“The Effects of the E-Rate Internet Subsidies in Education”

Michael R. Ward

University of Texas at Arlington

mikeward@uta.edu

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Abstract

Starting in 1998, the E-Rate program has provided up to $2.25 billion annually to subsidize Internet access in schools and libraries serving low income populations in the US. I analyze the effect of E-Rate subsidies on educational outcomes for Texas high schools over the 1994-2004 time period. I find significant college entrance exam improvements at schools serving predominantly high income students but lower standardized test scores at these schools. At schools serving predominantly low income students, I find broad improvements in the scores on various standardized tests but minor changes in college entrance exam scores. Implicitly, the program appears to cost on the order of $400 per pupil per percentage increase in correct answers on standardized tests. These results suggest that the E-Rate program's targeting of low income students may tend to reduce income-based test score differences, but that it appears to be an expensive way to do so.

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I. Introduction

The primary focus of US Telecommunications Act of 1996 was to codify changes to telecommunications competition policy. One aspect of the Act that was not related to competition policy, however, was the creation of a $2.25 billion per year fund from which school districts and libraries could hope to recover most of the costs of providing Internet and related telecommunications services. This new federal subsidy, called the E-Rate program, was intended to increase US students' ability to work with the latest information technology. My estimated relationships between educational outcomes and E-Rate subsidy levels largely confirm that the targeted students attain higher test scores. However, they magnitude of the change in test scores suggests that the E-Rate program may not be a cost-effective way of increasing educational outcomes.

The E-Rate program was designed to provide larger subsidies to schools serving more economically disadvantaged students where educational resources, including IT infrastructure, are thought to be lowest. In this way, the E-Rate program was meant to help bridge the so-called "digital divide" between the population that has access to and uses computers and the Internet and the population that does not. Since this divide tends to separate based upon income and racial lines, E-Rate program implementation includes a fair degree of implicit progressivity.

While the progressivity of the implementation of the E-Rate subsidy program may have been driven by equity issues, doing so may also have targeted a group with higher expected marginal impacts. Consumer decisions to own a home computers and obtain Internet access a strongly related with income (Rappaport, Alleman and Taylor, 2004). Higher income students are more likely to have computers and Internet access at home. For them, the marginal benefit of school based IT might be negligible. In contrast, in predominantly low income areas, many students may only be able to access computers and the Internet at school. If the benefits are largest among low income students and low income students are less likely to enter college, then changes in college preparedness measures alone may mask much of students' improved educational attainment. Also, differential educational impacts by income group suggest that targeting subsidies, as the program has, may generate larger benefits per dollar spent than if subsidies were provided uniformly across schools.

This study measures the educational outcomes related to implementation of the E-Rate program by tracking performance measures in schools in Texas. A consistent set of data on characteristics, performance measures, and staffing characteristics for about 1,500 high schools for the years 1994-2005 is available from the Texas Educational Agency (TEA) and the Texas Higher Education Coordinating Board (THECB). Since the E-Rate program began in 1998, this allows for establishment of a school or district level "baseline" before implementation of the program. Moreover, these data exhibit variation in treatment because not all districts, or schools within a district, received E-Rate subsidies and those that did, received subsidies of differing magnitudes. Finally, the TEA data allow one to disaggregate the schools by how many low income students they serve and average test scores based on the income status of students taking them.

The major result of the analysis is to find improvements in educational outcomes from an IT intervention in education that has not been detected in other economic studies (Fuchs and Woessman (2002), Angrist and Lavy (2002), and Goolsbee and Guryan (2006)). Beyond this, I uncover disparate effects for schools serving predominantly high income students versus those serving low income students. Education gains at high income schools are in the form of better college preparedness at the cost of lower standardized test scores. Education gains at low income schools are in the form of broadly higher standardized test scores with little, or perhaps worsened, effect on college preparedness. The effect on the average student is found almost exclusively in improved standardized test scores. While these average improvements are broadly based and statistically significant, they may not be economically important. That is, the implicit cost of an average one percent increase in test scores costs on the order of $400, about 7-10% of the current per pupil funding level over the sample period.

II. Background

Educators have largely embraced information technology in the classroom. In recent years, information technology has become an increasing part of a general education curriculum. There are now at least two scholarly journals devoted to the study of IT and education, *The Journal of Technology, Learning and Assessment* and *Journal of Research on Technology in Education*. In these journals, education researchers report an overwhelming body of research that finds positive educational outcomes from IT adoption. For example, Goldberg, et al. (2002) report meta-analysis of 26 studies between 1992 and 2002 of the effect of computers on student writing that finds both quality improvements and more engaged and motivated students.

Representative studies in this field tend to thoroughly examine a small number of students affected by the adoption of a particular IT program. For example, Gulek and Haken (2003) recently followed 259 middle school students who were given laptop computers for three years and found that positive educational outcomes resulted. O'Dwyer, et al. (2005) use test scores of 986 fourth grade students from 55 classrooms in nine school districts in Massachusetts to find that students who reported greater frequency of technology use at school to edit papers were likely to have higher total English/Language Arts test scores and higher writing scores. They also find out that students' recreational use of technology at home was negatively associated with the learning outcomes.

Economists, however, have not been as successful in finding educational outcome improvements from educational IT.[1] For example, Fuchs and Woessman (2002) and Angrist and Lavy (2002) found no impact, or a negative impact, of computers on educational outcomes after controlling for household characteristics.[2] Puma et al., (2002) and Goolsbee and Guryan (2006) find that the E-Rate program increased school district investment in Internet enabled classrooms. Table 1 suggests that, while schools serving lower income students lagged behind, Internet access has become nearly universally available across all classrooms in the US. Goolsbee and Guryan (2006) find that sensitivity of Internet classrooms to the E-Rate was among urban schools and schools with large black and Hispanic student populations. However, Goolsbee and Guryan's (2006) examination of two years of E-Rate experience in California finds no evidence of improved college entrance exam scores from E-Rate subsidies.

There are at least two possible sources for the discrepancies between the findings of educational researchers and economists. First, educational researchers typically study the effects

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[1]For that matter, economists have not found large effects from increased educational resources in general. See for example, Hanushek (1986), Card and Kruger (1996), Hanushek (2003) and Rivkin, Hanushek and Kain (2005).

[2]Fuchs and Woessman (2002)'s result that home computers have a negative effect on outcomes is consistent with the O'Dwyer, et al. (2005) that recreational use lowers learning outcomes.

of small isolated IT experiments while economists examine data that implicitly aggregates many such experiments. These experiments could be susceptible to a number of biases including: selecting better performers into the treatment group, selecting students of better teachers into the treatment group, a temporary increased effort on the part of students or teachers in the treatment group, or a "Hawthorn Effect" in which teachers or students in the treatment group exert more effort due to the researchers' evaluation. While some studies are designed to avoid these biases, where they are present, they will tend to bias upward measures of educational success.

Second, the measurement methodologies used differ considerably. For example, economists tend to place great emphasis on methodologies that control for potential omitted variables and selection biases. A common characteristic of these efforts, and one shared by the present study, is to include standardized data from a large number of treatment and control observations. While education researchers' results may be biased, economists' methodologies that attempt to correct for these issues often result in tests of increased power, perhaps too much power to detect the actual effects. This study is able to detect relatively small improvements only because of a relatively large set of outcome measures and school-year observations. In addition, the results presented below suggest that economists may not have fully appreciated the selection issues.

This study examines educational IT subsidies from the E-Rate Program. This subsidy program provides $2.25 billion annually to all eligible schools and libraries to make access to modern telecommunications and information services more affordable. Schools and libraries approved for the E-Rate Program receive discounts, thereby subsidizing market prices for telecommunication equipment and services. The subsidy can be used for spending on "all commercially available telecommunications services, Internet access, and internal connections." Administrative functions of a library or school may be supported if they are "part of the network of shared services for learning" (Department of Education, 1997). The E-Rate Program supports the acquisition of digital technology infrastructure, including telephone services (basic, long-distance, and wireless); Internet and web site services; and the acquisition and installation of network equipment and services, including wiring in school and library buildings. In the Texas sample used in this study, the breakdown was about 70% of subsidy amounts were allocated for internal connections, 25% for telecommunication services and 5% for Internet Access. The subsidies do not cover computers, software, or databases because they are not directly related to Internet connections (FCC, 2001). Other educational technology—including computer hardware and software, staff training, and electrical upgrades—are not covered under the E-Rate Program.

The E-Rate Program was designed to help schools and libraries gain access to the Internet and other digital technology, especially those serving poorer populations. The program subsidizes a portion of an eligible bid for internet and telecommunications connections and services solicited by school districts. Table 2 shows how the percentage of the bid amount covered by the E-Rate program depends on the percentage of students who are low income and on the school's urban/rural status. Low income is defined in terms of the percentage of students that qualify for the national school lunch program. Schools may apply for the program individually or as a school district, however, the data available here is aggregated to the district level.

III. Methodology and Data

Schools, rather than libraries, receive about 85% or \$1.9 billion of the \$2.25 billion E-Rate funds dispersed annually. By way of comparison, all federal, state, local and other funding for elementary and secondary education came to \$536 billion for 2004-2005. Since this program represents less than half a percentage point increase in school funding, it may be difficult to detect any consequent increase in educational achievement. However, three factors suggest that the actual impact may be detectable. First, these funds are targeted for classroom information and communications technologies which usually represent much less than 5% of a school district's costs. Second, not all schools receive E-Rate funds and, those that do, may not receive the funds every year. In fact, the average E-Rate grant receiving district was awarded about \$100 per student in the district, or, in Texas, nearly 2% of the average annual expenditure per student. Third, the E-Rate program is targeted toward economically disadvantaged schools within districts. This subset of all schools will receive a relatively large portion of the funds. Moreover, these schools tend to have lower levels of expenditure per pupil, especially levels of IT expenditures. These factors suggest that receipt of an E-Rate grant could substantially increase a targeted school's IT budget, and even its total education budget.

These data have natural treatment and control group properties that allow for straightforward interpretation of the effects of the E-Rate subsidy on educational outcomes. Table 3 suggests how the panel nature of these data lend themselves to a difference-in-difference estimation. Outcome data are available both before and after the implementation of the E-Rate program. Thus, we have a pre-treatment period with which to generate a "baseline," or, more precisely, a school fixed effect. Moreover, not all schools have received the E-Rate subsidy.

This cross-sectional variation allows us to compare the change from the baseline between districts and schools that received grants and those that did not.

The estimator also must take into account the likely time series nature of IT on educational attainment and of these grants. E-Rate subsidies represent both current consumption of telecommunications services and a durable investment in IT, and possibly teaching styles associated with IT, that provide a flow of services over a number of years. An educational outcome in any given year could have been affected by grant receipts over the past few years. IT infrastructure may depreciate faster than most durable goods and the effects of these investments are likely to diminish over time. The specification below allows for three years worth of lagged E-Rate subsidies affecting current educational outcomes. Grant receiving districts may receive grants in subsequent years, but also may not. In the data, once grants were available, about half of all grant receiving districts also received grants in the subsequent year. Even when a district receives a grant in subsequent years, the funds may flow to different schools within the district. Almost 15% of districts never received a grant over the eight-year sample period for which they were available. E-Rate subsidies average about 1.2% of a district's total expenditures but the standard deviation of this ratio is about 0.6%. Thus, even among the "treatment group," there is substantial variation in the timing and magnitude of the treatment. Finally, there could be secular trends in the sample, suggesting the inclusion of year dummy variables.

E-Rate subsidies to a school may be only one of many policy interventions. To the extent that they are year or school specific, they should be captured by year and school dummy variables. I am unaware of any reason why other interventions might be correlated with E-Rate subsidies. However, to the extent that they are, one way to isolate their impact is to include the inputs to the educational production function that they affect or that they target. The time and school varying measures I control for are teacher experience and the fraction of low income students.

The measure of E-Rate treatment used here is the E-Rate subsidy amount divided by total expenditures.[3] School level analyses are complicated because the data do not indicate which schools within a district received the funds. Furthermore, school level subsidy funds, if a grant were received, would depend on the percentage of low income students attending the school. For example, in a district with two schools with subsidy rates of 40% and 20%, we would expect two-thirds of the subsidy amount to be spent in the first school. For this reason, for each school, when the district receives a subsidy, I calculate the expected school subsidy amount from the district subsidy amount according to the relative discount rates that the schools would receive due to its percentage of low income students.[4] Measurement error may still occur because I do not know if a particular school was included in a particular grant proposal.

Not only are subsidy amounts larger for low income schools, the expected marginal impact of a given subsidy is expected to be larger for schools serving more low income students. I account for these hypothesized differential impacts by interacting the subsidy measures with dummy variables indicating whether the school serves predominantly high, middle or low income students. These designations are based on the fraction of "economically disadvantaged"

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[3]The results are qualitatively the same if the E-Rate subsidy is measured as dollars per student.

[4]The TEA identifies the fraction of students at a school who are "economically disadvantaged student." This is defined as one eligible for free or reduced-price lunch or eligible for other public assistance which is almost identical to the measure used for calculating E-Rate subsidies.

students the school serves. About one-third of schools, which I designate high income schools, have fewer than 24.4% students classified as "economically disadvantaged" while one-third, designated low income schools, have more than 48.4% of their students so classified.

These considerations above lead to the following regression specification:

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\begin{aligned}
Outcome_{st} \quad = \quad & \sum_{t=1}^{3} \phi_t^H \frac{Subsidy_{st-t}}{Expend_{st-t}} HighIncSch_s \\
+ \quad & \sum_{t=1}^{3} \phi_t^M \frac{Subsidy_{st-t}}{Expend_{st-t}} MedIncSch_s \\
+ \quad & \sum_{t=1}^{3} \phi_t^L \frac{Subsidy_{st-t}}{Expend_{st-t}} LowIncSch_s + \beta X_{st} + \varepsilon_{st}
\end{aligned}
$$

where X includes district dummies, year dummies, average teacher experience, and the fraction of low income students in the district that year, and the square of this fraction. More low income students at a school tends to be negatively associated with average student educational performance independent of interventions. Inclusion of these measures would capture any time varying effect above and beyond school and year fixed effects. The school subsidy amount is apportioned from the district amount as discussed above. With three lags of the variables of interest, the E-Rate variables, the full effect of a subsidy occurs over three years and is measured as the sum of the three coefficients.

Outcome measures include average standardized college admissions scores from the ACT and the SAT and a measure of the percentage of test takers scoring above a critical level associated with moderate college admissions standards.[5] To test for an inducement to take college admissions tests, the fraction taking either the ACT and SAT and the fraction enrolling in

[5]For the ACT, the critical value is 24. For the SAT, the critical value is 1110. Thus, this measure is the percentage of students taking either exam takers who scored above these values.

college are also examined. The percentage of students passing standardized tests was available for tests in reading, writing, and mathematics, and for all students in a school or district and for the subset of low income students in a district or school. Since all students are required to take these tests in preparation for graduation, they are likely to be mostly free of selection issues.[6] However, Texas substantively changed its standardized tests begriming in 2003, allowing for only nine years of consistent data for my sample.[7]

E-Rate data come from the Schools and Libraries reports of the Universal Service Administrative Company (USAC) available on the Internet.[8] Again, Table 3 indicates the frequency at which Texas public school districts received E-Rate subsidies. Educational outcome data come from the Texas Education Agency (TEA) Academic Excellence Indicator System (AEIS) also available on the Internet.[9] College enrollment data are from the Texas Higher Education Coordinating Board (THECB).[10] The analysis includes only high schools because 1) most of the outcome measures pertain to high school students, 2) IT is disproportionately used in high schools relative to junior high and elementary schools, and 3) students exposed to a subsidy in lower level school are likely to attend a high school and thus could be captured by the estimation strategy. By 2005, the TEA had data on 1,667 public high

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[6]Still it is possible that E-Rate subsidies induce poorer performing students not to dropout thus bringing down average scores. This effect, if it exists, is likely to be relatively small.

[7]The Texas Assessment of Academic Skills (TAAS) was the state-mandated assessment of student performance given to Texas public school students from 1990 through 2002. In 2003 the TAKS (Texas Assessment of Knowledge and Skills) was administered for the first time.

[8]See <http://www.sl.universalservice.org/>.

[9]See <http://www.tea.state.tx.us/perfreport/aeis/>.

[10]See <http://www.thecb.state.tx.us/>.

schools in 1,228 Texas public school districts.[11] The match rate between the TEA and E-Rate data was above 98%. Not all high schools reported valid values for all variables of interest. Table 4 provides some summary statistics for the outcome variables used in the analyses.

The fraction of low income students at a school factors prominently into the analysis. Table 5 demonstrates how the outcome measures differ from the third of high schools serving the smallest percent of low income students, the middle third, and the highest third. There is a nearly monotonic decline in a school's student outcomes as the fraction of low income students rises. The college entrance exam scores, in particular, show a dramatic decline with the percent of low income students. For example, the percentage of all students meeting the college exam critical value, that is, the product of the percent taking the exam times the percent of test takers meeting this goal, is 17.0% for the high income schools and only 5.6% at the low income schools. These differences in outcomes suggest differences in educational opportunities and thus are, no doubt, an impetus to an income-based subsidy program, such as the E-Rate program. However, the education of one's children is very likely a normal good and requires some home production. Some differences in outcomes would likely emerge even if educational opportunities were identical across all schools.

IV. Results

Regression results for the usable set of high school campuses are reported for college

[11] In 2004, there were 153 districts with no high schools, 815 with one high school, 171 with two high schools, 31 with three high schools and 58 had four or more high schools.

readiness outcomes in Table 6 and for standardized tests in Table 7.[12] Fixed effects for each school and year are not reported but are typically significant. E-Rate subsidies are captured by nine variables, three covering funds over the past three academic years for each of three sets of schools serving different income groups. The fraction of schools designated as low, middle and high income may not be precisely one-third because the set of schools reporting missing values for different outcome measures varies but does not affect a school's income designation across regressions. Average teacher experience is always associated with higher student achievements and is significant for all outcomes except for standardized test scores for low income students at a school in Table 7. Likewise, controlling for school fixed effects, a greater fraction of low income students at a school generally tends to reduce average school performance at a decreasing rate. The exception again is for standardized test scores of low income students where the effect is positive and sometimes significant in Table 7.

The variables of interest are those relating to the E-Rate subsidies. The sign of an estimate is usually consistent across lags for an income group and always is for significant coefficients. This pattern suggests that the effects of Internet access in the classroom, whatever they are, have relatively long lasting effects. It may also serve as a robustness check against spurious correlation from collinear subsidy measures. This pattern, however, makes it difficult to interpret the full effect over the three year period of a one percent increase in funding for Internet access. To better understand these effects, the estimated full effect to the different school groups, as well as the average effect calculated at the sample means, are reported as rows in Table 8 for

[12]Many of these outcome measures are also available aggregated to the school district level. When districts are classified by income status rather than schools, analyses at the district level yield results that are qualitatively unchanged.

the various outcome measures.

Table 8 highlights the disparate impacts of E-Rate subsidies to different school types. For example, there are positive and significant college preparedness effects for students in high income schools, but no detectable effects in the middle group and negative and significant effects for low income schools. Likewise, while six standardized test scores measures display statistically significant improvement for low income schools, only two are marginally significant for the middle income group and the scores fall for the high income group, though the effects for low income students at high income schools are not significant. Again similar results for similar measures (college readiness versus standardized tests) provide a robustness check against spurious correlation. However, the different effects by income group and type of measure warrants further examination.

The effects at high income schools are consistent with E-Rate subsidies leading to a substitution of resources away from lower performing students toward higher performing students. The increase in college entrance exam scores and in the percent enrolling in college suggest that the E-Rate tended to benefit the nearly half of the students at these schools who will go on to college. However, the decrease in average standardized test scores suggests that these gains may have come at the expense of lower performing students. One possible explanation is that college entrance exams test different concepts than the standardized tests and that instruction was diverted toward the former at the expense of the latter. Another possible explanation is that college-bound students standardized test scores rose, just as their college entrance exam scores rose, but not enough to overcome the poorer performance of the non-college-bound students who also take these tests If lower income students tended to be lower performers, evidence for this hypothesis would be relatively worse standardized test scores for low income students at these schools, which is not the case.

The effects at the low income schools suggest broad gains and not a substitution from one type of student or one type of instruction toward another. Standardized test scores improve significantly for both the low income subset and the school average. This suggests broad gains across income groups that may also proxy for student abilities. The poorer college preparedness results might be reconciled by the increase in the number of ACT and SAT takers. There is a marginally significant increase in the fraction of students choosing to take these college entrance exams. Since these additional students are likely to be marginal performers relative to the existing set of ACT and SAT takers (i.e, there is negative selection bias), they could bring down average exam scores even if individual student ability was unaffected. In fact, for low income schools, the percent of a school's students reaching the ACT/SAT critical value, the product of the percent taking the exams and the percent of exam takers reaching the critical value, was barely affected, falling only from 5.6% to 5.4%. In contrast, at higher income schools this percentage rose from 17.0% to 18.1%. This suggests that the E-Rate may have had only a negligible effect on the educational attainment of these high performers' at low income schools.

At the middle income schools, fewer effects on outcome measures were found to be significant. However, those that were, standardized math tests for low income students and possibly standardized writing tests, exhibited improved performance.

These disparate results may have various explanations. First, high income schools may install and use IT with or without a 20% subsidy to costs. For these schools, the subsidies merely make overall budget constraints less binding. In contrast, for low income schools, the difference of a 70-90% subsidy to costs may make a meaningful difference in the decision to make IT available. Second, as mentioned above, access to IT at school is less likely to be the only access available to higher income students. Household internet service defused throughout the US over this period predominantly in moderately to highly affluent families. Home based Internet access has been rare among low income families. Regardless of the mechanism that favors schools serving low income students, this evidence suggests that the program benefits are primarily falling to the informational "have nots" rather than "haves" just as it was designed to do.

The fourth column of Table 8 calculates the estimated effect of the E-Rate subsidies on outcomes at the sample means of E-Rate subsidies during the E-Rate granting period (post-1997). During this period high income schools' expenditures rose by an average of 0.15% due to E-Rate subsidies while middle and low income schools' expenditures rose an average of 0.33% and 1.57% respectively. These calculations highlight the problems from relying on college entrance exam scores. First, while ACT and SAT scores rose for students at high income schools, they may have fallen at low income schools resulting in negligible average effects. In this regard, my estimates are consistent with Goolsbee and Guryan (2006) finding of no change in college entrance exam scores. Second, even though average ACT and SAT scores fell at low income schools, this may have been due to selection bias into the sample of test takers. Third, the main effects may occur among non-college bound students and, therefore, better measured with different outcomes.

It is possible that the improvements in educational outcomes do not emanate from IT directly but are simply the result of more educational resources generally. IT investments may be infra-marginal and budget allocations could be fungible. Local money budgeted for IT may have simply been replaced by E-Rate money, freeing up funds for a variety of educational inputs. One principal reported, "This program has allowed us to have more and better communications equipment and greater, faster access to the Internet. It has freed funds for other activities that would not have been available." (Puma, et al. (2002)). If the E-Rate simply relaxed budget constraints, however, we might expect test scores to be affected across a variety of schools. Instead, the finding that the improvements were largely confined to the low income schools where the bulk of the IT investments were made suggests that Internet connectivity specifically affected score outcomes.

The only consistently significant effects are on standardized test scores and not the college preparedness measures. It may be more appropriate to examine the overall effectiveness of the program from these measures than from college preparedness measures. For Texas, the E-Rate program has averaged $242 million annually or about 0.77% of all expenditures on K-12 education. The estimates for standardized tests indicate that the percentage of students passing each test increased by 1.7 to 3.6%. Since about there are currently about 4.4 million students Texas public schools, this implies, at most, an additional 75,000 to 155,000 students passing each of these tests.[13] This comes to between $1,550 and $3,200 per additional passing student if the benefits accrued only to the students marginal to passing these tests. Presumably, however, there were also test score improvements for students infra-marginal from passing or failing these tests so that more than this 4% of students benefitted.

One could calculate how large each student's score would have had to rise to cause the

[13]This calculation assumes that students at other grade levels would experience comparable test score improvements as identified here for high school students.

estimated increase in the percentage of students passing the exam under specific distributional assumptions. For example, if one assumes that test scores are normally distributed, for reading scores at low income schools, the mean percentage test score satisfies $(z_0) = 1 - 86.1\%$ initially and $(z_1) = 1 - 88.9\%$ post E-Rate treatment. If only the mean of the test score distribution changed and not the standard deviation, the mean would have had to rise by about 1.4% of one standard deviation to achieve this change in the commutative distribution function. If the standard deviation of percent test scores were 10%, the increase in each student's tests scores would average 0.14 percentage points which implies about $400 per student per additional percentage correct on these exams.[14] Since this is nearly 7-10% of the current expenditure per pupil, this calculation suggests that the E-Rate program represents an expensive way to improve educational outcomes.

VI. Conclusion

At $2.25 billion per year, the E-Rate subsidy program is a large intervention into primary education. As such, it merits asking the question whether there are identifiable returns to this investment. Since it is directed at specific IT investments, it merits asking whether this is the best allocation for these educational expenditures. Finally, since the program is directed toward improving student attainment in low income areas, it merits asking whether any improvements

[14]The standard deviation in the percent correct may be more than 10% leading to a smaller calculated cost per unit of improvement. On-the-other-hand, since the implied change in scores is smaller for the writing test and for the low income students, the implied cost per unit of improvement for these tests would be higher if the calculations were based on them. Similarly, if the effects of the E-Rate at other grade levels were smaller than those measure in this study, the calculated cost would be higher. This is a "back-of-the-envelope" calculation merely meant to demonstrate that the cost per unit of improvement appears high.

come at a cost to performance in higher income areas. This study attempts to answer some of these questions using Texas public school data for up to eleven years spanning the inception of the program. In general, I find broad improvements in educational attainment due to the E-Rate program at schools serving low income students and improvements related to college preparedness at schools serving high income schools at the expense of lower standardized test scores. Additionally, the estimated values suggest that the cost of improving average test scores by one percent via the E-Rate program are one the order of 7-10% the current per pupil expenditures for the sample period.

The different estimated effects for schools serving different income groups call into question the use of measures associated with college preparedness. These effects are consistent with the expectation that lower income and lower achieving students are less likely to have exposure to advanced IT at home. They also suggest strategies for measuring the effects on labor market outcomes. That is, more students may be better trained for non-professional jobs using IT than previously, but there may be no substantial effect on the number of students prepared for professional careers usually associated with college educations.

The existence of these E-Rate educational effects suggest that there may be other consequences of the E-Rate program, some of which may be unintended. The educational outcomes from the E-Rate are predicated on more computer and Internet use by adolescents who typically have low exposure to computers and the Internet. Greater IT exposure could lead to social and economic changes unrelated to education. For example, greater use of the Internet may have expanded these adolescents' social networks, it may have broadened their exposure to the world beyond their usual day-to-day experiences, and it may have increased their online acquisition of products. These effects might be evidenced by increased breadth of communications partners via Internet or other communications media, by the faster and broader spreading of fads, and by increased downloading of music.

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Table 1
Percent of all Classrooms, Computer Labs, and Library/Media Centers with Internet access

	Fraction of Low Income Students			
Year	Less than 35%	35%-49%	50%-74%	75% or more
1994	3%	2%	4%	2%
1995	9%	6%	6%	3%
1996	17%	12%	11%	5%
1997	33%	33%	20%	14%
1998	57%	60%	41%	38%
1999	73%	69%	61%	38%
2000	82%	81%	77%	60%
2001	90%	89%	87%	79%
2002	93%	90%	91%	89%
2003	95%	93%	94%	90%

source: US Department of Education
<http://nces.ed.gov/programs/digest/d05/tables/dt05_416.asp>

Table 2
Percent Discount Levels of E-Rate Subsidies

Percent of Students Eligible for the National School Lunch Program	Urban School	Rural School
Less than 1%	20%	25%
1% to 19%	40%	50%
20% to 34%	50%	60%
35% to 49%	60%	70%
50% to 74%	80%	80%
75% to 100%	90%	90%

Source: Universal Service Administrative Company
<http://www.usac.org/>

Table 3
E-Rate Data Summary Statistics

Year	Number of Districts		Award Amount as Percent of Total Expenditures	
	Non-Grant Recipients	Grant Recipients	All Districts	Grant Receiving Districts
1994	1,062	0		
1995	1,061	0		
1996	1,060	0		
1997	1,059	0		
1998	566	615	0.65%	1.39%
1999	470	831	0.53%	0.93%
2000	490	851	0.51%	0.84%
2001	462	943	0.79%	1.27%
2002	429	1,024	1.00%	1.54%
2003	370	1,153	1.02%	1.47%
2004	349	1,104	0.78%	1.09%

Table 4
Summary Statistics

Variable	Valid Observations	Mean	Standard Deviation
E-Rate/Total Expend.	14,861	0.40%	
Average ACT Score	11,235	19.74	1.85
Average SAT Score	10,418	940.2	97.63
Pct. Meeting SAT/ACT Critical Std.	11,880	19.3%	12.9%
Pct. Students Taking ACT or SAT	11,639	57.2%	23.1%
Pct. College Enroll.	12,986	43.5%	14.4%
Pct. Passing Reading Test - All Students	9,169	86.1%	11.9%
Pct. Passing Writing Test - All Students	9,155	88.2%	10.8%
Pct. Passing Math Test - All Students	9,189	76.8%	18.1%
Pct. Passing Reading Test - Low Inc. Stud.	8,653	78.7%	14.8%
Pct. Passing Writing Test - Low Inc. Stud.	8,629	82.5%	12.9%
Pct. Passing Math Test - Low Inc. Stud.	8,664	69.1%	21.1%

Table 5
Descriptive Statistics by
Fraction of Low Income Students at the School

	Percent of Low Income Students		
	0-24% High Third	24-43% Middle Third	43-100% Low Third
E-Rate/Total Expend.	0.09%	0.22%	0.73%
Average ACT Score	21.0	19.9	18.3
Average SAT Score	982.6	952.11	876.7
Pct. Meeting SAT/ACT Critical Standard	26.9%	19.7%	11.1%
Pct. Students Taking ACT or SAT	63.2%	57.8%	50.4%
Pct. Students Enrolling in College	48.5%	43.8%	39.6%
Pct. Passing Reading Test - All Students	90.1%	86.9%	78.3%
Pct. Passing Writing Test - All Students	91.6%	89.0%	83.1%
Pct. Passing Math Test - All Students	80.6%	77.7%	67.7%
Pct. Passing Reading Test - Low Inc. Stud.	80.7%	79.2%	71.8%
Pct. Passing Writing Test - Low Inc. Stud.	83.8%	83.4%	78.6%
Pct. Passing Math Test - Low Inc. Stud.	70.1%	69.4%	61.7%

Table 6
Effects of E-Rate Subsidies on Average Campus Performance
College Readiness Measures

	ACT Score	SAT Score	Above Critical Value	Percent Taking Exams	Percent College Enrollment
E-Rate Subsidy T-1	0.115	4.599	0.478	0.522	0.699
if High Inc. School	(0.055)*	(2.119)*	(0.348)	(0.469)	(0.544)
E-Rate Subsidy T-2	0.059	0.861	0.202	-0.014	0.074
if High Inc. School	(0.037)	(0.974)	(0.298)	(0.347)	(0.210)
E-Rate Subsidy T-3	0.044	1.665	0.524	0.615	0.766
if High Inc. School	(0.058)	(2.169)	(0.531)	(0.460)	(0.430)
E-Rate Subsidy T-1	0.026	2.011	0.057	-0.154	0.150
if Middle Inc. School	(0.022)	(1.134)	(0.161)	(0.205)	(0.207)
E-Rate Subsidy T-2	0.040	0.212	0.011	-0.138	0.006
if Middle Inc. School	(0.036)	(1.602)	(0.251)	(0.296)	(0.331)
E-Rate Subsidy T-3	0.010	0.572	0.064	0.066	-0.324
if Middle Inc. School	(0.033)	(1.472)	(0.246)	(0.212)	(0.218)
E-Rate Subsidy T-1	-0.002	-0.645	-0.129	0.038	-0.066
if Low Inc. School	(0.008)	(0.316)*	(0.032)**	(0.075)	(0.048)
E-Rate Subsidy T-2	0.005	-0.757	-0.141	0.083	0.049
if Low Inc. School	(0.007)	(0.341)*	(0.031)**	(0.078)	(0.054)
E-Rate Subsidy T-3	-0.015	-1.461	-0.169	0.140	0.135
if Low Inc. School	(0.009)	(0.497)**	(0.041)**	(0.099)	(0.067)*
Average Teacher	0.021	1.585	0.164	0.277	0.193
Experience	(0.008)*	(0.357)**	(0.052)**	(0.069)**	(0.046)**
Low Income Fraction	-1.100	-39.812	-4.791	-7.606	-14.743
	(0.400)**	(17.666)*	(2.517)	(3.568)*	(2.324)**
Low Income Fraction	-0.490	-17.408	-5.817	9.767	7.094
Squared	(0.399)	(17.387)	(2.291)*	(3.596)**	(2.259)**
Constant	19.945	855.855	13.994	54.782	48.508
	(0.138)**	(5.905)**	(0.870)**	(1.151)**	(0.876)**
Observations	11,235	10,418	11,880	11,639	12,986
Number of Campuses	1,130	1,098	1,223	1,353	1,389
R-squared	0.03	0.56	0.20	0.02	0.12

Standard errors in parentheses
* significant at 5%; ** significant at 1%

Table 7
Effects of E-Rate Subsidies on Average Campus Performance
Standardized Test Score Measures

	Standardized Test Scores					
	All Students			Low Income Students		
	Reading	Writing	Math	Reading	Writing	Math
E-Rate Subsidy T-1	-0.694	-0.381	-1.050	-0.921	-0.523	-0.916
if High Inc. School	(0.305)*	(0.222)	(0.423)*	(0.495)	(0.401)	(0.380)*
E-Rate Subsidy T-2	-0.968	-0.873	-1.516	-0.814	-0.657	-1.033
if High Inc. School	(0.569)	(0.473)	(0.831)	(0.733)	(1.093)	(0.865)
E-Rate Subsidy T-3	-0.773	-0.505	-1.172	0.028	0.439	0.387
if High Inc. School	(0.374)*	(0.450)	(0.684)	(0.646)	(0.547)	(0.828)
E-Rate Subsidy T-1	-0.016	-0.025	0.089	0.369	0.178	0.544
if Middle Inc. School	(0.152)	(0.141)	(0.269)	(0.278)	(0.256)	(0.337)
E-Rate Subsidy T-2	-0.001	0.249	0.558	0.080	0.277	0.920
if Middle Inc. School	(0.202)	(0.174)	(0.356)	(0.358)	(0.280)	(0.397)*
E-Rate Subsidy T-3	0.071	0.328	-0.392	0.281	0.594	0.129
if Middle Inc. School	(0.256)	(0.238)	(0.352)	(0.489)	(0.422)	(0.502)
E-Rate Subsidy T-1	0.508	0.152	0.470	0.398	0.095	0.169
if Low Inc. School	(0.094)**	(0.082)	(0.123)**	(0.098)**	(0.093)	(0.111)
E-Rate Subsidy T-2	0.733	0.499	0.818	0.554	0.501	0.465
if Low Inc. School	(0.135)**	(0.105)**	(0.170)**	(0.137)**	(0.118)**	(0.147)**
E-Rate Subsidy T-3	0.795	0.494	1.286	0.491	0.563	0.762
if Low Inc. School	(0.249)**	(0.216)*	(0.310)**	(0.255)	(0.237)*	(0.270)**
Average Teacher	0.185	0.280	0.194	0.016	0.153	0.098
Experience	(0.070)**	(0.075)**	(0.097)*	(0.103)	(0.102)	(0.122)
Low Income Fraction	-12.641	-4.387	-5.420	5.182	12.729	10.459
	(3.785)**	(3.523)	(4.685)	(5.518)	(5.532)*	(6.244)
Low Income Fraction	24.613	11.646	21.648	16.943	1.373	9.457
Squared	(4.365)**	(4.206)**	(5.288)**	(5.348)**	(5.308)	(6.201)
Constant	90.850	78.018	86.438	62.038	66.642	81.134
	(1.229)**	(1.141)**	(1.581)**	(1.801)**	(1.787)**	(2.204)**
Observations	9,169	9,155	9,189	8,653	8,629	8,664
Number of Campuses	1,251	1,245	1,252	1,188	1,184	1,190
R-squared	0.51	0.23	0.71	0.46	0.21	0.67

Standard errors in parentheses
* significant at 5%; ** significant at 1%

Table 8
Long-run Effects of E-Rate Subsidies
by School's Fraction of Low Income Students

	High Income Schools	Middle Income Schools	Low Income Schools	Average Predicted Effect
ACT Score	0.218	0.076	-0.011	0.041
	(0.086)*	(0.048)	(0.013)	(0.031)
SAT Score	7.125	2.795	-2.864	-2.492
	(3.063)*	(2.186)	(0.731)**	(1.546)
Pct ACT/SAT Above	1.203	0.131	-0.439	-0.463
Critical Value	(0.770)	(0.335)	(0.064)**	(0.209)*
Pct Taking ACT/SAT	1.123	-0.227	0.261	0.507
	(0.733)	(0.377)	(0.157)+	(0.318)
Pct Enrolling in College	1.540	-0.168	0.118	0.365
	(0.719)*	(0.378)	(0.092)	(0.241)
Reading Test Pass Pct	-2.435	0.054	2.036	2.847
All Students	(0.690)**	(0.357)	(0.283)**	(0.512)**
Writing Test Pass Pct	-1.759	0.551	1.145	1.713
All Students	(0.652)**	(0.332)+	(0.234)**	(0.425)**
Math Test Pass Pct	-3.738	0.255	2.574	3.560
All Students	(1.009)**	(0.528)	(0.382)**	(0.712)**
Reading Test Pass Pct	-1.707	0.730	1.442	2.248
Low Inc. Students	(1.100)	(0.638)	(0.281)**	(0.570)**
Writing Test Pass Pct	-0.741	1.050	1.159	2.056
Low Inc. Students	(1.268)	(0.574)+	(0.261)**	(0.550)**
Math Test Pass Pct	-1.562	1.593	1.395	2.480
Low Inc. Students	(1.264)	(0.698)*	(0.323)**	(0.657)**

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%