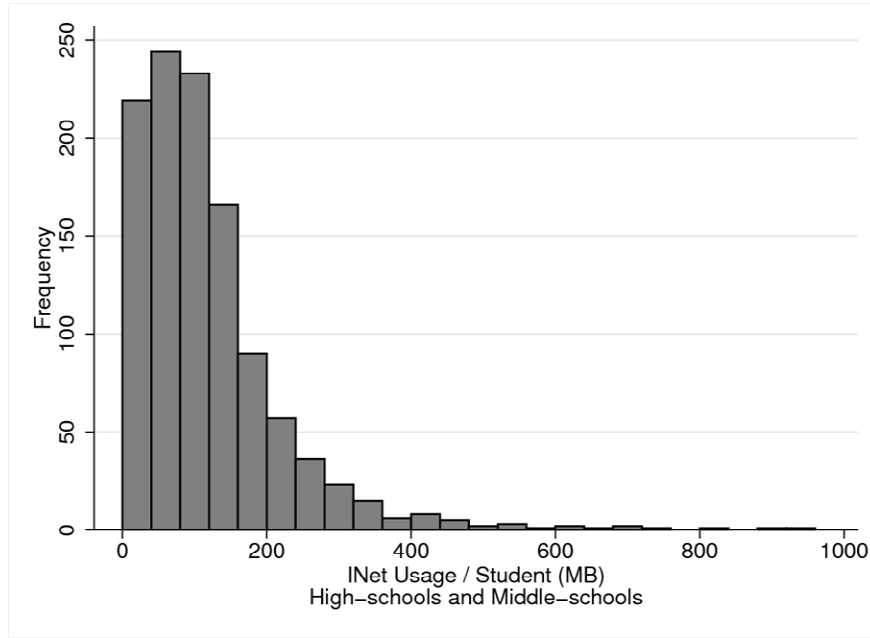


Figure 2: High school and middle school Internet traffic evolution (2003-2009).

<sup>7</sup> We use as academic year the period between September and June.



**Figure 3: High school and middle school monthly average Internet use per student in 2009.**

Performance is measured by the school’s average score at the 9<sup>th</sup> grade and at 12<sup>th</sup> grade national exams. The Ministry of Education publishes anonymous disaggregated data at the exam level since 2005, including information on exam score, course, gender, and age of the examinee. 9<sup>th</sup> graders are examined in two subjects, Portuguese and Math, and their exam scores constitute part of their final score on that subject and might determine whether the student graduates. For the 12<sup>th</sup> graders, each student takes one final examination per core class she is enrolled. Final examinations are a requirement to complete a high-school degree and are also an important part of each student’s application to higher education: exam scores contribute to as much as 50% of students’ rankings in their application to the University. Therefore, students have clear incentives to perform well in both the 9<sup>th</sup> grade and in the 12<sup>th</sup> grade national exams.

Figure 4 shows average exam scores for both the 9<sup>th</sup> and the 12<sup>th</sup> grades normalized to a 0-100 scale<sup>8</sup>. Average exam scores have also increased from 2005 to 2009, both in the 9<sup>th</sup> and in the 12<sup>th</sup> grade, which is consistent with a positive impact of Internet on students’ performance. Alternative explanations for this rise include unobserved factors – such as special subsidies to some schools – or simply because exams became easier with time.

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<sup>8</sup> 12<sup>th</sup> grade exam scores are originally published in a 0-200 scale (with increments of 1) while 9<sup>th</sup> grade exam scores are published in a 1-5 scale (with increments of 1).

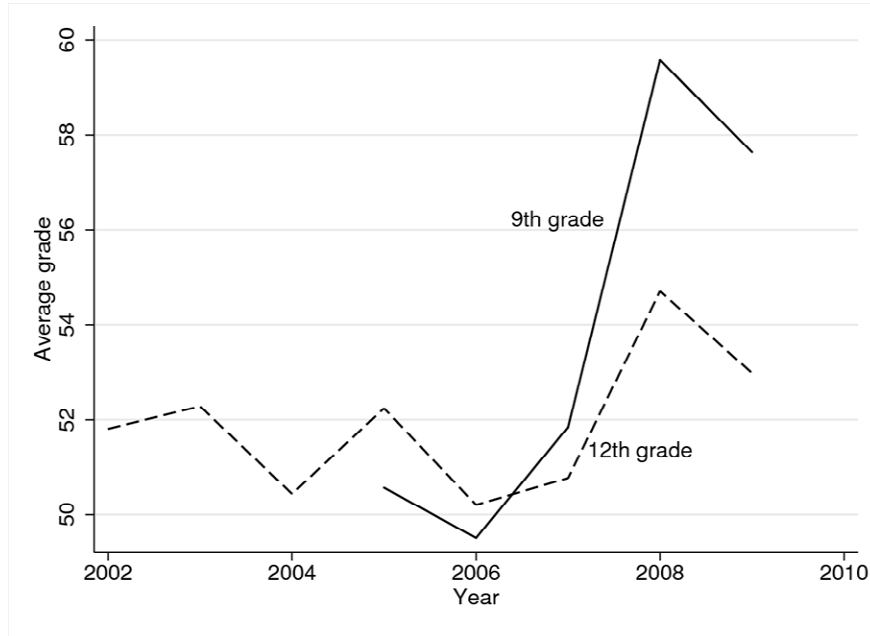


Figure 4: 9<sup>th</sup> and 12<sup>th</sup> grade average exam scores evolution (2002-2009).

Finally, regional data were provided by the Portuguese National Statistics Institute. These data include population density (2001 census data; at the civil parish level), average earnings and regional dropout rate (2005; at the municipality level). Table 1 presents summary statistics of these variables for schools with 9<sup>th</sup> grade students.

Table 1: Summary statistics for schools with 9<sup>th</sup> grade students.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Avg. Grade 2009 (0-100)	987	57.20	5.057	34.29	74.71
Avg. Grade 2008 (0-100)	985	59.05	4.844	39.23	81.60
Avg. Grade 2005 (0-100)	962	49.95	4.906	26.25	69.58
INet Usage 2009 (GB)	987	65.50	45.63	3.79e-04	295.6
INet Usage 2008 (GB)	987	50.82	35.78	0.0648	223.1
INet Usage 2009 / Student (GB)	987	0.117	0.0955	4.22e-07	0.800
INet Usage 2008 / Student (GB)	987	0.0897	0.0877	3.61e-05	1.766
Distance (Km)	987	0.979	0.705	0.0472	5.134
Students	987	683.9	349.0	72	2,826
ln(Pop. Density)	987	6.337	1.752	1.560	9.935
ln(Earnings 2005)	987	6.637	0.217	6.257	7.305
Dropouts (%)	987	2.280	1.630	0	14.46

## Empirical Specification

School performance is assumed to depend on Internet use, on socio-economical factors, such as average earnings and literacy rates in the region, as well as on school-specific unobserved factors, such as the quality of teachers and of other resources. This relation can be expressed by the structural equation

$$p_{it} = \delta_0 + \omega I_{it} + \mathbf{X}_i \boldsymbol{\beta} + c_i + u_{it} \quad (1)$$

where  $p_{it}$  represents the performance of school  $i$  at time  $t$ ;  $\omega$  is the effect of Internet use on school performance, our parameter of interest;  $I_{it}$  represents Internet usage in Gigabytes per month;  $\mathbf{X}_i$  is a row vector with school- and region-specific control variables<sup>9</sup>;  $\boldsymbol{\beta}$  is a parameter vector;  $c_i$  is an unobserved time-constant school specific effect; and  $u_{it}$  is a random error term.

This is the classic fixed-effects specification. Specifying a separate dummy for each school in the form of  $c_i$  allows for controlling for school-specific unobserved factors. Alternatively, we can write this as a first-differences model by differencing both the dependent and independent variables. We use three- and four-year differences, which allows for looking at the accumulated effect of Internet on students' performance, overcoming problems with a year-by-year approach, such as noise and small effects within the first years of the broadband deployment. The first-differences specification looks like

$$\Delta p_{it} = \delta + \omega \Delta I_{it} + \mathbf{X}_i \boldsymbol{\beta} + \Delta u_{it} \quad (2)$$

In general, if  $\mathbf{X}_i$  terms are not time varying, they will get differenced out. However, to account for the fact that some school-specific variables in  $\mathbf{X}_i$  might also drive the change in performance and Internet use, we include the baseline values of  $\mathbf{X}_i$  as additional controls. Furthermore, we assume broadband use to be zero in 2005, our baseline year, which makes the change in Internet use ( $\Delta I$ ) equal to the Internet use in the second period of analysis<sup>10</sup>. Note also that  $\delta$  in equation 2 captures the average change in the exam scores over the period. For example, a  $\delta > 0$  will capture the fact grades increased because exams got easier.

We use three- and four-year differences to capture the accumulated effects of Internet use, because we believe that differences in broadband Internet usage from year to year within a school hardly have an immediate impact on that given year's exam scores. We estimate difference specifications by running separate regressions for the 2005-2008 and 2005-2009 differences. We have also estimated pooled 2005-2008 and 2005-2009 first-difference regressions. Both approaches yield the same qualitative results<sup>11</sup>.

### **Identification**

Despite the first-differences setting and the controls in  $\mathbf{X}_i$ , potential unobserved *time-varying* factors may result in increased Internet usage and better (or worse) exam scores in 2008 and 2009, leading to inconsistent estimates for  $\omega$ . For example, a change in the resources available to a school<sup>12</sup>, internal organization or technical savviness, might have influenced both Internet usage and scores during the period of analysis. The school-specific dummies do not capture these time-varying unobserved effects and therefore our estimates might become inconsistent.

We ensure identification by exploiting the variation in the quality of Internet connections across schools as an exogenous source of variation in our setup. Schools that benefit from a better connection to the Internet are more likely to use it more and therefore more likely to register more traffic. With ADSL, a greater distance between the customer's premises and the ISP's Central Office (CO) results in a lower transfer bit-rate. Therefore, schools further away from the CO enjoy worse connectivity. Such degraded performance decreases the attractiveness of the

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<sup>9</sup> We include school size, measured by the number of students in each school, population density, earnings and dropout rate of the region where the school sits as controls variables.

<sup>10</sup> Broadband was brought to schools during the second half of 2005. Thus, it is safe to assume there was no broadband Internet use for most of 2005, and in fact Internet use in 2005 is close to zero when compared to 2008 and 2009 levels. Additionally, we have used the exact differences and obtained similar results.

<sup>11</sup> When pooling differences, we add a 2009 year-dummy and an interaction term between Internet use and the year 2009 to control for different effects in each of the differences. Additionally, we aggregate standard errors at the school level.

<sup>12</sup> During the period of analysis students were awarded laptops, under a parallel Governmental program. This may have changed both Internet usage patterns and scores.

broadband connection at the school and thus the amount of traffic exchanged with the Internet<sup>13</sup>. Consequently, we use line-of-sight<sup>14</sup> distance between the school and the closest ISP's CO as a proxy for connection quality, and estimate a two stage least squares (2SLS) specification as follows:

$$\Delta p_{it} = \delta + \omega \Delta I_{it} + \mathbf{X}_i \boldsymbol{\beta} + \Delta u_{it} \quad (3)$$

$$\Delta I_{it} = \mu + \eta \text{Distance}_i + \mathbf{X}_i \boldsymbol{\beta} + \varepsilon_{it}$$

## Results

Moreover, in Portugal most schools are usually close to the CO. This ensures that there are no significant school specific differences due to distance. Distance, in particular, is a particularly good instrument because grades in 05 are unaffected by distance.

We report results only for the 9<sup>th</sup> grade because our instrument does not seem to be effective for 12<sup>th</sup> grade schools. In Portugal, 12<sup>th</sup> grade schools are essentially very close to the ISP's COs, which does not provide enough variation for our instrument to work.

### *OLS results*

9<sup>th</sup> grade OLS results show a positive and statistically significant relationship between change in scores and change in Internet use for between 2005 and 2008 and a positive but not significant relationship between 2005 and 2009 (see Table 2). The 2008 estimate suggests that the average broadband use of 51 GB/month in schools in 2008 is associated with an increase of 0.9%<sup>15</sup> in the average exam scores, i.e., an increase of a tenth of a standard deviation in 2008 scores. Control variables estimates seem reasonable. Namely, schools with more students have increased their average by less than smaller schools and schools in regions with higher dropout rates have also increased their scores by less.

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<sup>13</sup> Data obtained from [http://whirlpool.net.au/wiki/?tag=DSLAM\\_speeds](http://whirlpool.net.au/wiki/?tag=DSLAM_speeds)

<sup>14</sup> Line-of-sight distance is calculated from information on the GPS coordinates of both schools and the ISP's COs.

<sup>15</sup> Sample average score in 2008 is 59.2. See Table 1.

**Table 2: Regressions for the 2005-2008 and 2005-2009 changes in 9<sup>th</sup> grade performance as a function of change in Internet use.**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	2008 OLS	IV: 1st Stg	IV: 2nd Stg	2009 OLS	IV: 1st Stg	IV: 2nd Stg
Δ INet Usage (GB)	0.0108** (4.40e-03)		<b>-0.103**</b> (0.0458)	4.35e-03 (4.01e-03)		-0.0344 (0.0343)
Students	-1.24e-03** (5.35e-04)	0.0408*** (5.18e-03)	3.53e-03 (2.21e-03)	-1.00e-03* (5.57e-04)	0.0462*** (6.86e-03)	8.46e-04 (1.83e-03)
ln(Pop. Density)	0.0495 (0.142)	-3.536*** (0.866)	-0.386 (0.245)	-0.114 (0.121)	-3.769*** (1.119)	-0.276 (0.204)
ln(Earnings 2005)	-0.188 (0.996)	-26.52*** (6.005)	-3.147* (1.742)	-2.302** (0.901)	-55.09*** (7.824)	-4.404** (2.235)
Dropouts (%)	-0.248** (0.108)	-0.714 (0.558)	-0.343** (0.135)	-0.182 (0.121)	-0.398 (0.742)	-0.204 (0.130)
Distance (Km)		-4.563*** (1.166)			-6.424*** (1.733)	
Constant	10.90* (6.235)	226.4*** (38.86)	35.94*** (12.89)	24.07*** (5.815)	430.2*** (50.18)	40.35** (16.64)
Observations	976	976	976	963	963	963
R-squared	0.016	0.174		0.026	0.189	

Robust standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### ***Instrumental Variables Results***

Our OLS estimates may be spurious due to time-varying unobserved effects. Namely, a change in the internal organization of the school or new resources that a school might have obtained during the period of analysis can influence both test scores and Internet use. To over this problem, we estimate our instrumental variable specification as given by equation (3). The first stage of the IV specification yields a negative and significant coefficient for distance, which shows that our instrument behaves as expected. The IV specification yields a negative sign for the broadband usage coefficient, significant at the 5% level for the 2005-2008 regressions (see Table 2). We do not find a positive effect of broadband use on students’ performance anymore. In fact, we find that broadband use adversely affects performance.

Moreover, this effect seems to be reasonably large. The 2008 estimate suggests that the average broadband use in schools of 51 GB/month in 2008 leads to a decrease of 8.9%<sup>16</sup> in the average exam scores, i.e., a decrease of about one standard deviation in 2008 scores. This effect is still negative for the 2005-2009 period, though it becomes smaller in magnitude and statistically insignificant, which seems to suggest that it might wear off with time.

In summary, for OLS specifications, we find no effect or a positive effect of Internet use on students’ performance. However, once we instrument for the Internet use, we consistently find a strong and negative effect. Therefore, our results seem to suggest that broadband use in school is generally detrimental, at least right after its introduction into the school’s environment. Certainly, schools need to adapt to fully benefit from this technology. Such adaptation is a complex process that hardly yields results in the short-term.

<sup>16</sup> Sample average score in 2008 is 59.2. See Table 1.

### Gender-specific results

Distinct groups of students might use the Internet to perform different activities, which would affect them differently. For example, we expect students that tend to perform more distracting activities to become more adversely affected with increased Internet use.

According to a survey administered by the Portuguese Telecom Regulator (ANACOM)<sup>17</sup> to 659 students<sup>18</sup> in 2008 (337 girls and 322 boys between 10<sup>th</sup> and 12<sup>th</sup> grades<sup>19</sup>), boys and girls tend to perform different sets of activities on the Internet (see Table 3). For instance, a higher percentage of boys reported watching YouTube videos and TV, listening to online radio and music, and playing online games. Most of these differences are statistically significant. Thus, according to our framework, if we consider Games, TV, Music and MySpace & YouTube distracting activities, we should observe that boys suffer more from the adverse effect of increased Internet use than girls. We test this hypothesis by calculating separate average scores for boys and girls, and running separate regressions for each of them.

**Table 3: Internet activities by gender (%). Boys are more likely to participate in activities considered as distracting.**

Activity	Male	Female	Diff.
Email	93.1	89.5	3.7**
VOIP	14.1	9.3	4.7**
Chat	89.4	88.2	1.1
MySpace & YouTube	75.9	61.7	14.2***
General Information	59.4	57.8	1.5
News & Magazines	43.8	23.8	20.0***
Search for Scientific Info	67.5	74.1	-6.6**
Radio	48.4	42.5	6.0*
TV	27.8	13.9	14.0***
Music	75.6	52.7	22.9***
Games	71.9	34.9	36.9***

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1 (t-tests eq. var.)

Table 4 shows the results from separate IV regressions for 9<sup>th</sup> grade boys and girls and for 2005-2008 and 2005-2009 differences. Boys seem to be the most affected group in 2008. In fact, in 2008, this effect is not statistically significant for girls. The 2005-2008 estimates suggests that the average broadband use in schools of 51 GB/month in 2008 leads to a decrease of 12.1%<sup>20</sup> in the average exam scores, i.e., an decrease of about 1.5 standard deviations in 2008 scores. These results are consistent with our hypothesis that boys should be the most affected group, given they perform more distracting activities on the Internet. This effect reduces in magnitude and loses significance for both boys and girls in the 2005-2009 difference.

<sup>17</sup> ANACOM provided us with disaggregated data from the survey, which allowed us to calculate separate statistics for boys and girls. A public report of this study is available at ANACOM's website (ANACOM, 2008).

<sup>18</sup> 652 students (332 girls and 320 boys) answered the question about activities performed in the Internet.

<sup>19</sup> Note that the survey was performed to students from the 10<sup>th</sup> to the 12<sup>th</sup> grade and we are applying its results to 9<sup>th</sup> grade students' scores. We believe student's behavior does not change in a radical fashion from the 9<sup>th</sup> to the subsequent grades, and thus it is still informative to use these data as we do.

<sup>20</sup> Sample average score in 2008 is 59.2. See Table 1.

**Table 4: Changes in 9<sup>th</sup> grades as a function of change in Internet usage. Separate results for boys and girls.**

VARIABLES	(1)	(2)	(3)	(4)
	2008 Male	Female	2009 Male	Female
INet Usage (GB)	<b>-0.141**</b> (0.0646)	-0.0744 (0.0538)	-0.0477 (0.0418)	-0.0321 (0.0450)
Students	5.82e-03** (2.94e-03)	2.03e-03 (2.52e-03)	1.59e-03 (2.22e-03)	8.12e-04 (2.30e-03)
ln(Pop. Density)	-0.596* (0.313)	-0.300 (0.285)	-0.284 (0.247)	-0.419 (0.261)
ln(Earnings 2005)	-2.902 (2.486)	-3.356** (1.711)	-5.576* (2.970)	-3.668 (2.634)
Dropouts (%)	-0.287 (0.179)	-0.424*** (0.131)	-0.176 (0.155)	-0.245 (0.156)
Constant	35.02* (18.41)	37.45*** (13.29)	47.89** (21.96)	37.01* (20.02)
Observations	966	965	955	952

Robust standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### **Low Performance vs. High Performance Schools**

We now study which schools suffer more with the introduction of broadband Internet. For that end, we split our sample of schools in quartiles based on their 9<sup>th</sup> grade average exam score in 2005, thus just before the deployment of broadband Internet, and apply our IV setup separately for each group of schools.

Table 5 shows that schools in the lowest quartile are the ones that get more negatively affected by broadband in 2008<sup>21</sup>. The adverse effect loses statistical significance for all the other quartiles. The effect is still negative for schools in the 2<sup>nd</sup> and 3<sup>rd</sup> quartile, though it loses magnitude from the 1<sup>st</sup> quartile to the 2<sup>nd</sup> quartile and from the 2<sup>nd</sup> quartile to the 3<sup>rd</sup> quartile. The effect becomes positive, though not statistically significant, for schools in the 4<sup>th</sup> quartile.

This suggests that broadband Internet use does not affect all schools in the same way. Schools that were already worse-off before the deployment of broadband in 2005 are the ones that suffer the most. This shows that schools might need a certain level of maturity to be able to effectively counter the disruptive effect that introducing broadband Internet into schools might entail.

<sup>21</sup> 2009 regressions show consistent coefficients but no significance in any of the quartiles.

**Table 5: Change in 9<sup>th</sup> grade performance as a function of change in Internet use (2005-2008 differences).**

VARIABLES	(1) 1st Quartile 2005	(2) 2nd Quartile 2005	(3) 3rd Quartile 2005	(4) 4th Quartile 2005
INet Usage (GB)	<b>-0.118*</b> (0.0621)	-0.0570 (0.0449)	-2.87e-03 (0.0655)	0.175 (0.398)
Students	6.34e-03* (3.61e-03)	8.05e-04 (2.85e-03)	7.03e-04 (2.57e-03)	-6.52e-03 (0.0123)
ln(Pop. Density)	-1.078*** (0.466)	-0.172 (0.330)	0.201 (0.320)	0.871 (0.694)
ln(Earnings 2005)	-1.113 (2.060)	0.608 (1.573)	1.508 (2.697)	6.833 (18.63)
Dropouts (%)	-0.213 (0.257)	-0.406*** (0.141)	-0.344 (0.217)	0.00655 (0.954)
Constant	28.53** (12.87)	10.06 (11.09)	-2.713 (20.66)	-48.93 (139.9)
Observations	254	265	253	204
R-squared			0.052	

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

## Conclusion

While there is a generalized belief that providing schools with computers and broadband Internet improves the quality of education and, consequently, increases productivity levels and wages, reliable empirical evidence of this fact has been hard find. Our paper uses a comprehensive dataset on broadband Internet use in every school in Portugal to examine its impact on the students' performance. Using the distance between the school and the ISP's central office as an instrument for broadband Internet use, we find evidence that broadband hurts the score of 9<sup>th</sup> grade students, as measured by national exams scores. The magnitude of this effect is significant (8.9%).

An evaluation of the effects of Internet use on boys and girls separately shows that the adverse effect tends to be reinforced for boys and weakened for girls, when compared to the pooled estimates. Their grades reduce, on average, 12.1% between 2005 and 2008. This seems to be justified by the fact that boys tend to engage more in distracting activities than girls do. In addition, we find also that schools are not uniformly affected by broadband Internet use. Schools that were worse-off before broadband deployment suffer more.

Broadband may still be beneficial for students in ways that are not captured by test scores, which our study cannot appreciate. For example, broadband deployment in schools allows students to be exposed to sets of technologies that they will most likely use later in their future professional and personal lives. These kinds of benefits are difficult to measure. Nevertheless, we must emphasize that today schools' performance is a key metric largely used to setup education policy in any country.

Our study, applied to the case of Portugal, shows that the introduction of broadband in schools does not necessarily contribute to an increase in students' performance, as measured by national exam scores. The introduction of this technology in the school environment should be accompanied by complementary policies, such as providing ICT training for teachers and implementing tools that moderate Internet use at school.

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