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The Effect of Home Computers and the Internet on Children's Human Capital Development

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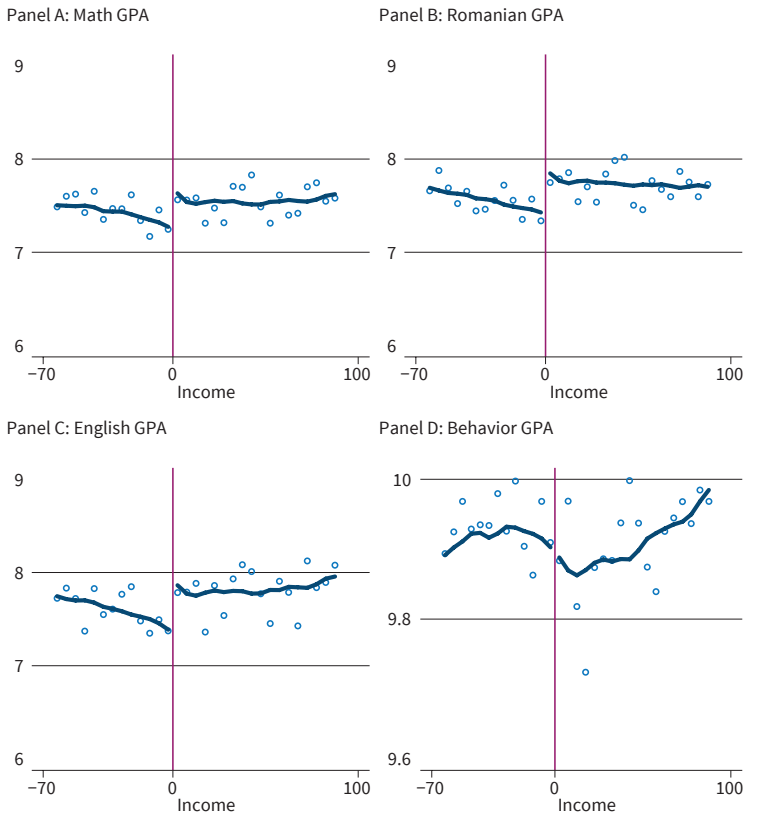
The development of the personal computer in the late 1970s enabled households to purchase a computer for the home and made it possible for children to gain access to an important new technology. This technology was further augmented by the rapid expansion of internet access to households starting in the mid-1990s. Today, home computers and internet access are practically ubiquitous in developed countries: over 95 percent of 15-year-old students in OECD member countries report having a link to the internet at home (OECD 2017). In contrast, access to home computers and the internet in middle-income and developing countries continues to lag. For example, less than half of 15-year-old students in Algeria, Peru, and Vietnam report having internet access at home (OECD 2017). In an effort to alleviate this "digital divide," many governments and non-governmental organizations have invested substantial resources to expand computer and internet access to children in developing countries. Yet until recently, compelling evidence on the causal impact of home computers and internet access on children's outcomes has been lacking.

There are many potential mechanisms through which home computers and internet access can affect children's outcomes. First and foremost, exposure to computers and the internet can develop digital skills that may be valuable on the labor market (Krueger 1993). Computers and internet access might also improve learning through educational software. For example, if children lack educational materials, internet access could improve academic achievement by providing access to educational websites with subject-specific content, as well as e-books and other reading materials such as newspapers, blogs, and online encyclopedias. On the other hand, home computers and internet access could diminish learning if children spend more time on activities that are not conducive to developing academic skills, such as playing online games, and less time reading and doing homework. Computer and internet access may also affect cognitive skills by exposing children to activities that alter cognitive processes (Johnson 2006; Mills 2014). In addition, use of home computers and the internet has been associated with a lack of physical activity, increased risk of obesity, decreased social involvement, and more aggressive behavior when playing violent computer games or engaging with other adult content (Subrahmanyam et al. 2000; 2001). Finally, it is possible that the internet could expose children to broader cultural and social perspectives.

Viewed through an economic framework, the introduction of computers and internet access into a household is likely to alter the relative price and time cost of certain activities available at home. Children would then substitute into activities that are made relatively cheaper or become newly available. Any change in the mix of activities could then impact children's human capital developmental and subsequent adult outcomes. Computers and internet access may also change the productivity of certain activities in the

Figure 1

Impact of Winning a Computer Voucher on Academic Achievement in Romania



Source: Malamud and Pop-Eleches (2011).

development of human capital. To the extent that children do not choose those activities that necessarily improve their skills and their future outcomes, there is an important role for parents to monitor and supervise their children's use of technology.

The remainder of this article summarizes some of the evidence on the causal impact of computer and internet access on children's outcomes, drawing especially on my recent work with several coauthors in a variety of different settings. This is not intended to be an exhaustive review but one that hopefully helps shed light on this important topic.

THE EFFECT OF COMPUTER ACCESS: EVIDENCE FROM ROMANIA

In Malamud and Pop-Eleches (2011), we examined a government program administered by the Romanian Ministry of Education that subsidized the purchase of home computers. The program awarded approximately 35,000 vouchers worth EUR 200 (about USD 300) in 2008 towards the purchase of a personal computer for low-income students enrolled in public schools. The computers purchased through this "Euro 200" program had to fulfill certain minimum specifications (2 GHz CPU, 1 GB RAM, 160 GB HD), but internet access was not one of them. Vendors were encouraged to install educational software but, in practice, this was rarely done.

Since the fixed number of vouchers were allocated based on a simple ranking of family income, we employed a regression discontinuity design that allowed for comparisons across students very similar in family income and other respects, but markedly different in their access to a computer at home. Using data on approximately 3,500 households, which we collected through in-person interviews one year after receipt of the computers, we estimated the impact of winning a EUR 200 voucher on a broad range of skills and child outcomes.

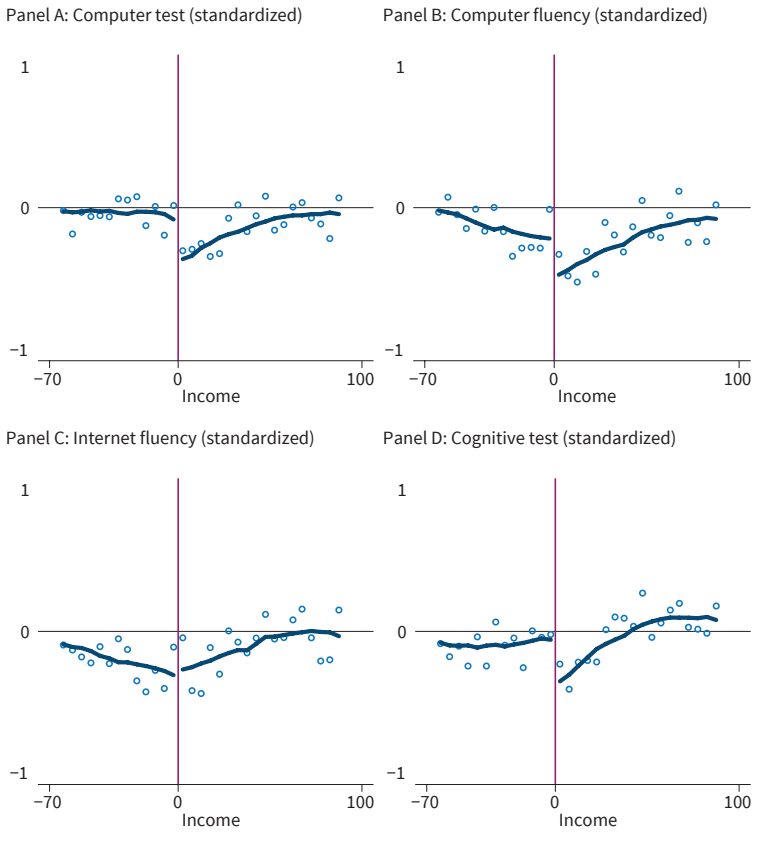
Our findings indicate that home computers had both positive and negative effects on child outcomes. Winning a voucher increased the likelihood of households owning a home computer by over 50 percentage points, making them almost twice as likely to own a computer compared to households with incomes just above the program threshold. As expected, these higher rates of computer ownership also led to increased computer use, with children in households that won a voucher using computers about 3 to 4 hours a week longer than their counterparts in households that did not win a voucher. As shown in Figure 1, we found strong evidence that children in households that just barely won a voucher had significantly lower school grades in Math (panel A), Romanian (panel B), and English (panel C) compared to those where income was just below the threshold. There was no significant difference in a grade that captured behavior at school (panel D).

On the other hand, as can be seen in Figure 2, we estimated that children in households that just barely won a voucher had significantly higher scores in a basic test of computer skills (panel A) and in self-reported measures of computer fluency (panel B). Unsurprisingly, given the low levels of internet access, there were no significant differences in self-reported internet fluency (panel C). Finally, there was also some evidence that winning a voucher increased cognitive ability, as measured by a Raven's Progressive Matrices test (see panel D). We found little evidence that winning a computer voucher affected any behavioral outcomes.

How can we reconcile the negative effects on academic

Figure 2

Impact of Winning a Computer Voucher on Digital/Cognitive Skills in Romania



Source: Malamud and Pop-Eleches (2011).

achievement with the positive effects on digital and cognitive skills? The effects on academic achievement are not so surprising given that few parents or children reported having educational software installed on their computers, and few children reported using the computer for homework or other educational purposes. Instead, most computers had games installed and children reported that most of their computer time was spent playing games. There was also some evidence that winning a computer voucher reduced the time spent doing homework, watching TV, and reading for pleasure. Thus, even if computer use improved certain skills, it appears to have caused a shift away from educational activities so that the net effect on academic achievement was negative.

In addition, we found that the presence of parental rules regarding homework helped to mitigate some of the negative effects of winning a computer voucher without affecting the gains to computer skills and cognitive ability. Yet the presence of rules regarding computer use reduced the positive impacts on computer skills without improving academic achievement. These results are merely speculative, since such rules were not randomly assigned and were measured after treatment occurred, but they suggest that encouraging children to do homework might be more effective than restricting their computer use.

THE EFFECT OF INTERNET ACCESS: EVIDENCE FROM PERU

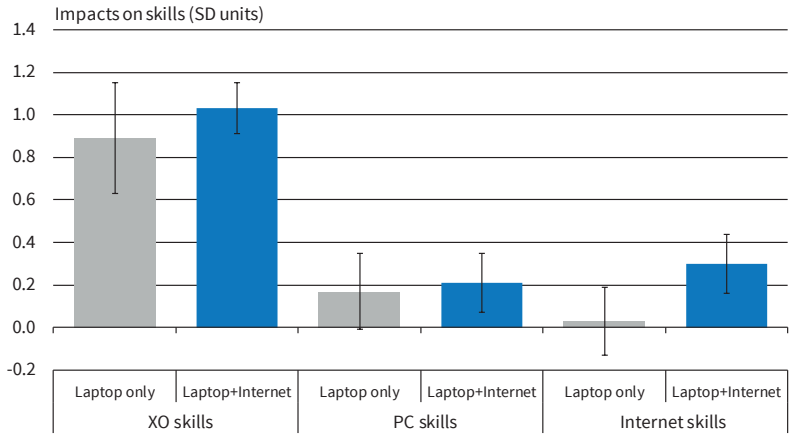
The findings from Romania raise the question of whether similar patterns would be observed in other contexts, and whether the availability of internet access could make a difference. Malamud, Cueto, Cristia, and Beuermann (2019) examined the effects of providing internet access using a randomized experiment in Lima, Peru.[1] We began by providing access to XO laptops for home use to a random sample of 540 out of 2,457 children in June/July 2011.[2] These children were enrolled in grades 3 to 5 of low-achieving public primary schools. Then, among children who received these laptops, we randomly selected about 350 children to receive free high-speed internet access in July/August 2012. The laptops included 32 applications selected by Peru's Ministry of Education for its national program, and we offered training and manuals on how to use them. We also offered tutorials and manuals to children who received internet access in which we showed them how to take advantage of freely available educational websites created by Peru's Ministry of Education and other online resources, such as Khan Academy and Wikipedia.

To evaluate the impacts of our interventions, we conducted a follow-up survey in November 2012, approximately 17 months after the laptops were initially distributed and 5 months after the provision of internet access. We also conducted an additional follow-up survey in March 2013 to check for longer-run impacts after the summer vacation. We compare (i) children who were randomly chosen to receive laptops with internet access to (ii) those who received only laptops without internet access and (iii) those who did not receive laptops at all. This enables us to estimate the impact of internet access both separately from, and in conjunction with, the impact of the laptops themselves. The figures below show the impact of our interventions on groups (i) and (ii) relative to group (iii), which did not receive laptops or internet access.

Our interventions were successful in increasing children's use of technology at home and led to substantial improvements in digital skills. Figure 3 below shows that children who were offered laptops with internet access scored 0.3 standard deviations higher on a test of internet literacy than those who were not offered internet access or those who were offered laptops without internet. They also scored 1 standard deviation higher on a test that measured proficiency on the XO laptop compared to those who were not offered laptops, but their scores were not significantly different from those of children who were offered laptops without internet. In addition, children who were offered laptops (with or without internet) showed significant improvements on a Windows-based computer test, suggesting that gains in computer literacy were not lim-

Figure 3

Impact of Access to Home Internet on Digital Skills in Peru



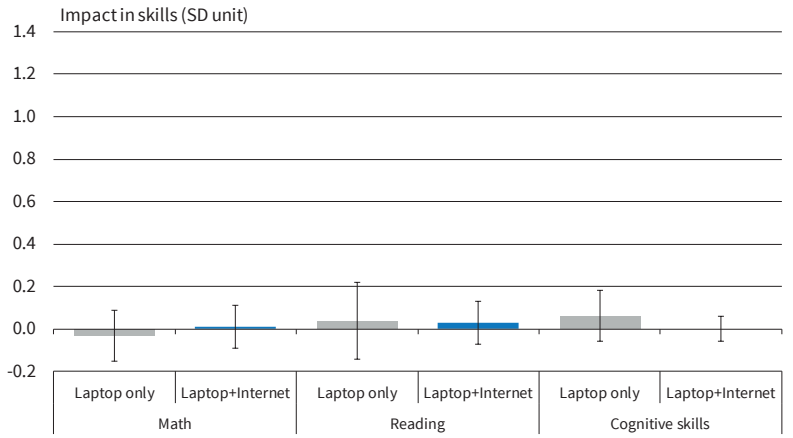
Source: Malamud, Cueto, Cristia, and Beuermann (2019). © ifo Institute

[1] This followed an earlier study by Beuermann, Cueto, Cristia, Malamud, and Cruz-Aguayo (2015) examining the short-term impacts of access to computers without internet access.

[2] The XO laptops were developed by the One Laptop per Child (OLPC) program with an emphasis on self-empowered learning and with specialized software intended to encourage such learning.

Figure 4

Impact of Access to Home Internet on Academic and Cognitive Skills in Peru



Source: Author's calculations.

ited only to the specific XO platform but also transferred to skills for using other types of computers.

Despite the increase in the use of home technology and the improvements in digital skills, internet access had no significant impacts on academic achievement. Figure 4 below indicates that we can rule out impacts larger than 0.08 standard deviations in math and 0.13 standard deviations in reading with 95 percent confidence when comparing children who were offered internet access to those who did not receive laptops. Nor were there any significant effects on an index capturing a broad set of cognitive skills, as measured by the Raven's Progressive Matrices test, a verbal fluency test, a test of executive functioning, a coding test, a working memory test, and a test of spatial reasoning (or any of these individual tests).

Moreover, we found no significant effects on a self-esteem index measured using a self-reported questionnaire. Based on teacher reports, children in the treatment groups were equally likely to exert effort at school compared to their counterparts in the control group, and there were no differences in grades obtained from administrative school records or in teacher perceptions of children's sociability. Finally, there was no evidence of any improvement when we resurveyed children 8 to 9 months after internet provision following the summer vacation, despite the potential benefits of engaging children to counteract summer learning loss.

Why were there no significant impacts on academic achievement and cognitive skills from providing children with internet access? The intervention itself was not directly linked with pedagogical activities at school, but we did provide children with training to make more effective use of their computers and the internet for educational purposes. We explore reasons for the absence of impacts using time diaries and survey questions on time allocation, as well as detailed computer logs that registered the specific applications and internet sites that children used at a daily level. When we attempted to classify the main applications and internet sites used by children, we found that children engaged in digital activities that are focused less on information or communication, and more on entertainment.

THE ROLE OF PARENTS: EVIDENCE FROM CHILE

As noted earlier, Malamud and Pop-Eleches (2011) found that parental rules might attenuate the negative effects of computer ownership, suggesting that parental monitoring and supervision may be an important mediating factor. In a follow-up study by Gallego, Malamud, and Pop-Eleches (2017), we examined two factors that might affect parents' ability to monitor their children's internet use. First, parents may lack information about their children's internet use. Children are often quicker to adapt to new technologies, meaning parents encounter challenges in understanding how children use technology. Second, even with perfect information, parents may not be able to influence their children's actions through indirect transfers and threats (Weinberg 2001; Berry 2015). In these cases, parents may wish for a way to control their children's actions directly.

We designed and implemented a set of randomized interventions to test the impact of sending parents weekly SMS messages containing specific information about their children's recent internet use and/or encouragement and assistance with installing parental control software. Providing parents with information about their children's internet use should help alleviate informational frictions. Encouraging parents to install parental control software can help parents bypass the need to incentivize their children or enforce rules related to computer use, assuming that parents are able to install and operate such parental control software.

We focused on a sample of children in 7th and 8th grade who received free home computers and 12 months of free internet through Chile's "*Yo Elijo mi PC*" (YEMPC) program in 2013. The primary data on the intensity of internet use at the daily level came from the internet service provider (ISP) that served all of the computers provided to the children in our sample. According to this data, children downloaded approximately 175MB of internet content daily, which translated to about three hours of internet use per day. This is similar to recent estimates from the 2015 PISA survey showing that children in Chile spent 195-230 minutes

per day online, the highest rate among all the countries surveyed (OECD 2017).

The experiment consisted of delivering weekly text messages to the 7,700 parents in our experimental sample over the course of 14 weeks. We sent three different types of SMSs using the following texts:

- SMS only: "We hope your child makes good use of the Yo Elijo Mi PC laptop that he/she won."
- ISP: "We hope your child makes good use of the Yo Elijo Mi PC laptop that he/she won. Your child downloaded XX MBs the week of the DD-MMM, {"more than" or "similar to" or "less than"} what a typical child downloaded: YY MBs."
- Windows 8: "We hope your child makes good use of the Yo Elijo Mi PC laptop that he/she won. The Parental Control program of Windows 8 can help you supervise your child's computer use. Call us at XXX-XXXX for assistance."

We also incorporated a treatment arm that included both ISP information and assistance with Windows 8 parental controls to test for possible interactions between these treatments. To disentangle the informational content and the offer of assistance from the cue associated with SMS messages, we compare the ISP and Windows 8 treatments to the SMS-only control group in which parents received a weekly SMS reminding them that children should make good use of their computers, a message that was included in every treatment.

We found that households in which parents received ISP information about internet use had 6–10 percent lower intensity of internet use during the treatment period relative to households in the control group. These effects persisted in the weeks and months after treatment ended. This can be seen in Figure 5 below, which shows the estimated impacts of the ISP information treatment on weekly internet use relative to the control group (where the red vertical lines bracket the intervention period).

This suggests that our temporary intervention providing information on internet use may have altered the permanent intra-household equilibrium. Indeed, some parents who received information reported that they were more likely to punish their children while others reported having calm discussions with their children about internet use. There is even some evidence that parenting styles became less permissive. Furthermore, we found that our informational interventions may substitute for the presence of a parent at home but are complementary to parents' capacity to be involved in their children's lives.

We also showed that there are statistically significant reductions in use precisely on the days immediately after receiving the ISP information, and that this effect is more relevant in the early weeks of the experiment. Moreover, it was the SMS messages conveying the "bad news," i.e., that children used more internet than the reference group in a specific week, that produced a much larger decline in internet use. These findings confirm that it is the specific information provided to parents about their children's internet use that leads to a significant reduction in internet use.

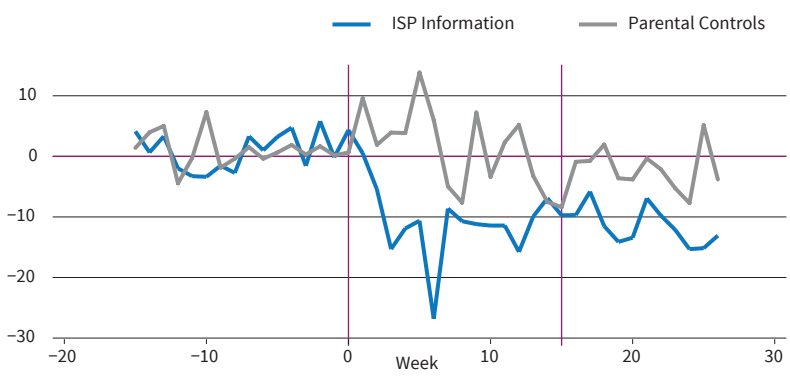
We do not find significant impacts from helping parents directly control their children's internet access. In particular, we find no difference in internet use between parents who were encouraged and provided assistance to install parental control software versus those in the control group who received only a generic message. Moreover, among the 15 percent of parents who installed parental control software with our assistance, we did not find changes in internet use on the days immediately after installing this software. We believe these findings may reflect the considerable obstacles faced by low-income parents in implementing technological solutions for monitoring and supervising their children.

OTHER EVIDENCE

There are several other studies that examine the causal impact of home computers and internet access in different settings.[3] Fairlie and Robinson (2013) conducted a randomized experiment in which they provided home computers with partially subsidized dial-up internet access to 1,123 students in 15 middle and high schools in California. The experiment generated a large increase in computer ownership and computer use, as well as increased internet access. However, they found no impacts on educational outcomes such as school grades, standardized math and reading test scores, or the num-

Figure 5

Impact of Parental Information and Parental Controls on Internet Use in Chile



Source: Gallego, Malamud, and Pop-Eleches (2017).

[3] We focus here on more recent studies that use experimental or quasi-experimental variation in computer and internet use. Previous studies include Attewell and Battle (1999), Fuchs and Woessmann (2004), Fairlie (2005), Schmitt and Wadsworth(2006), Beltran et al. (2010), and Fiorini (2010).

ber of credits earned after 9 months. There were also no impacts on attendance or disciplinary actions. Using the same experimental setting, Fairlie and Kalil (2016) did find positive impacts on the likelihood of having a presence on a social networking site and time spent communicating with friends, but no effects on school participation and engagement.

Vigdor et al. (2014) exploited within-student variation in access to home computers as well as local variation in the introduction of high-speed internet service to examine the effect of both home computers and internet access among public school students in North Carolina. They found evidence for modest but persistent and significant declines of 0.01-0.03 standard deviations in math and reading test scores. Along the same lines, Faber et al. (2016) exploited differences in broadband connection speeds across neighboring residences in England and found a precisely estimated zero effect of internet speed on test scores or time spent studying.

Finally, Mo et al. (2013) conducted a randomized experiment in which they distributed laptops installed with learning/remedial tutoring software to 300 third-grade migrant students in Beijing. They found positive impacts on self-reported computer skills after 9 months of exposure. They also found marginally significant impacts of 0.17 standard deviations on a standardized math test in some specifications (although these are smaller and insignificant at 0.07 standard deviations without the inclusion of controls). Beyond these studies, there are many others that examine the effect of technology in school and after-school settings, but these are outside the scope of this article.[4]

DISCUSSION

The evidence described above indicates that home computers and internet access have different impacts on different outcomes. Perhaps not surprisingly, there is strong evidence for positive and significant improvements in digital skills, related to either computer or internet fluency depending on the respective intervention. There is also some evidence suggesting positive improvements in cognitive skills, as measured by the Raven's Progressive Matrices test, although this is not a robust finding across all settings.[5] On the other hand, there is almost no evidence for positive impacts on academic outcomes. Some studies find negative effects; others find precisely estimated null effects. To the extent that children spend more time on their computers without a corresponding decline in academic achievement, it could indicate an increase in productivity. However, among those that find negative effects, it appears that children substitute away from homework and other school-related activities, while spending most of their computer and online time on entertainment activities, such as games and social media.

There is also evidence that parents play an important role in moderating and mediating the impacts of home computers and internet use. Providing information to parents about children's internet use does affect internet use. Furthermore, it appears to influence parent-child interactions in a way that persists over time. But simply providing access to parental control software may not be sufficient to help (low-income) families monitor and supervise their children's internet use.

In spite of this new evidence on the impacts of home computers and internet access, there are many important questions that remain unanswered. For example, given both positive and negative effects on different skills, what is the (net) effect of technology on later-life outcomes? What are the best tools for parents to spur effective use of home technology? What is the effect of mobile devices such as smartphones and tablets? Are there specific applications or portals (e.g. Khan Academy) that can lead to improved academic outcomes? And how can we measure the effect of technology on 21st-century skills beyond the usual academic outcomes? Each of these questions requires further study so we can better understand the effect of home computers and internet use on children's outcomes.

[4] Cristia et al. (2012) conducted a randomized evaluation of the OLPC program in schools in rural Peru, where children could also take their laptops home. They found no impacts on academic achievement but some positive and significant impacts on cognitive skills (as measured by the Raven's Progressive Matrices test). However, only 40 percent of laptops were actually used at home because of the concerns of school principals and parents.

[5] This is consistent with early evidence from small-scale lab studies showing impacts of playing video games on spatial skills. See Okagaki and Frensch (1994) and Subrahmanyam and Greenfield (1994).

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