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Access to Educational Technology and its Implications on Learning Outcomes of 15-year olds in Saudi Arabia* Empirical Evidence from OECD PISA 2018 in the context of COVID-19

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Abstract:

Fueled by the increasing availability and sophistication of digital technology, applications of Educational Technology (EdTech) have gained popularity at home and school. EdTech applications have been argued to address global education challenges by increasing access to education, identifying and teaching at the right level, managing class-sizes, and enhancing teacher development. The COVID-19 global health emergency has accelerated interest in how technology may support learning given that the mode of schooling is likely to be seriously impacted in the short-, medium, and potentially long-term. According to the Educational Production Function (EPF) theory evolved after the Coleman report (1966), more emphasis should be laid upon input factors that can be controlled by policymakers like the educational physical environment available to students. EdTech access is one such input factor. Education policymakers across the world, including Saudi Arabia, are now relying upon online portals and digital gadgets to provide lessons at home. Given this context, the current paper has used the Programme for International Student Assessment (PISA) 2018 dataset administered on a representative group of 15-year olds in the Kingdom and applied the EPF model to understand the role of EdTech access at home in improving learning outcomes. The paper finds a positive and statistically significant association between the availability and usage of EdTech resources with students' academic performance on subjects like reading, mathematics, and science. In addition, the paper shows that EdTech use varies across student subgroups in Saudi Arabia. For instance, students belonging to

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higher income households benefit more from EdTech usage. Further, female students outperform male students in both EdTech usage and test scores. Based on such findings, the paper concludes with key policy recommendations to inform a holistic EdTech response to the COVID-19 pandemic.

Keywords: EdTech, Saudi Arabia, PISA, COVID-19

الجابري. نياف بن رشدي، بوتوريا. أديتي. (٢٠٢٠). الوصول إلى تقنيات التعليم وانعكاساتها على نواتج التعلم للطلبة بعمر ١٥ عامًا في المملكة العربية السعودية، دليل تطبيقي من نتائج التقويم الدولي للطلبة (بيزا ٢٠١٨) في سياق فايروس كورونا (كوفيد-١٩). ***مجلة العلوم التربوية، ٦ (١)***، ٣٦٧-٤٠٠.

الوصول إلى تقنيات التعليم وانعكاساتها على نواتج التعلم للطلبة بعمر ١٥ عامًا في المملكة العربية السعودية
دليل تطبيقي من نتائج التقويم الدولي للطلبة (بيزا ٢٠١٨) في سياق فايروس كورونا (كوفيد-١٩)

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المستخلص:

توسع استعمال تقنيات التعليم في المنازل والمدارس بفضل التقدم المستمر في التقنيات الرقمية، تقنية ونضجًا، وهناك من يرى في تقنيات التعليم وتطبيقاتها ما يعد بتذليل التحديات التي تواجه نظم التعليم عبر العالم، باعتبار أن التقنية يمكن أن تزيد من فرص الوصول للتعليم، كما تساعد في اتخاذ القرار المتعلق بتقديم المستوى الملائم من التدريس، وفي إدارة الصف الدراسي، فضلًا عن إسهامها في تطوير المعلمين مهنيًّا. وقد زادت جائحة كورونا والمشكلات الصحية المصاحبة لها من الاهتمام بتقنيات التعليم وكيف يمكن من خلالها دعم عمليات التعلم، خاصة مع تزايد احتمال أن نمط التعليم والمدارس قد يتغير تأثرًا بالجائحة، على المدى القصير والمتوسط والطويل. وبحسب نظرية دوال الإنتاج التعليمية، التي بدأت بتقرير كولمان في عام ١٩٦٦م، فإنه ينبغي العناية بالمدخلات التي يمكن لصناع القرار ضبطها والتأثير فيها، مثل البيئة المادية المحيطة بالطالب، ومنها تقنيات التعليم والوصول إليها. ويعتمد صانعو السياسة التعليمية حاليًّا في دول العالم المختلفة -ومنها المملكة العربية السعودية- على المنصات الإلكترونية والأجهزة الرقمية لإيصال الدروس للطلبة في منازلهم. وفي هذا السياق، فإن الورقة الحالية قد وظفت بيانات المملكة العربية السعودية في البرنامج الدولي لتقويم الطلبة (بيزا ٢٠١٨)، الذي يطبق على الطلبة في سن ١٥ عامًا، واستعملت نظرية دوال إنتاج التعليم، بهدف الكشف عن مدى الوصول لتقنيات التعليم من المنزل وإسهامها في تحسين نواتج التعلم. وقد وجدت الورقة علاقة إيجابية دالة إحصائيًّا بين وفرة

تقنيات التعليم للطالب واستعمالها من قبله من ناحية وبين أدائه في اختبارات الرياضيات والقراءة والعلوم من ناحية أخرى، لكن تأثير تقنيات التعليم في التحصيل الدراسي يختلف باختلاف المستوى الاجتماعي الاقتصادي للطلبة، فالطلبة الذين ينتمون إلى مستويات اجتماعية اقتصادية مرتفعة يستفيدون بدرجة أكبر من استعمال تقنيات التعليم، كما تفوقت الإناث على الذكور في اختبارات اللغة والرياضيات والعلوم وكذلك في استعمال تقنيات التعليم. وبناءً على ما توصلت إليه من نتائج، انتهت الدراسة إلى توصيات لسياسة التعليم بهدف الاستفادة الأفضل من تقنيات التعليم، خاصة في ظل جائحة كورونا.

الكلمات المفتاحية: تقنيات التعليم، المملكة العربية السعودية، بيزا، كوفيد -١٩.

1. Introduction:

1.1 Background:

Education Technology (EdTech) can be broadly defined as any application of computing devices, software, and digital advancements to impart efficiency in access to education. EdTech is now being used as a tool for students to discover new topics and solve complex problems so as to enhance their learning processes. There is also an increased impetus on using EdTech because it provides a creative sharing environment and promotes collaborative learning at home and school (Chai et al., 2010). Technological advancements, particularly related to computers, mobiles, and the internet have created a plethora of EdTech options and service providers. The EdTech sector is getting further compounded by advances in other fields like computer sciences. For example, the advent of newer technology like Artificial Intelligence (AI), Deep Learning, and Big Data are expanding the already large choice set of EdTech solutions. Dede (2016) discussed data-informed instruction methods and how greatly they can improve quality of teaching and learning. A recent education policy paper by Sun et al.(2020) made good use of big data techniques to compile and analyze a dataset created using varied data management systems.

The ongoing COVID-19 pandemic has worked as a catalyst for enhancing EdTech demand. While there has been a steep rise in EdTech usage, which has accelerated the overall growth of the sector (more discussion on this is presented in Section 1.2), a sudden sectoral transformation is likely to amplify the already ingrained educational inequalities and discrimination in society. Regions with low access to EdTech or disadvantaged socio-economic groups are at the forefront of facing the brunt of COVID-19 induced school closures. Policymakers across both developed and developing nations are looking at ways to insure themselves from such crises in the future.

Considering the global rise of EdTech (Escueta et al., 2017), education policy needs effective decision-making to ensure investment in the right types of EdTech resources. However, current research shows that policymakers are far from consensus on investing in particular EdTech solutions and there is a lack of information on ‘what works’ in the sector (Molnar, 2017). Needless to say, this has only added impetus on educational leadership across the globe that has already been reeling under active pressure to achieve the goal of “ensuring inclusive and equitable quality education and opportunities for all" per the Sustainable Development Goals (SDGs) (UNESCO Institute for Statistics, 2015). Alternatively, if the EdTech expansion opportunity is prudently handled, it can potentially assist policy makers to outreach scalable learning solutions to diverse population groups.

It should also be noted that most of the policy and research initiatives thus far have focused on accentuating EdTech resources at the school level. However, in times of the current COVID-19 crisis, the mode of schooling is likely to be seriously impacted in the short-, medium-, and potentially long-term. Hence, EdTech access at home, its role, and requirements need further attention and evaluation, particularly to remove communication frictions and differential access to quality education on the grounds of socio-economic or cultural differences. Here, EdTech access at home can be defined as the availability of educational technology to students within their household for enhancing their cognitive and non-cognitive learning.

Interestingly, such access to EdTech resources at home is sparse across the globe. For example, in South-East Asia, only handful of countries cross the benchmark of 80 percent digital penetration which is a serious situation considering the newfound realities of a pandemic-ridden world (Jalli, 2020). Apart from this, there is also a "digital-use" divide where students, despite having access to EdTech at home, may not know how to use them efficiently because of digital illiteracy. Such information on EdTech has been collected because of its increasing importance over the years. In fact, EdTech has also been included (through technology-based questions) in large-scale international-level educational assessments like Organisation of Economic Cooperation and Development's (OECD's), Progress in International Reading Study (PIRLS), Trends in International Mathematics and Science Study (TIMSS), and Programme for International Student Assessment (PISA). Technology related details in these surveys enable an understanding of EdTech availability and usage frequency for a representative population of education stakeholders across the globe. For instance, in the 2012 PISA assessment, 93 percent of students from the OECD sample reported using a computer at home (OECD, 2015). PISA data over the years has also found EdTech usage and access to be widely affected by social fragmentation and cultural practices across OECD nations. Drabowicz (2014) has shown how EdTech access is differentiated across gender and socio-economic position in society, with richer boys, generally reporting higher frequency of EdTech usage compared to their more disadvantaged counterparts. Our paper aims to study similar aspects in the context of Saudi Arabia, which has not been explored so far.

Following in this section is a snapshot of why EdTech-based research has become increasingly pertinent in the context of the COVID-19 pandemic. Next, Section 2 presents a theoretical model to discuss the direct and indirect impact of EdTech on students' academic performance. It uses the Education Production Function (EPF) theory to explicitly model the pathways through which EdTech inputs impact outputs. Section 3 details the data used in this paper to determine the proliferation and implications of EdTech on test scores. It first visualizes the EdTech trends for Saudi Arabia and then presents the research hypothesis. Section 4 presents the results from analysis. Finally, Section 5 provides a policy discussion around the results and conclusions.

1.2 EdTech and COVID-19:

The COVID-19 crisis has exposed the vulnerabilities of our traditional educational systems. The crisis is already exasperating various forms of inequalities in terms of access and quality between low- and high-income groups, between different genders, across race and ethnicity. It has the potential to create a large dent in students' learning trajectory, potentially more strongly for the vulnerable sections of society. Although students in the past have been affected by health crises like EBOLA, H1N1, amongst others, the sheer magnitude of COVID-19 and its ripple effects through stringent lockdown and closure of educational institutions has left almost 87.4 percent of students worldwide in disarray (Pellini et al., 2020). The pandemic has stalled the global economy and has been detrimental to various sectors but there are a few sectors, like EdTech, which have seen a rise due to changing consumer preferences. Various EdTech firms like BYJU's, world's largest EdTech firm, has witnessed a rise in their subscriber base with a 200 percent increase in new subscriptions after the advent of the pandemic (World Economic Forum, 2020). In Wuhan, where the pandemic was first reported, more than 80 percent of students are attending online classes via Tencent K-12 software. Global EdTech firms are bolstering their platform to provide a one-stop solution for teachers and students. For example, ByteDance started offering Lark, an educational software for providing teachers and students with unlimited video-conferencing time, autotranslation capabilities, real-time co-editing of project work, and smart calendar scheduling amongst other features (World Economic Forum, 2020). To prepare for this, they ramped up their server infrastructure and engineering capabilities to ensure reliable connectivity. Similarly, Alibaba's distance learning solution DingTalk tapped the potential of its sister product Alibaba Cloud to deploy 100,000 new servers in two hours in March 2020. Even media outlets like British Broadcasting Corporation (BBC) are powering virtual learning and has rolled out a program called Bitesize Daily to offer 14-weeks of curriculum-based learning for children across the United Kingdom. The latest report by an EdTech firm, GSV Ventures has projected that the EdTech market is to touch $1 trillion by 2026, a rise that can be attributed to the COVID-19 crisis (Medium, 2020).

In the Kingdom of Saudi Arabia, 20 televised channels (iEn Educational Channels) have broadcasted lessons for all grades on a daily manner, using both the satellite and YouTube. Additionally, iEn National Education Portal has offered a wide range of learning materials, including PDF format textbooks, recorded lessons covering topics of all subjects, learning games, 3D simulations, and more of learning enriching resources. Both iEn Educational Channels and iEn National Educational portal were launched few years before the pandemic. They used to mitigate the learning loss in the southern border, where frontier schools have been closed to protect students from projectiles of Houthi rebels in Yemen since the fall of 2017. Although both are non-interactive, they assisted remote teaching during the 40 days of school closures at the time. Full interactivity between students and teachers require a learning management system, where each student is connected to his/her teachers, classmates and schools, and where the student activities can be monitored by teachers and school managers. In a well-established learning management system, teachers can normally run their scheduled classes online (synchronized learning), record their classes such that students can watch them again (asynchronized learning), assign homework and exams for students, mark submitted assignments and provide the needed assessment and feedback, and so on. Also, EdTech solutions such as learning management systems can produce data that help teachers and managers of education assess quality of instruction and learning, student performance, and attendance, amongst other things. Two learning management systems, Future Gate and The Unified Education Systems, were in use in Saudi Arabia during the 40 days of school closure. Future Gate is the Education Digital

Transformation Initiative that was launched in 2017 as part the Saudi Vision 2030. It has gone through a gradual development and rolling out. At the time of the pandemic it was embracing almost 3700 middle and senior high schools, leaving out more than 50% of middle and senior high schools as well as primary schools and early childhood schools. Hence, the Ministry of Education emergently developed The Unified Education Systems to serve schools that are not served by Future Gate.

A large part of EdTech surge during COVID-19 is driven by global policymakers and educationists encouraging online classes at home. Both public and private players are innovating and developing newer ways of continuing education without the students having to go to school. Some countries, like Saudi Arabia, are also trying to develop long-term, sustainable EdTech solutions which can be continued and made mainstream in the post-COVID world. There is a disparity in the availability of such resources across different social strata, at the system, school, teacher, student, and household levels. Programmatic linkages and research synergies between education in emergencies and education in disease outbreaks remain weak. Within this, education and technology infrastructure can be considered a key enabling condition for EdTech. However, infrastructure sounds better on paper, as what is often theoretically assumed is not necessarily available (Joynes et al., 2020). Thus, it is imperative to understand the contextual availability of EdTech resources and their impact on test-scores to undertake educational policy decisions amidst the crisis.

Given this setup, some key questions emerge which should be studied on a case-by-case basis. The current paper focuses on the case of Saudi Arabia. Firstly, what is the state of availability of EdTech resources at a household level to successfully implement home-based learning? Secondly, has access to EdTech in terms of hardware or software or online discussion/activity fora led to improved cognitive skills of students, thus far? Thirdly, does the existing data support the use of EdTech? Finally, which population groups are the most likely to have higher gains from home-based online learning? Going forward this will be an important indicator to study and formulate EdTech policies. These aspects are discussed theoretically in the next section and then explored empirically for the Saudi case in Section 3.

2. Theory:

EdTech is a relatively new area of research. The first studies on the use of computers for learning were only undertaken post-1960 with a skewed focus on developed economies. A highly influential paper by Angrist and Lavy (2002) found that the influx of new computers does result in higher usage of EdTech in instruction. EdTech access is also differentiated based on the environment - home or school. Woessmann and Fuchs (2004) show that benefits for students in academic terms are visible if students use computers at home for academic activities and discussion. Similarly, Spiezia (2011) showed, basing on PISA 2006 scores, that higher frequency of computer use at home has a significant and positive relationship with science test scores. Findings on the positive relationship between EdTech access at home and test scores have been replicated for different PISA scores and different countries (for example, Bussière and Gluszynski (2004) in Canada, Zahner (2019) in Switzerland, and and Ponzo (2011) in Italy). Previous literature also suggests the heterogeneous nature of technology usage based on gender. Tomte and Hatlevik (2011) in their analysis on Norwegian and Finnish students showed that male students have higher self-efficacy in conducting high-level information and communication technology tasks. Similarly, Volman et al. (2005) using primary data from Netherlands highlighted that boys had more favorable opinion towards EdTech usage compared to girls.

To understand the direct and indirect effects of EdTech, taking into account various heterogeneities such as gender-based differences, the current paper relies on the Educational Production Function (EPF) approach, an established methodology in economics of education and policy analysis (Hanushek, 2020), which traditionally has accommodated inputs like school resources, family characteristics, amongst others.

EPF approach makes use of the concept of the production function in standard economic analysis to the economics of education. It was ignited by the Coleman Report, authored in chief by the sociologist James Coleman (Coleman et al., 1966), which provided influential analysis about differential marginal effects of school and family characteristics on achievement levels of a child. A simple EPF relates various student-centric inputs like study environment, school's characteristics, socio-economic status, household characteristics, peers, to name a few, with the student's learning levels. Pritchett and Filmer (1999) showed that the literature on EPF over-uses inputs that are teacher-centric like wages rather than inputs which are student-centric like expenditure on books and instruction materials. On similar lines, Becker (1997) had made a case for educational reforms based on a student-based approach instead of a teacher-based approach. EdTech acts as a catalyst to amplify the outcomes of such reforms and is skewed towards student-centric learning. For example, the introduction of e-readers has already changed the outlook of book reading as it helps children to go through thousands of books on a single device (Ballatore and Natale, 2016). Nonetheless, EPF theorists are yet to establish agreement upon selection of inputs, for example, what type of investments in home resources impact student's test scores? However, there is a consensus on the broad idea that the achievement of students should be related to inputs that can be controlled by policymakers. EdTech access is one such component.

We present a simple optimizing model for EdTech. Suppose the agent owns a fixed budget B across the list of inputs. The agent, in our case, could be a student's parent or guardian. Suppose the educational output is test scores, denoted by S, and is related to educational inputs (e.g. educational resources, ICT resources, etc.) which are denoted as elements x_i of input vector X. Each of these inputs has price p_i and is related to the output S by a technically determined function $F^s(X)$. The implied objective function here is:

$$S = F^s(X)$$

- Eqn.1

The objective function will also be determined by the structure of the utility function represented by $F^s(X)$. A way to intuitively interpret this is that that utility function is derived from two components of educational resources: (i) Digital educational resources like a computer, educational software (computer-assisted learning), etc. and (ii) Non-digital educational resources like books, tuition expenditure, etc. Non-digital resources are primary sources of school education and thus impact test scores. On the other hand, digital resources act as a secondary source and are expected to provide impetus to the learning process. So, we can write $F^s(X)$ as $\alpha F^d(X_d) + (1-\alpha)F^{nd}(X_{nd})$ where X_d is vector of digital inputs and X_{nd} is vector of non-digital inputs. $F^d(X_d)$ and $F^{nd}(X_{nd})$ is utility derived from the digital and non-digital inputs respectively. α lies between 0 and 1 can be interpreted as an index of EdTech ownership. Higher its value, more EdTech resources are owned by the agent. The final educational utility optimization problem is represented by the equation:

$$\max_{X_d, X_{nd}} [\alpha F^d(X_d) + (1-\alpha)F^{nd}(X_{nd})]$$

$$subject\ to\ p^d(X_d) + p^{nd}(X_{nd}) = B$$

- Eqn.2

The above model is a simple generalization of the education production function which embeds EdTech and helps illustrate how test scores are impacted by the availability of EdTech - directly through $F^d(X_d)$ and indirectly through $F^{nd}(X_{nd})$. For instance, Notten and Kraaykamp (2009) using data from 2006 PISA has shown that the frequency of ICT resources (including media resources like TV) at home has a positive impact on test scores. There are some examples of how EdTech could indirectly impact learning outcomes through traditional inputs as well. In terms of student-level factors, EdTech access presents a chance for pupils to get involved in secondary education at home and leverage its potential to explore peer coaching and peer reviews. Students can alter the intake of educational resources according to their characteristics. Pozo and Stull (2006) show how initial provisions like secondary studies or tuition with the help of the Internet or an online tutor are important to drive a student's eventual success in university. Further, a student's attention, effort, and motivation are also critical student-level factors for achieving subject-matter excellence. A paper by Becker (2000) highlights that use of computers increases student engagement and motivation which results in larger time spent studying beyond class hours. Theoretically, students with EdTech access at home can access academic material at a time of their convenience and undertake asynchronous learning which then impacts their academic performance. Similar examples can be found for school-, teacher-, and parental-factors that are used in traditional EPFs and are expected to improve student learning.

3. Analysis:

In the first part of this section, we present descriptive analysis of the EdTech usage pattern in Saudi Arabia. In addition, we will look at gender-based differences in EdTech use. In the following parts, we discuss our research hypothesis which we aim to address using the Ordinary Least Squares (OLS) method. An OLS technique is widely used as an econometric tool in empirical economics to estimate average treatment effects. We conclude with a subgroup analysis to determine the gains from home-based online access and participation for different student characteristics in the Kingdom. Generally, the study presented in this paper can be classified under the descriptive analytical research methodology, using the econometric methods and EDP approaches.

3.1 Data:

Programme for International Student Assessment (PISA) is conducted by the Organization for Economic Co-operation and Development (OECD) for 15-year old students to assess cognitive achievement in mathematics, science, and reading. The PISA dataset for Saudi Arabia contains observation for 6136 students in the age group of 15-16 years, which are representative of all Saudi students in this age group. PISA selects the particular group assuming that 15-16-year olds have either completed or about to finish their compulsory schooling. The variables related to Information and Communication Technology (ICT) and learning outcomes, which are a part of PISA's student questionnaire as well as its supplementary questionnaire on ICT familiarity, have been used in this paper.

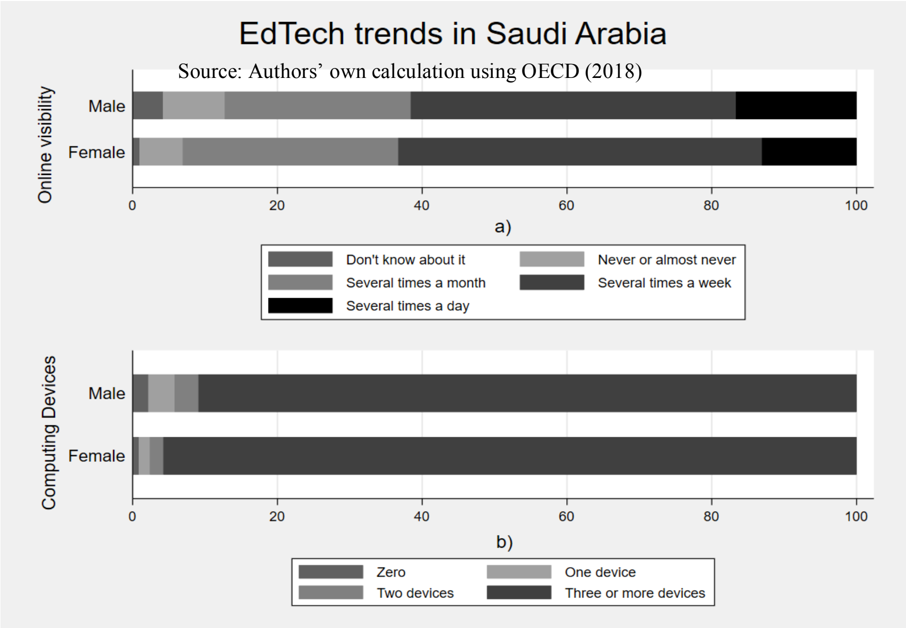
3.2 Descriptive Statistics:

Saudi Arabia participated in PISA for the first time in 2018 and data aspects related to access and use of EdTech across the Kingdom have remained unexplored. This paper presents an analysis of the PISA 2018 data for the Kingdom of Saudi Arabia that were released on December 3, 2019; hence, it is one of the first large-scale quantitative explorations of recent EdTech data in the context of Saudi Arabia.

Figure 1 part **a** shows descriptive statistics for the online activity index, which is a mean index created using OECD-PISA (2018) dataset for Saudi Arabia. The online activity index incorporates six Likert-scale questions related to online activity: (1) how often a student involves in online chatting with his/her friends and relatives; (2) how often a student takes part in online discussions; (3) how often a student indulges in online browsing for receiving news; (4) how frequently a student checks his/her email; (5) how often he/she does online browsing; and (6) how often student uses the Internet to schedule an event.[1]

Figure (1)

EdTech trends in Saudi Arabia



Saudi students frequently access the Internet in their daily lives. Approximately 61 percent of male students and 62 percent female students who took part in the PISA 2018 report using the Internet several times a week while only five percent of all students reported not knowing about Internet features or never using it. Statistics on the gender differentiation on EdTech usage contrasts with previous observations for other OECD countries. Drabowicz (2014) analyzed 39 developed countries on the 2006 PISA framework and showed that boys use computers and the Internet more often than girls. Similarly, Notten et al. (2009) had observed that female adolescents have lower odds of Internet access at home than males. On this parameter, Saudi Arabia reports a higher EdTech exposure for girls than boys, as also seen in part **b** of the same figure.

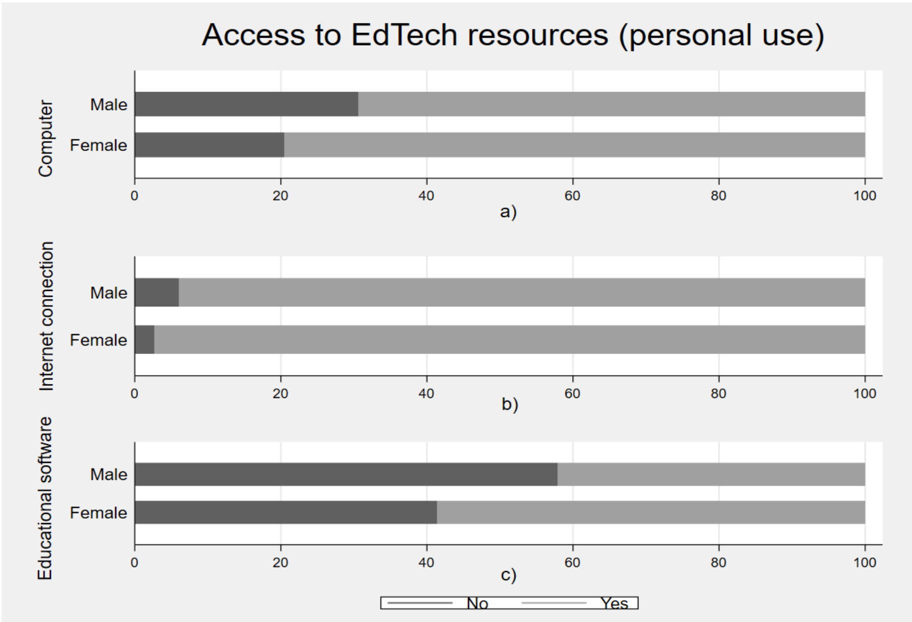
Figure 1 part **b** presents the Saudi trends for the number of computing gadgets in a student's household. Computing gadgets here comprise the total

(1) The Likert-scale responses range from "Don't know about it" to "using Several times a day".

number of mobiles, computers, or tablet computers in a student's households. As can be observed, EdTech resources access in Saudi Arabia is high, for both genders. Ninety percent of male students and 95 percent of female students have three or more gadgets in their homes. However, this figure should be read with the caveat that it only indicates household access to computers/tablets, which may well be different from the number of computers/tablets available for a student's personal use.

Figure (2)

Access to EdTech resources (personal use)



Source: Authors' own calculation using OECD (2018)

Figure 2 on the other hand represents the availability of EdTech resources for the personal use of students. While the computing gadgets index discussed earlier was a score of the total number of gadgets at home, this records the dummy response for the availability of personal ICT resources to the student. One in every four 15-year old does not have access to a personal computer. Moreover, almost every other student does not have educational software, which is an explicit investment usually undertaken to enhance EdTech usage to promote self-paced learning. Finally, only about one tenth of Saudi students own one or more e-readers, which are conducive for digital and habitual reading. Internet connectivity for personal use, on the other hand, is readily available. Following similar trends to Figure 1, female students report higher access to ICT gadgets compared to male students.

Table (1)

Polychoric correlation matrix

Variables	Computing gadgets	Internet at home	Online activity
Computing gadgets	1.0	---	--
Internet connectivity	0.6285	1.0	----
Online Activity	0.2542	0.3376	1.0

Source: Authors' own calculation using OECD (2018)

Table 1 reports the polychoric correlation matrix for computing gadgets at home, Internet connectivity, and overall online activity of a student. Here, the computer gadgets variable denotes the availability of relevant items like computers, mobile *phones*, and tablets at home; Internet connectivity represents the internet connection in student's household; and the online activity variable remains the same as defined earlier - an index of how often a 15-year old participates in online fora. Having a large number of computing devices at home is positively associated with Internet connectivity and online activity with a more substantial degree of association with the Internet. It can be conjectured that while the availability of ICT at home is not solely responsible for online participation of 15-year olds, it does associate with more than one-fourth of such activities.

3.3 Empirical Strategy:

We have used an Ordinary Least Squares (OLS) model to estimate the *average* treatment effect of EdTech usage on the students' academic performance. Our regression model controls for gender, family status measured by PISA 2018 Economic, Social, and Cultural Index (ESCS) index, and school type. These variables have been previously found to be directly impacting the test scores of a student (Duncan Thomas, 2001; and Machin et al., 2008). Apart from these, we also include variables like learning time devoted to each subject and student's motivation index.

For the econometric estimation of average EdTech usage impact, we use the following model:

$$Y_i = \alpha + \beta_1 Online\_Activity_i + \beta_2 Public_i + \beta_3 Female_i + \beta_4 ESCS_i + \beta_i X_i + \epsilon_i$$

- Eqn.3

where student's reading scores, *mathematics* scores, and science scores are captured by the dependent variable Y_i. "Online_Activity" variable, as described in Section 1 is the primary variable of interest. It captures the student's online activity in the form of web browsing, online discussion, online news extraction, and others. The coefficient β_1 measures the impact of online activity on test scores. The ESCS Index is an extensive term created by OECD PISA that summarizes different aspects of student's family background and status, including parental income and education. Female is a dummy variable, 1 for female and 0 for male. X_i is the set of other variables that may account for achievement scores of a student, such as learning time devoted by a student to each subject and PISA's Motivation to Learn index for a student. Finally, the error term ϵ_i captures the effect of unobservables in the model. The descriptive statistics of each of the variables included in the empirical model is provided in Table A.1 in Appendix.

Heterogeneous-treatment effects: to further analyze the potential variation in the impact of EdTech usage across students, students are divided into different sub-categories based on their ESCS index. ESCS index is created by PISA surveyors *by* standardizing it across OECD sample countries. Here, it is divided into four categories by quartile. The four income quartiles are referred to as low-ESCS, middle-ESCS, upper-ESCS, and uppermost-ESCS respectively. Equation (1), then, is augmented to include subgroup interaction effects of the ESCS index with the ICT resource index [1] and Online activity variables,

(1) General ICT resources index created by PISA covers all ICT-related variables ranging from computers and access to the Internet (i.e. hardware resource for general use) to cameras (hardware resource for specific use), and also includes social networking websites or educational software (computer-assisted learning).

respectively. The ICT resource index and Online activity variables are considered as proxies for use of EdTech at home.

$$Y_i = \alpha + \beta_1 Public_i + \beta_2 Female_i + \beta_3 ESCS_i + \beta_{ie}(student\ i \in EdTech\ category\ I) * (student\ e \in ESCS\ group\ G) + \beta_i X_i + \sigma_i$$

- Eqn.4

In the above model, EdTech category variables could be either i) Online activity as described earlier or, ii) ICT resource index. Each of these two indices have *been* further divided into three categories (low, medium, and high) based on usage and possession. Further, X represents other variables like OECD's Motivation Index and Learning Time devoted to each test subject. The coefficient of interest is β_{ie} which represents the interaction effect for students (where i ranges from 1-3) belonging to category *i* of EdTech variable and category *e* of ESCS index (e ranges from 1-4). For example, "low∗lower-ESCS" represents a student who has low EdTech usage and belongs to the low-quartile ESCS index. Finally, while this paper uses absolute PISA test scores for analysis, findings were validated through robustness checks conducted by using standard PISA proficiency levels as the dependent variable. This was done by creating different levels of proficiency for each test subject as directed in OECD's technical report (OECD, 2018). Each proficiency level reflects a unique level of understanding of the subject.

4. Results:

Average Effects of EdTech usage: this section shows results for the association between the access to ICT resources and frequency of online activity undertaken by students and the PISA test outcomes of Saudi 15-year olds. The regression results are presented in Table 2.

The total number of computing gadgets used in PISA covers a subset of these items like computers, mobile phones, and tablets

Table (2)

Average Effects of EdTech usage

	Math Score	Reading score	Science Score
Online activity Index	6.783***	9.241***	5.031***
	(1.312)	(1.308)	(1.080)
Public School	-16.315**	-17.926***	-17.298***
	(5.672)	(4.815)	(5.170)
Female	10.675*	50.671***	25.921***
	(4.625)	(3.754)	(4.296)
ESCS index	17.559***	8.852***	16.880***
	(1.587)	(1.640)	(1.606)
Motivation Index	11.558***	14.176***	11.803***
	(1.257)	(1.134)	(1.202)
Constant	349.361***	355.104***	355.168***
	(7.557)	(7.149)	(6.948)
Observations standard errors in parentheses *p < 0.05, **p < 0.01, ***p < 0.001	6136	6136	6136

Source: Authors' own calculation using OECD (2018)

Online activity of students has a significant positive association with all three subject scores. Each point increase on online activity index is associated by 9.2 points increase reading test score, 6.8 points in mathematics test score, and 5 points in science test score. Hence, online activity impact most reading skills and least science skills, although all coefficients are positive and statistically significant. This finding is in line with findings of Odell et al. (2020) who showed comfortability with ICT as an inducer of better performance in science in Bulgaria and Finland.

ESCS is statistically and positively associated with student's test scores while inducing the highest marginal gains in mathematics. Higher the index, better the proficiency level of a student. As discussed earlier, the ESCS index covers a vast spectrum of indicators like parent educations level, home environment, and family wealth, amongst others. Having a higher ESCS index signifies that the student is privileged and has better access to digital resources. This kind of "digital-divide" is quite a rampant issue even among OECD sample and should be taken care of while formulating EdTech policies. Amongst OECD countries, whilst 95 percent of students in Switzerland, Norway, and Austria have a personal computer to use (World Economic Forum, 2020), for Saudi Arabia this figure is approximately 75 percent.

Being a female has advantages in Saudi Arabia in terms of test scores. Female students significantly outperform male students in reading, with the score gaps narrowing down in mathematics. Hence, girls in Saudi education system have consistently outperformed boys across EdTech access, usage, and achievement outcomes. Results in favor of female students align with general OECD findings of a reverse gender-gap in Middle Eastern countries (OECD, 2018). However, one limitation of the OECD PISA 2018 dataset is that while we can determine that girls are doing better than boys it is difficult to attribute specific reasons to why girls are doing better. In our analysis, we do find that girls are more motivated to excel in academics than boys with a standardized mean motivation index of 0.37 compared to 0.09 for boys. However, future research can focus on determining the causal factors for the reverse gender-gap in academic performance.

Public schools are at a disadvantageous position in Saudi Arabia, given that being in a public-school student results in lower test scores across the subjects, on average. Public school students achieved, on average, 16.3, 17.9, and 17.3 less points in mathematics, reading, and science, respectively. However, using a two-level regression and aggregating ESCS at the school level to gauge the overall peer effect might lead to different findings. As expected, students with higher motivation to learn perform better in tests. Each incremental point on the motivation index is associated by extra 14.2 points in reading test score.

Heterogeneous Effects of EdTech usage: It is a well-established fact that reforms undertaken in the education field have varied impacts on students. As showed in our previous section, being a female has an added advantage in terms of test outcomes. Similarly, students belonging to higher echelons of the society scored better than their counterparts in lower stratum. Further, results on the heterogeneous effects for different socio-economic groups (represented by levels of the ESCS index) on EdTech access and usage are presented in the tables 3 and 4.

Table (3)

Heterogeneous Effects (ICT resource index interacted with ESCS index)

	Math Score	Reading score	Science Score
Public school	-15.554**	-16.897***	-17.644***
	(5.500)	(5.070)	(4.660)
Female	10.150*	25.470***	50.015***
	(4.602)	(4.313)	(3.743)
ESCS index	12.202***	12.600***	15.498***
	(3.179)	(3.484)	(3.622)
Low*Lower ESCS index	0.000	0.000	0.000
	(.)	(.)	(.)
Low*Middle ESCS index	-3.192	-1.691	-3.194
	(4.780)	(4.889)	(4.824)
Low*Upper ESCS index	3.665	4.247	1.678
	(7.794)	(7.117)	(6.907)
Low*Uppermost ESCS index	17.656	17.331	13.160
	(10.003)	(11.047)	(10.160)
Medium*Lower ESCS index	8.316	12.558	16.643
	(9.817)	(10.107)	(10.929)
Medium*Middle ESCS index	8.267	8.801	9.980
	(7.969)	(7.514)	(8.289)
Medium*Upper ESCS index	10.626	7.324	6.925

	Math Score	Reading score	Science Score
	(9.241)	(8.579)	(8.718)
Medium*Uppermost ESCS index	26.537*	18.932	21.113
	(11.678)	(11.825)	(11.459)
High*Lower ESCS index	16.922*	12.977*	17.339*
	(7.981)	(6.228)	(7.035)
High*Middle ESCS index	18.867**	17.026*	19.737***
	(5.985)	(6.630)	(5.028)
High*Upper ESCS index	18.410*	16.324*	17.685*
	(8.060)	(6.910)	(7.204)
High*Uppermost ESCS index	24.524**	19.020	18.609
	(9.234)	(9.984)	(9.691)
Constant	358.974***	361.638***	377.414***
	(9.349)	(8.149)	(8.518)
Observations	6136	6136	6136
standard errors in parentheses *p < 0.05, **p < 0.01, ***p < 0.001			

Source: Authors' own calculation using OECD (2018)

Note:- ESCS index is created by PISA surveyors by standardizing it across OECD sample countries. Specifically, for the purpose of conducting the heterogeneity analysis, we divide the ESCS index into four categories by quartile ranging from 1 to 4, forming a categorical variable. The four income quartiles are referred to as low-index, middle-index, upper-index, and uppermost-index. We augment Equation (1) to include subgroup interaction effects of the ESCS index with the ICT resources index with three categories (low-, medium-, high-ICT access)

Table (4)

Heterogeneous Effects (Online activity index interacted with ESCS index)

	Math Score	Reading score	Science Score
Public school	-15.733**	-16.838***	-17.664***
	(5.538)	(5.060)	(4.705)

	Math Score	Reading score	Science Score
Female	9.767*	25.160***	49.618***
	(4.576)	(4.258)	(3.734)
ESCS Index	13.285***	13.477***	16.280***
	(3.108)	(3.527)	(3.590)
Low*Lower ESCS index	0.000	0.000	0.000
	(.)	(.)	(.)
Low*Middle ESCS index	-13.445	-14.761	-11.401
	(8.657)	(7.806)	(7.475)
Low*Upper ESCS index	-11.706	-7.515	-8.998
	(10.736)	(11.195)	(10.118)
Low*Uppermost ESCS index	-16.932	-26.436*	-17.232
	(11.154)	(13.070)	(11.767)
Medium*Lower ESCS index	14.629*	11.068	21.114***
	(6.385)	(5.762)	(5.783)
Medium*Middle ESCS index	15.363*	11.026	20.022**
	(6.747)	(7.176)	(6.733)
Medium*Upper ESCS index	19.155*	15.027	25.701**
	(8.801)	(9.413)	(9.311)
Medium*Uppermost ESCS index	25.529*	21.422	26.300*
	(9.934)	(12.032)	(11.467)
High*Lower ESCS index	16.097**	11.290*	25.802***
	(6.034)	(5.390)	(5.725)
High*Middle ESCS index	17.196*	15.096*	26.726***
	(7.308)	(6.848)	(7.522)
High*Upper ESCS index	23.072**	18.146*	28.558**
	(8.243)	(8.361)	(8.832)
High*Uppermost ESCS index	36.800***	28.345*	39.370***
	(9.713)	(11.539)	(11.333)
Constant	352.736***	357.098***	362.516***
	(9.861)	(10.162)	(10.006)
Observations	6136	6136	6136
standard errors in			

	Math Score	Reading score	Science Score
parentheses *p < 0.05, **p < 0.01, ***p < 0.001			

Source: Authors' own calculation using OECD (2018)

Note:- ESCS index is created by PISA surveyors by standardizing it across OECD sample countries. Specifically, for the purpose of conducting the heterogeneity analysis, we divide the ESCS index into four categories by quartile. The four income quartiles are referred to as low-index, middle-index, upper-index, and uppermost-index. We augment Equation (1) to include subgroup interaction effects of the ESCS index with the Online activity index with three categories (low-, medium-, high-online activity)

Table 3 and Table 4 reconfirm the previous findings from Table 2 in the presence of interaction terms. Various researchers and scholars have iterated how the socio-economic divide stands in the way of the efficient rise of EdTech (Macgilchrist, 2019). Here too, as seen in Table 3, students belonging to the upper strata of the society perform better than their counterparts in lower strata. Belonging to the upper ESCS with medium to high EdTech usage gives a statistically significant leverage of about 20-25 score points. Results are significant from both economic and policy perspective.

Even if a lower ESCS student has high EdTech possession, they do not gain much relative to upper ESCS. This finding can be partially attributed to the theory of "digital-use-divide" which states that even when disadvantaged groups possess EdTech or ICT resources, they may lack the proper knowledge or support to effectively harness its potential (Brotman, 2016). Given these findings, any policy prescription adopted should take into consideration supplementary aspects like digital literacy for lower income strata in society, in addition to a blanket proliferation of EdTech devices.

Further, it is interesting to find that students show marginally diminishing gains from usage of ICT resources as depicted by the interaction terms involving online activity and ESCS in Table 4. Similar trends have been observed in some recent studies too. For example, Bettinger et al. (2020) finds a diminishing marginal rate of return for EdTech. While such trends need to be explored further through future research, one reason that can be attributed to it based on previous literature is that very high possession of EdTech resources can distract students from doing productive work, especially at home (Youssef and Dahmani, 2008).

5. Conclusions and policy implications:

This study has discussed the potential of EdTech and a recent surge in the sector given COVID-19. However, for a successful transformation towards EdTech, policymakers, and educationists need to consider various factors. The existing socio-economic inequalities have come to the fore during the pandemic and they have the potential to amplify the already prevalent gaps in student achievement. Policy directions, which we think can be useful to tackle the current challenges related to the efficient use of EdTech, are briefly discussed below.

Firstly, one of the primary impediments to large-scale use of EdTech is “inequality” in its various forms. Unequal access to resources and opportunities remains one of the fundamental problems in social sciences, and the education sector is no different. Education policy needs to be cognizant of the ‘digital divide’ in terms of hardware, software, and environmental factors, especially in the home environment, to foster productive digital learning. Education policy should ensure access to EdTech resources to children from low income and middle-income households to ensure that learning gaps due to variations in access are minimized. Inequality can also persist based on gender or school-choice. These factors need to be taken into consideration while designing sustainable EdTech solutions and policies.

Secondly, in a crisis like COVID-19 where all student in the Kingdom of Saudi Arabia are affected due to school closures, more emphasis needs to be given to EdTech resources at home, as also suggested by Pellini et al. (2020) and Wherry (2004). Schools are only responsible for primary academic learning while other aspects of student growth and secondary learning take place outside school. In the discussed context, findings of this study suggest that policymakers should work closely with education researchers to decide the optimal division of EdTech resources between school and home. Guidelines and availability of basic EdTech infrastructure such as internet facilities and distribution of EdTech resources for home access, especially for lower-income groups, is imperative. Further research using large-scale and nationally representative assessments can help identify vulnerable sub-populations and formulate targeted policy responses.

Thirdly, this study suggests the importance of personal access of educational resources to students. Household access to the Internet and EdTech resources does not necessarily result in commensurate access to students. Parents or caretakers may own a digital device for their personal or professional use but may not be able to share it effectively with their children for the purposes of e-learning. Further, access differs based on gender. In fact, in the Kingdom of Saudi Arabia, there is a reverse gender-gap with girls having marginally higher access to EdTech resources compared to boys. Further research is needed on how EdTech access and usability varies across regional contexts (urban and rural) for a better understanding of within-country variations.

Lastly, before earmarking funds for EdTech, policymakers also need to decide and differentiate between different EdTech solutions, gauging direct and indirect benefits. For instance, while it is being acknowledged that basic hardware and the Internet alone may not increase achievement scores, they do increase digital literacy and computer skills that can help effectively use other educational software. Policymakers need to invest in and take help of evidence-based policy research to check the efficacy of various EdTech solutions. For example, an impact evaluation of an adaptive-learning software Mindspark in India found an impact of 0.19 standard deviation (IDinsight, 2014). It has also been argued that computer-assisted learning could be quite effective in improving learning, particularly with math (J-PAL, 2019). Further research is also needed to determine the impact of EdTech models (including LMS systems like the recently implemented, i.e., Unified Education Systems) in the Saudi context to inform better policy.

In summary, the current study presented the proliferation of EdTech access in Saudi Arabia. Almost every Saudi student has Internet connectivity for personal use at home with every three out of four students having a computer for personal use. The majority of Kingdom's students frequently access the Internet and resources for online discussion, chatting, and reading news. Contrary to other OECD countries, Saudi Arabia's EdTech use and access are skewed in favor of female students. Further, students' frequency of online activity has a statistically significant and positive association with reading, mathematics, and science scores. Belonging to the higher strata of society and studying in a private school result in subject-specific benefits. In congruence with Bettinger et al. (2020) there are diminishing marginal returns of EdTech or ICT applications. However, one limitation of the analysis in this study is that it is correlational nature; it does not provide any causal mechanism for its findings. Next research may compare findings across countries participated in PISA 2018, to test the validity of findings across varied contexts.

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Appendix

Table A.1: Descriptive Statistics for variables of interest

Male			Female			Total
	mean	sd	Mean	sd	min	max
Online activity	3.613	0.997	3.685	0.809	1	5
Learning time: Maths	222.830	66.093	216.912	65.397	0	675
Learning time: Reading	231.594	70.819	231.898	71.633	0	675
Learning time: Science	212.809	94.526	215.373	101.613	0	675
ICT Resources Index	-0.385	1.208	-0.222	1.005	-3.804	3.6012
Economic, Social and Cultural (ESCS) Index	-0.688	1.197	-0.639	1.156	-4.829	2.779
Motivation Index	0.090	1.146	0.367	0.949	-2.737	1.816
Public School	0.801	0.400	0.912	0.283	0	1
Observations	3144		2992		6136	

Source: Authors' own calculation using OECD (2018)

In Table A.1 above, we present the descriptive statistics for the variable used in the regression model. The online activity index ranges from 1 to 5. To illustrate, One denotes "illiteracy for Online usage" while five denotes "several times a day". It is clear that students in Saudi Arabia are highly engaged online with a mean of 3.6, which represents usage of "several times a week". The learning time variable tells us how much time a student devotes to a particular test subject in a week in minutes. ESCS is a very broad variable covering following parameters of interest: the International Socio-Economic Index of Occupational Status (ISEI); the highest level of education of the student's parents, converted into years of schooling; the PISA index of family wealth; the PISA index of home educational resources; and the PISA index of possessions related to "classical" culture in the family home. ICT resources index is created by PISA covering all ICT-related variables ranging from computers and access to the Internet to cameras and also includes social networking websites or educational software (computer-assisted learning). Motivation Index denotes the motivation of students to master tasks. Students report the level of agreement with the statements about themselves. Some of the questions/statements included are: “I find satisfaction in working as hard as I can”; “Once I start a task, I persist until it is finished”. Scale Indices like ESCS, ICT resources and Motivation Index have been standardized across the OECD countries, so the mean of the index is zero for the OECD sample with one standard deviation. Saudi Arabia falls below OECD average in ICT resources index. A student with a positive ESCS belongs to a higher economic and social background than the average OECD household. The last variable, “Public” is dummy variable; 1 for a public-funded school and 0 for a private.