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EdTech for Equity in China: Can Technology Improve Teaching for Millions of Rural Students?

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Abstract

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Keywords: Teaching, EdTech, Educational technology, Teaching quality

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A Landscape Paper

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Keywords: Technology-assisted Instruction; Educational Equity; Teaching Quality; Rural Schools; China

JEL Classification Codes: I24; I28; O53

EdTech for Equity in China:
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I. Introduction: Why Poor Teaching is Widening China's Education Gap

In recent decades, as China's economy has grown exponentially, China's education system has achieved a number of notable successes. The adult literacy rate increased from 66% in 1982 to 97% in 2019 (UNESCO, 2019a). Students from large cities in China have performed among the best on international standardized evaluations, such as the Organization for Economic Cooperation and Development (OECD)'s Program for International Student Assessment (PISA). In fact, on the 2012 PISA, students from Shanghai, China outperformed students from 64 other countries in all subject areas tested (OECD, 2014). Finally, overall school access has increased dramatically over the past decades. Today, nearly all (99%) of China's children—both urban and rural—are finishing primary school, and all children are entitled to nine years of free schooling (which includes primary and lower secondary school in China – Chung and Mason, 2012). Since 2005, the share of youth attending upper secondary school (grades 10-12) has also increased rapidly (Bai et al., 2019).

Despite these accomplishments, large disparities in academic performance still exist between China's urban and rural youth. Gaps in school performance between China's urban and rural children emerge as early as primary school (Zhang, Li, and Xue, 2015) and have been shown to exist not only in the national aggregate but also at the provincial level (Xiang et al., 2019). Differences in achievement on international assessments make these gaps even more apparent. While Shanghai students have performed among the top in the world on standardized tests, students from lower-income, inland, and rural provinces have performed among the lowest

(Gao et al., 2017). This is worrisome, as rural children make up approximately 70% of China's school-aged population (National Bureau of Statistics, 2018).

As a result of academic performance disparities, there are significant differences in educational attainment between students across urban-rural and regional boundaries. For example, only 60% of students from poor counties in Ningxia Province take the high school entrance exam while almost 100% of students from non-poor counties do (Loyalka et al., 2017). Another study with data from 2009–2011 found that almost 15% of students among four rural counties in the northwestern provinces of Shanxi and Shaanxi dropped out of lower secondary school (grades 7-9) before completion, with even higher dropout rates among students from poorer families and students with worse academic performance (Yi et al., 2012). Without sufficient years of quality education, it is possible that rural students will be unable to develop the human capital needed to succeed in the knowledge economy (Wang et al., 2018).

Research in recent years has shown that there are many reasons for why rural students in China are struggling in school. For example, despite substantial improvements over the past few decades, schooling facilities in rural areas are still worse than in urban areas (Wang et al., 2017; Yang et al., 2013). Urban parents also usually have attained a higher level of education and have more time and/or ability to help their children with their studies (Huang and Du, 2007). Average incomes in urban areas are also more than 2.5 times higher than those in rural areas, so urban families also have more resources to invest in their children's education (NBS, 2018). Furthermore, health problems among rural students negatively impact their academic performance. Specifically, studies have shown that, at least over the past decade, conditions such as anemia (Li et al., 2018), intestinal worms (Liu et al., 2017), and uncorrected visual acuity (Ma et al., 2014; Nie et al., 2018) negatively affect the performance of students in rural schools.

Among the most important factors driving low student performance among rural children may be the poor quality of teaching received by rural children. The close relationship between teacher quality and student outcomes has been demonstrated in numerous studies in the international literature (Boyd et al., 2008; Kane, Rockoff, and Staiger, 2007; Sanders and Rivers, 1996; Goe, 2007; Rice, 2003; Rockoff, 2004). Using hierarchical linear analysis, Hattie (2003) found that, aside from the innate ability of the students themselves, teacher quality—defined as what teachers know, do, and care about—is the most important factor that determines student achievement. One study in the United States estimated that higher student grades improves three times more when taught by a high-quality teacher versus a low-quality teacher (Hanushek, 2011).

In China, research also has demonstrated the importance of teacher quality for student learning. Chu et al. (2015) found that students with teachers of the highest credential rank perform significantly better academically than students with lower-ranked teachers, with students of low socioeconomic status benefiting in particular. Another study that matched student-teacher data from rural schools showed that teacher quality (also in terms of rank), is responsible, in large part, for variance in student performance on math and language scores (Park and Hannum, 2001). The authors estimated that at least one-quarter of the variation in student test scores was due to teacher quality. These results were echoed by Zhang et al.'s study (2018) of 10,712 middle school students in Guangxi province, which showed that the urban-rural gap in teacher quality is a significant contributor to the urban-rural gap in academic achievement. Based on the findings of this body of research, it appears that if the gap in teaching quality were eliminated, a significant reduction in the achievement gap may follow.

Why is teacher quality so poor in rural China? Rural schools in China—as in other parts of the world—have difficulty attracting high-quality teachers for a variety of reasons, including lower salaries that are often paid late, remote living environments, relatively poor infrastructure, fewer promotion opportunities, and heavier workloads (Liu and Onwuegbuzie, 2012). For these reasons, rural schools not only have difficulty recruiting new teachers but also have a hard time retaining their current faculty. Many rural teachers with the necessary ability seek to move to urban schools or completely change professions (Niu, 2009; Liu and Onwuegbuzie, 2012), while those teachers who ultimately stay behind often have lower education levels, lower ranks, and less experience (Zhang and Campbell, 2015). Due to the insufficient staff in these schools, rural teachers are often required to teach multiple subjects at the same time, even if they do not have the required qualifications or mastery (Liu and Onwuegbuzie, 2012). Moreover, they also lag behind in terms of their use of modern pedagogical techniques (Chung and Mason, 2012). At least part of this reluctance may be due to a lack of passion for their career (Sargent and Hannum, 2005). Recent data indicate that worldwide, rural teachers in China are among the most dissatisfied with their profession (authors' surveys, 2019).

While teacher quality is key in any effort to enhance student performance, the literature has shown that the teaching received by rural students in China lags far behind that received by urban students. This raises a number of questions: What are conventional ways—approaches tried in other contexts (i.e., approaches used in other countries)—to resolve a school system's teaching quality problem? Would these ways work in rural China? Why or why not? If not, are there alternative ways of teaching rural students with the assistance of technology? If so, what are the challenges of harnessing these approaches in ways that can sustainably raise the quality of teaching and ultimately the academic performance of students in rural schools?

The overall goal of this paper is to seek out answers to these questions. In meeting this overall goal, we have four specific objectives. First, we will review common approaches to improving teaching quality for disadvantaged student populations and discuss reasons they may not work in China's context. Second, we will explore the existing international literature on an alternative approach to improving teaching by examining the effectiveness of educational technology (or *EdTech*) in improving rural student outcomes. Third, we will examine the potential role of EdTech in narrowing China's education gap. Finally, we will assess the potential challenges of using EdTech to improve teaching quality in rural China.

To meet these objectives, we will use the following strategy. First, we will examine the existing literature on three different strategies that educators in other nations (and China) have used to address the needs of rural students and provide evidence for why such approaches have not been universally effective in rural China. Second, we will explore analyses of the potential of the newly emerging EdTech sector to improve student outcomes and hypothesize why EdTech interventions have never undergone large-scale adoption in low-resource areas in any nation. Third, we will draw on official statistics, our own data, EdTech industrial sector reports, and government policy briefs to discuss why China may be a rare example of a country capable of using EdTech to raise the quality of teaching received by millions of disadvantaged students. Finally, we further explore the potential challenges of adopting and upscaling these technologies and approaches by reporting on the results of a series of qualitative interviews that we conducted in three rural schools where major EdTech companies are conducting Corporate Social Responsibility (CSR) projects.

II. Traditional Ways to Improve Teaching: Can They Work in Rural China?

How then can China improve the quality of teaching for rural students? In theory, there are three traditional solutions that have been used internationally that China could implement, but due to structural and political barriers they are either not feasible or have been tried and failed. These three traditional solutions are a.) to allow children to migrate to urban areas to access better schooling; b) to attract well-trained, well-educated urban teachers to rural schools; and/or c.) to raise the quality of rural teachers through teacher training or professional development (PD) programs.

A. Rural-Urban Migration

The first, and in most countries easiest, solution is for children in low-resource school districts to migrate to more developed areas, where they would then be able to access higher-quality education. According to data collected from the 2015 PISA (Echazarra and Radinger, 2019) schools in urban areas across the world tend to be larger and have superior educational resources than rural schools (including the quantity and quality of teachers). Consequently, students who grow up in areas characterized by poverty—especially remote, rural ones—rarely have access to high-quality schooling. In response, many families try to relocate to more affluent areas—which in most countries means the major cities. Although some of these families may still face obstacles, such as limited access to affordable housing, there are usually no legal barriers preventing them from moving into cities in pursuit of better schooling. In some cases, families may even receive government assistance such as housing vouchers or access to low-cost housing programs (Crowley, 2003; Deluca and Rosenblatt, 2010).

In China, however, moving rural students to city schools to gain access to higher quality teaching is not feasible for the vast majority of rural families. Of course, as in other countries, many families from rural China who wish to move to cities for the education of their children face financial barriers due to the huge urban-rural income gaps that exist in China. However, even for those that can afford urban housing and the costs of living, rural families face administrative restrictions in the form of the household registration, or *hukou,* system. Under the hukou system, a person's access to social services—including public education—is tied to their hukou registration (which is inherited at birth). As a result, those children with rural hukous have historically been unable to legally enroll in urban primary schools (Chan and Buckingham, 2008). Although policy shifts on the national level in recent years have mandated that local authorities provide free education to rural migrant students, schools in some—especially larger—cities continue to impose an array of difficult-to-fulfill administrative and academic requirements that can prevent migrant students from attending at all (UNESCO, 2019b).

B. Teacher Relocation

With rural children unable to access the higher-quality educational resources of urban areas, another approach to reducing educational disparities between urban and rural areas could be to attract high-quality teachers from urban areas to rural schools. Developed and developing countries alike have faced teacher shortages in remote areas and have accordingly used a number of methods to attract and retain educators in low-resourced school districts, which have had varying degrees of success. Roberts (2004), Harmon (2001), Hudson and Hudson (2008), and McEwan (1999) detail efforts of the Australian and US governments to use a combination of monetary and non-monetary incentives, which they claim have not been fully successful due to the neglect of other factors such as the need to prepare new hires for the local rural context prior to on-boarding. Another study in Ghana (Cobbold, 2006) described a scheme to attract new students at teacher training colleges to commit to teaching in rural areas for at least three years through an incentive package, which failed to have an impact on retaining teachers in rural schools over the long term. Reasons for the failure to influence participants' career plans include the lack of a hands-on practicum in the rural school districts prior to graduation, insufficient professional development, and inadequate financial incentives.

The design of the Free Teacher Education (*FTE*) program of China's national government is in many ways analogous to that of Ghana's district sponsorship scheme. Starting in 2007, due to a perceived shortage of the supply of high-quality teachers to rural areas, China's FTE program offered qualified students at six of the top normal universities in different parts of China a package of financial benefits, which included tuition exemption for a degree in teaching, free accommodation, and a monthly stipend (MOE, 2007). After graduation, FTE graduates were guaranteed teaching posts by the government. In exchange for these benefits, FTE students were required to sign a contract to serve for a period of ten years in primary or secondary schools in their home provinces. Those FTE teachers who found employment in urban schools were obliged to first teach in rural schools for at least two years. Breaking these requirements would result in penalties: violators had to repay all educational costs in addition to paying a penalty, and they were blacklisted in the Credit Record Archives established by the educational authorities (MOE, 2007; MOE, 2018).

While ambitious, according to the literature the FTE program has so far failed in its key goal of attracting teaching majors at high-quality universities to work in rural schools after universities. One study included a randomly selected sample of 1,059 FTE participants at six of the top normal universities (a term in China used to identify universities that train future teachers). Among these participants, who were among the first graduating class of FTE students, 47% were teaching in urban schools in large cities after graduation, 35.5% were teaching in urban schools in their hometown's county seat, and less than 10% of them were teaching in a rural school in a township or village (the two administrative levels that are classified as "rural" in China—Fu and Fu, 2012). A more recent study including five cohorts of FTE participants at Northeast Normal University found that less than 32% of sampled FTE students were teaching in rural schools post-graduation and that this proportion decreased each year (Shang, 2017).

Studies of FTE student attitudes toward their obligations reflect what may be the root of the problem. According to Zhou (2010), students begin to renege on their pledges before graduation while they are still attending university. In the Zhou study, which surveyed 1,800 students on their post-employment job plans, more than 80% of the students showed a strong willingness to break their contract and move to other occupations following graduation. Another survey at Central China Normal University found that only 5.2% of 400 FTE students in the study were willing to work in remote rural areas, while 78% of the surveyed students aspired to obtain positions in urban elite schools, which offered much better working conditions and higher pay (Li et al., 2011).

So why are these students reluctant to work in rural schools? First, FTE students are all from universities included in Projects 985 and 211 (MOE, 2005; MOE, 2006), which designate which universities in China receive the most funding and status. Attending an elite university is thought to produce a sense of superiority and entitlement, partly contributing to student rejection of long-term service in low-status, underdeveloped rural schools (Wang and Gao, 2013). Second, since the FTE program relies heavily on financial incentives to attract candidates, most students lack intrinsic motivation to become a rural teacher when they initially enroll in the program (He and Wang, 2016; Li, 2010). Third, past research also has revealed that FTE students hold negative attitudes towards some provisions of the contract and therefore refuse to comply with them. According to a survey taken in 2013-2017 of FTE graduates of Northeast Normal University, those who had chosen to renege on their FTE commitment did not think the following provisions were reasonable: period of service, mandate to teach in a rural setting, mandate to return to one's home province, and restrictions barring application to graduate school (Shang and Yu, 2018).

In sum, while the FTE program has succeeded in attracting incoming students to enroll at the outset, few students carry through with their commitment. This is due to a misalignment between their own aspirations and the post-graduation requirements of the program. Although recent adjustments to the policy have attempted to address some of these issues, such as by shortening the mandatory period of service (MOE, 2018), so far it is too early to tell whether or not such revisions will improve outcomes.

C. Teacher Training

Considering the restrictions barring the enrollment of students in urban schools and the reluctance of urban teachers to move to rural areas, a third approach to improving educational outcomes for rural students would be to raise the quality of existing rural teachers through teacher training programs. Initiatives to train teachers have been implemented elsewhere to varying degrees of success (Yoon et al., 2007; Gersten et al., 2014). In one review of nine U.S.-based studies in which teachers received an average of 49 hours of formal professional development training, teacher participants were able to boost their students' academic achievement significantly due to the training (Yoon et al., 2007). Likewise, McEwan (2015) conducted a comprehensive review of teacher training programs in developing countries and found that on average teacher training programs were effective in raising student performance. A caveat in the McEwan paper, however, warns that it is difficult to summarily say that all teacher training programs are effective, as a share of the individual studies that were included in the McEwan paper did not find positive and significant effects. More importantly, in a large number of the studies, teacher training programs were combined with other interventions (e.g., provision of new course materials), making it impossible to precisely identify the independent effect of the training part of the intervention. Those caveats aside, when evaluating the cost-effectiveness of such interventions, the McEwan study found that teacher training programs were both effective and were relatively more cost-effective than many other types of interventions.

While a number of studies elsewhere in the world looking at impacts of teacher training programs have shown an ability to positively affect student outcomes, the same is not true in China—in particular when examining the effect of training programs on the performance of rural students using rigorous impact evaluation approaches. In one study of Beijing migrant schools by Zhang et al. (2013), the researchers conducted a randomized controlled trial and measured the impact of an intensive, short-term in-service teacher training program on teacher performance and student achievement. The results displayed no significant impact of the teacher training program on either the teaching style of teachers or the scores of students on standardized testing scales.

In a province-wide study of rural schools in central China by Loyalka et al. (2019), the research team evaluated the effectiveness of the National Teacher Training Program (NTTP). Teachers were randomly assigned to either the teacher training program or to a control school (that did not receive the training). The results showed that the training program was not effective in raising student academic performance. The analysis also could not identify significant changes in the teaching approaches of the participating teachers after the program.

Finally, the results of Loyalka et al. (2019) were basically supported by Lu et al. (2019), who also evaluated the impacts of the NTTP. They analyzed data from a randomized trial that included 84 teachers and 3,006 students from a northwestern province in China. As the training program removed the teacher from the classroom and normal teaching duties for a considerable share of the school term, they concluded that the program may have even negatively impacted the performance of students on a standardized math test—at least in the short run.

Each of these three studies identified a number of factors that can explain the non-impact of the interventions. While there were a number of design-related factors that may have reduced the effectiveness of the program, each of the studies demonstrated that some of main barriers resided with the teachers themselves. For example, in the Zhang et al. (2013) study, the authors clearly demonstrated that the failure of the teacher training programs was due to the poor baseline level of English ability of teachers before the training began. No matter what the quality of the program was, it was impossible to improve the foreign language ability of a teacher in a short-term training program. Loyalka et al. (2019) also concluded that there was a reluctance of the participants to focus on the materials when they were in training and an even greater reluctance to use what they learned when they returned to the classroom. According to the authors, due to the busy schedules of teachers and their lack of motivation, the program did not succeed in improving the quality of instruction or the performance of students.

It thus appears as if—at least according to these rigorously-implemented impact evaluations—China's attempts to improve the academic performance of rural students through teacher training have not been successful. If true, the large efforts over the last several years—which include national, provincial, and sub-provincial government-sponsored training programs and billions of RMB in funding—are not sufficient to narrow the urban-rural schooling gap (Liu et al., 2016). If the results of the three studies reviewed above are representative, it may be that novel approaches are needed to meet the NTTP's goal to strengthen China's quality of teaching, especially in rural schools.

In conclusion, the three traditional approaches to improve teaching quality—and hence student performance—do not appear feasible in rural China. First, in terms of migration to urban areas, structural barriers with historical foundations in a discriminatory residence registration system have prevented children from rural areas from attending higher quality public schools in cities. Second, policy initiatives aimed at bringing new graduates to rural areas have failed to do so despite employing a host of incentives and contractual obligations. Finally, as for teacher training, both small-scale, independent programs and nationwide programs initiated by the Ministry of Education (MOE) have not been able to improve the pedagogy of rural teachers due to a number of reasons including low motivation on the part of teachers. In light of the above, in the rest of this paper we turn attention to the promise of a fourth approach that has only become practical in recent years: using new technologies to further enhance teaching quality in rural China and, in turn, systematically raise student academic performance.

III. The Potential of EdTech to Improve Teaching and Achieve Equity

With rural children unable to migrate to cities for access to better education, urban teachers unlikely to move to rural areas, and mediocre returns (if any) on the attempted teacher training programs, are there other options for improving the teaching quality that Chinese rural students receive? One opportunity that has arisen in recent years is the use of new internet and mobile-based technologies to improve the educational experience. We refer to these technologies as EdTech in the rest of the paper. In this section, we provide relevant background on EdTech in general and describe different types of EdTech that could be potentially used as alternative solutions to poor teaching in remote, rural schools.

A. Introduction to EdTech

EdTech can be broadly defined to include all technologies used in education. This comprises hardware, software, and internet connectivity components, as well as the content delivered through these platforms. For example, the Abdul Latif Jameel Poverty Action Lab (J-PAL, 2019) recently reviewed the literature on EdTech and notes that EdTech includes "hardware distribution, educational software, text message campaigns, online courses, and more." Bulman and Fairlie (2016) focus their review of the educational impacts of EdTech on the effects of "computers, the Internet, and software such as computer assisted instruction" while also discussing recent studies on online education. This latter category has become particularly important in the past decade, as advancements in internet access in schools and the home—particularly in high-income countries such as the U.S.— has enabled online education to become the driving force behind the swift development of EdTech (Delgado et al., 2015; Owl Ventures, 2018).

While there are many goals and uses of EdTech—such as improving forms of technological literacy, broadening the number of available curricular choices, and raising convenience by enabling learning outside of the classroom—studies in the economics of education generally focus on how technology may or may not impact academic outcomes in major subject areas such as math or language. Most studies examine the impacts of technology on measurable outcomes, such as grades, test scores, retention, graduation, and attendance. Many use Randomized Control Trials (RCTs) to rigorously quantify impacts. Fortunately, answering questions about whether EdTech is effective lends itself well to using RCTs because new technologies are constantly being introduced and experimented with naturally by schools, teachers, students, and families.

One unifying theme in the evaluation of EdTech effectiveness is that the use of technology is placed in the context of educational production functions commonly discussed in the economics literature. Investment in computer hardware, software, and connectivity may offset other inputs that affect student achievement in the context of the household and the school. Likewise, time spent using computers offsets other educational or recreational activities. Carefully considering how technology use complements or crowds out other investments is crucial to conducting a cost/benefit analysis of introducing new technologies in education. A better understanding of how EdTech affects educational outcomes is critical because such an understanding would make clear whether technology is an important input in the educational production process and whether it will serve to narrow or further exacerbate educational disparities.

EdTech can affect learning by targeting students directly, or by targeting parents or teachers. Software such as Khan Academy targets learners by providing online content—including videos and practice questions—that the student can use to learn material from scratch or review material already learned in class (Thompson, 2011). In early childhood and K-12 education, another option is to focus on the child's parents or guardians. For example, text messaging interventions have been used to provide both information (such as data about their child's literacy skills) and nudges (such as weekly reminders about the importance of engaging in reading early on in a child's life) to influence parental behavior (Doss et al., 2019). Besides (or often in conjunction with) targeting students and parents, EdTech can also improve educational outcomes through impacting the teacher or educator. Improving the classroom teaching received by students may be the most promising approach because teacher quality has been repeatedly shown to be among the most important determinants of student achievement.

EdTech aimed at improving teaching may do so either a.) indirectly through giving professional development in subject content, pedagogy, and technology application (usually over the Internet or through mobile devices); or b.) directly by providing teachers with digital resources to aid them in classroom activities and day-to-day tasks (UNESCO, 2012). In the rest of this paper, we will focus on this second category of teacher-focused EdTech interventions, particularly those that can enhance or transform classroom instruction in K-12 education. Echoing Keegan et al. (2005)'s distinction, we define such interventions as "technology-assisted instruction" that primarily includes activities that teachers undertake (e.g. lecturing, questioning, and providing feedback). While there is some overlap, we differentiate these interventions from "technology-assisted learning" interventions that tend to involve activities that students engage in on their own (e.g. taking notes, studying, reviewing, and revising).

B. Types of Technology-Assisted Instruction

Nowadays, in places that have achieved broad access to hardware and Internet connectivity, there are a wide variety of digital resources available to teachers that can be used to improve classroom pedagogy. Because EdTech tools and approaches are so wide and varied, in an attempt to identify those that can be helpful in specific settings to address specific problems, it is important to understand both the functions of different EdTech tools as well as carefully identify strategies that can most effectively improve student performance. Previous scholarship has sought to identify different frameworks to better understand the functions of these tools. Cheung and Slavin (2012) describe the QAIT model, which outlines four opportunities for technology to improve education: a.) improving instructional quality; b.) ensuring the difficulty level is appropriate; c.) increasing student incentives; and d) increasing instructional time. Another recent framework, the SAMR model developed by Dr. Ruben Puentedura, also divides classroom technology integration into four different categories: a.) substitution, b.) augmentation, c.) modification, and d.) redefinition. These categories differ mainly in the degree that they alter the educational process. For example, while those technological tools that "substitute" or "augment" merely enhance existing tasks (for example, by improving the efficiency of grading or the efficacy of feedback), technologies that "modify" or "redefine" can fundamentally transform existing tasks to create previously inconceivable ones (e.g., allowing students to learn a foreign language by communicating with native speakers over the Internet—Puentedura, 2014).

Building upon Puentedura's framework, McKnight et al. (2016) identify six common strategies used by educators to apply technology in the classroom: a.) communication and information management; b.) direct instruction of content; c.) access and accommodation; d.) collaboration on online work between students; e.) research, exploration, and creativity; and f.) assessment and feedback. In line with these strategies reported by the teachers, McKnight et al. (2016) write that technology can increase student engagement and performance through playing a number of different roles, including improving access (by increasing the breadth and depth of available resources); enhancing communication and feedback (through collaborative online work between students, online polling of students during class, and detailed analytics and progress monitoring); restructuring teacher time (by increasing the efficiency of grading so that teachers can spend more time on other tasks); extending the purpose and audience for student work (by allowing students to search for information on their own and share with others); and shifting teacher and student roles (for example, helping teachers move from providing students information to guiding students to manage their own learning). McKnight et al. (2016) acknowledge that while some of these strategies and roles may simply enhance existing functions, others can truly transform the educational process. It also is important to note that a single EdTech intervention or product may simultaneously enable teachers to engage in multiple strategies or perform multiple roles.

Of the many forms of technology-assisted instruction, distance learning (also known as long distance learning, or LDL) has become one of the major foci of research since the 1980s. LDL uses physical technology and educational processes to give access to students when they are removed from the source of instruction and resources by either space or time (Cavanaugh, 2001). Beginning in the 1990s, it became increasingly common for distance learning to be conducted online instead of through radio or television, forming a subset of LDL known as online learning (Means et al., 2009).

Online LDL can still further be split into two types: asynchronous and synchronous (Wicks, 2010; Hrastinski, 2008). Asynchronous online learning is separated by time. The teacher(s) and the student(s) are able to operate separately, as they do not need to be online at the same time. In this form of learning, students can watch prerecorded videos of the distance teacher can and communicate with the teacher via e-mail and discussion boards. The obvious advantage of asynchronous online learning is removing the need to operate simultaneously. However, this also raises the concern that the student may lack direct or sustained communication with a teacher and fellow students, thereby reducing their feeling of belonging to a learning community. Such communities have been shown to be essential for collaboration and learning (Hrastinski, 2008). Synchronous LDL, on the other hand, requires the teacher(s) and the student(s) to be online simultaneously, interacting in real time. It commonly utilizes media such as live video and chat. While this ensures that teachers and students can engage in more direct communication that is closer in nature to traditional face-to-face (F2F) instruction, an obvious practical drawback is the need to be online at the same time (Chen et al., 2005).

Nowadays, different types of online learning are being blended together along with F2F approaches to transform the teaching and learning process. One example of this is the flipped classroom. This model received its name for essentially reversing the traditional educational process, which requires that students attend an F2F lecture in the classroom (the group setting) and then practice what they learned at home (the individual setting). The flipped classroom model instead requires students to view an asynchronous video of the lecture at home before attending class. Then, in the classroom, students work in groups to practice and master the material while the teacher is free to walk around the room and provide guidance (Delgado et al., 2015). In recent years, the flipped classroom model has received extensive attention in the media and scholarly communities (Tucker, 2012; Gilboy et al., 2015).

C. Evidence of Impacts on Academic Performance

Does EdTech work inside or outside of the classroom to improve the academic performance of students? Even more than a decade ago (looking at a large number of studies that were mostly implemented and evaluated before 2000), there was already a large body of literature examining the relationship between technology-assisted instruction and student performance. However, most studies up to that point focused on post-secondary education and suffered from a number of weaknesses. For example, in her analysis of interactive distance education technologies, Cavanaugh (2001) found that only 19 out of 59 identified studies involved K-12 education. These 19 that she reviewed all had small sample sizes (42% had fewer than 26 students), generally did not standardize achievement measures, and often did not use random assignment to groups. The meta-analysis of Bernard et al. (2004) on synchronous and asynchronous distance education included 232 studies in total, but only 24 of these were conducted in K-12 settings. In addition, the authors acknowledged that the existing literature was weak in terms of both experimental and methodological design. Ultimately, both Cavanaugh (2001) and Bernard et al. (2004) did not find evidence that EdTech (in the form of distance education) was any more effective than traditional classroom learning. Zhao et al. (2005)'s meta-analysis also did not find any significant difference in outcomes between LDL and F2F instruction, though they did identify several key factors for effectiveness across the studies analyzed, including the use of live human instructors, a balanced mixture of human engagement and technology, and student-teacher interaction, among others. Overall, then, the findings from the body of technology-assisted instruction research before the turn of the century appear to be largely inconclusive. In a 2005 report on the use of information and communication technologies (ICT) in education by the World Bank, Trucano (2005) wrote that "for every study that cites significant positive impacts, another study finds little or no such positive impact."

Beginning in the 2000s, a more rigorous body of research gradually began to emerge with the goal of evaluating the effectiveness of EdTech, with some modest evidence of its benefits. However, even into the 2010s, most research has continued to focus on the use of technology-assisted instruction in post-secondary environments such as medical training and higher education (Escueta et al., 2017). In Means et al. (2009), the U.S. Department of Education reviewed empirical online learning studies between 1996 and 2008 and discovered evidence that students in online conditions performed better than those who received purely F2F instruction, particularly in contexts that blended online learning with F2F learning. However, the authors cautioned that such results may not be applicable to K-12 contexts, as only five of the 51 studies they reviewed included samples of primary or secondary school students and in those five studies EdTech had no impact on student achievement. Two of the meta-analyses that specifically looked at K-12 education in this time period, Cheung and Slavin (2012, 2013), found some evidence of a small positive effect (+0.15-0.16 SD) on reading and math achievement in comparison to traditional instruction. Similar to Trucano (2005), however, they acknowledged the more rigorous studies often had smaller and less significant effect sizes. Delgado et al. (2015) reported similar results, while also pointing out that most previous meta-analyses were marginal in quality.

Overall, the more recent body of literature that has formed on this topic—similar to that which already existed over a decade ago—does not provide convincing evidence about whether or not technology integrated into the classroom has an impact on student performance. This is partially due to inadequacies in the experimental and methodological designs of most previous studies, making it difficult to rely on their results. Another concern is that most research has focused on post-secondary education, which is not necessarily applicable to the K-12 environment. Even when looking past these limitations, there is no consistent trend among past meta-analyses regarding whether or not EdTech is any more effective than traditional classroom learning. At the very most, there may be some evidence that blended learning has more promise than pure online learning (Zhao et al., 2005; Means et al., 2009; Escueta et al., 2017). In addition, for those studies that do report positive impacts, it is often difficult to ascertain whether or not this was due to increased instructional time or the technology itself. In any case, in a rapidly developing sector such as EdTech, the existing body of literature will need to be frequently built upon in order to keep up to date with the most current technologies.

D. Previous Research in Low-Resource Contexts

Provided that there is an effective model available for implementing and scaling technology-assisted instruction, it might have the potential to improve educational outcomes for students in isolated, poorly resourced areas. For instance, with LDL, neither the students nor the teachers are required to physically relocate, while still matching skilled educators with the students who need them the most. Although there may be no clear trend about whether or not EdTech works in general, it is possible that in poorly-resourced schools the teaching and academic performance are low to such a degree that EdTech could make a significant difference in outcomes. Many studies in the international literature have raised the possibility of EdTech's potential in this regard (Hannum et al., 2009; Sattar, 2007; Sundeen and Sunden, 2017; Barker and Hall, 1994; Sharma, 2003).

Considering the gaps in the existing research on the use of EdTech in general, it is perhaps no surprise that there are few large-scale, rigorous studies on the effectiveness of using EdTech in remote, under-resourced areas to raise achievement and ultimately increase educational equity. A small body of literature has described efforts to use distance education in rural schools in high-income countries such as the US (Hannum et al., 2009; de la Varre, Keane, and Irvin, 2011, 2014) and Australia (Crump and Twyford, 2010), though none of these studies seem to report effect sizes on academic outcomes compared to a control group. In recent years a growing literature has evaluated the impact of self-study of content via computer/mobile-assisted learning in poorly resourced areas of developing countries (Castillo, 2017; Linden, Banerjee, and Duflo, 2011; Kam et al., 2010; Pal et al., 2006; Mo et al., 2015), but such experiments—which involve self-guided learning with little or no involvement of a teacher—cannot demonstrate whether EdTech can improve teaching quality in the classroom.

To our knowledge, the only rigorous randomized study that evaluated technology-assisted instruction in a developing country took place in an impoverished rural area of Ghana, where satellite dishes were installed in a randomly selected set of primary schools and urban teachers taught in an interactive, synchronous format over a two-year period (Johnston and Ksoll, 2017). In the treatment group, while the urban teachers lectured, in-person teachers employed at the local schools acted as facilitators as they set up and monitored the equipment, managed the classroom, and assigned grades. Students in the control group received the same amount of overall instructional time as the treatment group, so the authors were able to reasonably determine whether or not any impact was due to instructional quality (as opposed to increased instructional time). Ultimately, compared to the control group of 2,878 students in schools that did not receive the treatment, the 2,607 students in the LDL schools had significant gains in numeracy and foundational literacy skills. However, a drawback of the program was that it was quite costly, especially in upfront fixed costs (including installing the satellite dishes, setting up necessary equipment inside the classrooms, and operating the system).

Why have there been such few efforts to investigate and scale the use of technology-assisted instruction in remote, low-resource areas? For most high-income countries, students in rural areas only represent a small proportion of the population, and therefore such programs are relatively small scale. As for low- and middle-income countries, where the need is high, there are two fundamental barriers that make even initial attempts at such interventions unfeasible. First, as alluded to in Johnston and Ksoll (2017), many developing countries simply do not have the necessary information technology (IT) infrastructure (such as computers, a reliable Internet connection, video equipment, software, etc.) to carry out technology-assisted instruction, as the cost-effectiveness of installation is too high (Sundeen and Sundeen, 2017). Second, due to insufficient investment, and the small size of commercial EdTech industries in many of these countries, much of the existing EdTech content is developed in high-income countries and therefore is not likely to be fully appropriate for populations in poorer, developing economies (Gulati, 2008).

Could China—with its large economy, huge investment into infrastructure, and blossoming tech industry—be an exception to the limitations described above? In the next section, we will shift our focus from EdTech's potential to improve student outcomes in general to looking at its potential in rural China specifically. We will explore why China may be an exception to the common resource constraints in other contexts, which we believe is due to strong policy support and a fast-growing EdTech sector.

IV. Rural China: An Ideal Setting to Pilot EdTech?

So far in this paper we have demonstrated that subpar teaching may be a key reason why rural students in China lag behind their urban peers as well as why traditional methods to solve this problem such as student relocation, recruitment of talented teachers, and teacher training are not feasible. We have also reviewed the literature on the promise of EdTech (in the form of technology-assisted instruction) in improving student outcomes, ultimately finding that evidence of its effectiveness is mixed. As it turns out, very few randomized experiments have evaluated whether or not EdTech can positively impact remote schools, and in developing countries a number of limitations preclude the possibility of using large-scale EdTech interventions to reach these schools.

Even given these challenges, is it possible that conditions in China might allow rigorous study into the efficacy of EdTech in boosting outcomes for rural students? That will be the question that we will investigate in the present section of this paper. We will do this by reviewing China's situation in relation to two limitations faced by most other developing nations mentioned at the end of section 3: a.) insufficient IT infrastructure; b.) a lack of appropriate digital content. In the following pages, we will show that due to both the government's substantial investment in these two areas as well as the emergence in the nation of a booming private EdTech sector, most rural schools may already have access to the basic resources they need to integrate technology into their classrooms.

A. The State of IT Infrastructure in China's Rural Schools

Since the turn of the last century, the prevalence of technological hardware in China—such as computers and Internet connectivity at home—has gone from being a rare luxury to becoming relatively common (especially in urban areas), though regional differences in the rate of this increase has created a significant digital divide between urban and rural households. According to a survey in 2001, only about 2% of China's population had access to the Internet or owned a computer in the early 2000s (Chinn and Fairlie, 2004). Less than two decades later, in 2018, the China Internet Network Information Center reported that the Internet penetration rate had reached 55.8%, with the majority of netizens accessing the Internet through mobile phones and desktop computers. Despite these large overall increases, however, the gap between urban and rural access is large: in urban areas the Internet penetration rate was 71.0% while in rural areas the rate was 35.4% (CNNIC, 2018). Statistics from researchers reveal that as of 2010, while more than 70% of urban students had Internet and computer access at home, less than 10% of rural students had such access (authors' surveys, 2010).

Due to substantial investment from the public sector, however, the penetration of IT infrastructure into China's public education system has prevented the formation of a similarly wide digital divide between urban and rural schools. The MOE first initiated plans to apply the use of technology in education in the late 1990s (MOE, 1998). Then, in the year 2000, the MOE announced the launch of the “Network between Schools Project,” which sought to achieve Internet access in 90% of schools across the country within 5-10 years (MOE, 2001). Another initiative that helped to propel the spread of such infrastructure was the Modern Distance Education Project for the Western Rural Middle and Elementary Schools (MDEPRS). In 2002, China’s government launched this initiative in collaboration with the Li Jia Cheng Foundation, with the goal of using high-quality, technology-assisted teaching and learning to improve rural education in China’s central and western provinces. In order to provide the necessary infrastructure for this, the government aimed to build computer classrooms, establish CD/DVD players, and install satellite-receiving centers in tens of thousands of rural primary and secondary schools by 2007 (Yoxall, 2006; Yu and Wang, 2006).

According to a number of surveys in western and central parts of the country, China’s MOE has been largely successful in meeting its goals. Independently acquired data by the authors of this paper reveal that by 2018, approximately 78% of rural schools had Internet connectivity, 80% had computer access, and 83% had video equipment (authors’ surveys, 2018). This accords with the findings of Ren and Lu (2015), who estimate that Internet penetration had reached 85% of rural schools. A recent published study that reports data from the *Educational Statistical Yearbook of China* reveals that 89% of rural schools now have Internet connectivity (Yang, Zhu, and Macleod, 2018). In light of these data, it appears that a substantial proportion—around four-fifths—of China’s rural schools are now equipped with the basic equipment necessary to conduct technology-assisted instruction and learning. Therefore, it reasonable to assume that lack of infrastructure is not a limiting factor for the widescale deployment of EdTech in rural China.

B. The Availability of Digital Content

Although most rural Chinese schools now enjoy access to IT infrastructure thanks to sizeable government support over the past two decades, simply equipping schools with connectivity is not sufficient for fulfilling the conditions necessary to create meaningful improvements to the education system. As discussed earlier, in many developing countries a second barrier to carrying out EdTech interventions in remote areas is the lack of digital material appropriate to the local context.

There are two reasons to believe that China does not face the same limitation. First, despite relatively unsuccessful attempts in the past, the MOE has recently launched an ambitious policy to develop and centralize digital educational materials on the national and local levels. Second, China's booming Ed-Tech industry is continuously developing cutting-edge technology and resources that could be applied to China's rural areas (and already have been on a small scale).

EdTech Content Source #1: The National/Local Educational Resource Platforms. The public-sector delivery of software with high-quality education content for rural schools in the 2000s and early 2010s did not keep pace with the provision of hardware. Indeed, independent data from the authors in 2010 show that, while at least 80% of rural students had access to computers at school, only 35% used educational software on those computers (authors' surveys, 2010). Studies of the MDEPRS (the program discussed in the previous sub-section) conclude that one of its major shortcomings was the insufficiency of learning materials (McQuaide, 2009; Yu and Wang, 2006; Wang, Liu, and Zhang, 2018).

In the face of the absence of usable digital materials in rural schools, China's MOE recently launched a new effort to spur the development and spread of educational software and digital content, with the aim of bridging the uneven educational quality across the country. In a policy document released on December 22, 2017, the MOE admitted that partially due to an overemphasis on hardware and the lack of attention paid to educational content, previous policy initiatives and investments into EdTech had not reached their full potential (MOE, 2017). As part of a policy known as the "Three Links and Two Platforms," the MOE announced the development of the National Educational Resource Public Service Platform, which aimed to centralize all digital educational resources on a single database by 2020. The plan mandated that all sub-national levels of the public educational system—provincial, prefectural, and county—develop and maintain their own databases on this national platform with materials appropriate to their local contexts. It also called for partnerships between well-resourced and poorly-resourced educational bureaus and schools as well as performance-related rewards to create incentives for active participation.

While there have been no rigorous evaluations studying the effectiveness of this policy push, provincial policy documents and qualitative reviews reveal that local educational departments are well into the implementation stage. For example, Zhejiang province's platform alone already includes literally tens of thousands of online resources—including images, PowerPoints, audio recordings, video recordings, etc.—for every subject and for every level of schooling from preschool to high school. The province also launched a pilot program to partner high-performing, urban schools with low-performing, rural schools in order to encourage synchronous lectures as well as the close sharing of materials and experience. Zhejiang plans to upscale this one-on-one partnership program throughout the province in 2021 (Xinhua, 2019).

The existing literature also suggests that less wealthy inland provinces are also proceeding with the development and creation of platforms that make online resources available to schools and students in their regions (Zhao and Gan, 2017).

Currently, the content on these platforms are primarily developed by educators in China's public-school system and partnerships are conducted solely between schools. Besides the public education system, however, there is another source of educational software and content that could potentially be made available to rural schools: China's private EdTech sector.

EdTech Content Source #2: China's Massive Private EdTech Market. By many measures, the current size of the EdTech industry in China is one of the largest—if not the largest—in the world. In 2018, the market size of China's online education industry was 252 billion RMB (approximately 37 billion USD) with 135 million paying users (iResearch, 2019). According to global education data analysis firm Holon IQ, the amount of capital invested in China's EdTech startups surpasses investment in those of all other countries, with Chinese companies receiving 50% of all capital invested by venture capitalists worldwide HolonIQ (2019). In addition to receiving the most investment, China is unique in that two of its megacities—Beijing and Shanghai—have the two largest numbers of EdTech startups in the world (3,000 and 1,000, respectively), while Beijing has the highest concentration of EdTech startups per capita (120 per million people) of any city (EdTechCities, 2018). Of the EdTech startups that are valued over $1 billion USD ("unicorns"), the majority are located in China (HolonIQ, 2019; CBInsights, 2019).

While there are a wide range of EdTech startups, K-12 education has been the focus of the market in the recent past (iResearch, 2018), with venture capital for newer startups targeted at several sub-sectors of the overall EdTech sector. One is after-school test-prep, aimed at preparing students for competitive entrance examinations they must take to advance to upper secondary and tertiary education. Considering the significant influence these tests have on determining a child's life prospects, such as income (Li et al., 2012), as the wealth of China's affluent middle class has grown the market for test prep has accordingly expanded (Omidyar Network, 2019).

Beyond after-school learning, another major focus of China's EdTech industry is English language learning. Proficiency in English is not only seen by many Chinese parents as vital for performing well on standardized exams but as also being a door to a whole host of opportunities, including going abroad for further education, finding desirable jobs, and gaining promotion (Hu, 2010). Indeed, these beliefs seem to be grounded in reality, as higher scores on the College English Test (CET) are linked with significantly higher salaries post-graduation (Li et al., 2012).

Among the thousands of companies and products in China's EdTech market in China, many have achieved success. China's two leading education companies listed on the Nasdaq, TAL Education Group and New Oriental Education, were originally brick-and-mortar institutions that offered offline after-school tutoring and language training. Now these two institutions have transitioned to offering a wide range of online classes. Among the many models they offer, they have adopted a kind of LDL called the "dual-teacher model," with a company-employed teacher lecturing over live broadcast while cooperating with a live teacher who supervises the students (Lee, 2018).

TAL and New Oriental, however, share the market with an increasing number of more recently established start-ups that have specialized in online education since their inception (and they have likewise begun to invest in many of them). For after-school test preparation, startups like Zhangmen have achieved significant profits by connecting elite university students with K-

12 students through livestream platforms. Similar online one-on-one tutoring strategies have been used in the language learning subsection of EdTech. VIPKid, which became one of the largest online education start-ups in the world in 2018, uses LDL to connect young English language learners in China with native speakers in North America (Yu, 2018). Other successful online English tutoring start-ups—including 51Talk and Dada ABC—have similar models to VIPKid's (Medium, 2018a), while LAIX (aka Liulishuo) has relied on a more AI-focused—as opposed to teacher-focused—approach to language learning (Barrett, 2018). A number of other leaders in the industry, such as Yuanfudao, Onion Math, Zuoyebang, and 17zuoye, offer educational resources like interactive videos and practice questions that allow students to review and practice material in a self-guided manner and teachers to track their progress (Liao, 2018; Edsurge, 2019). A handful of China's well-known technological enterprises—including Tencent, Baidu, and iFLYTEK—have also begun to invest in the field of education (Li et al., 2019).

With increasing access to technological infrastructure and healthy supplies of venture capital, the market for EdTech is expected to continue to grow in the coming years, while its target user base is also expected to shift. Despite drops in venture investing in other sectors of the economy, in early 2019 investments in EdTech continued to grow, and the primary users of EdTech products continued to be students in China's first-tier and second-tier cities. However, as the market in these megacities becomes saturated, and if incomes rise in other parts of the country, it is predicted that third- and fourth-tier cities will become the new target user base (Medium, 2018b). Larger companies such as TAL have begun to acquire companies in these smaller urban areas, which are developing localized versions of existing products in their respective regions (Omidyar Network, 2019).

Although the EdTech industry has yet to focus on rural areas, some companies have made content available to rural areas either through providing free online content or by launching Corporate Social Responsibility (CSR) projects in rural schools. Several of the most widely-used EdTech solutions, such as Onion Math, Knowbox, 17Zuoye, and Zuoyebang, use freemium models in which a large array of basic services is free of charge, enabling schools with even the tightest budgets to gain access (Omidyar Network, 2019). In addition, some content providers, such as New Oriental and VIPKid, run CSR programs specifically targeted at improving educational quality in rural areas. One CSR model used by these companies is a form of synchronous distance learning that uses the "dual-teacher" model discussed earlier, in which the company-employed teacher cooperates with a rural teacher facilitator and livestreams lessons to rural students (Hao, 2018). In the next section of this paper, we will use the results of a small-scale qualitative survey of two of these companies' programs to assess some of the challenges of implementing technology-assisted instruction in China's rural areas.

V. Challenges of Implementing EdTech in Rural China

In the previous section, we showed that due to substantial policy investment and a booming EdTech sector, China is unique among developing countries in that it has the technological resources—including IT infrastructure and digital content—to improve teaching in rural schools across the nation. Moreover, as we have already seen, both the public sector (in the form of recent directives such as "Three Links and Two Systems") and the private sector (in the form of various CSR projects) have both launched pilots of one type of technology-assisted instruction interventions (specifically, long distance learning programs) at varying scales. It thus appears that China has both the resources and the momentum to make this happen.

What forms of technology-assisted instruction are most effective in rural China as well as what challenges implementers may face are thus far largely unclear, however. To our knowledge, these interventions have never received rigorous impact evaluations, either quantitative or qualitative. Successful implementation may depend on a number of factors besides the technology and content itself, including teacher and student preparation, willingness to use, appropriate use, proper scheduling, the adoption of new teaching methods, and resource management (Yu and Wang, 2006; Hannum et al., 2009), among other factors. Indeed, this makes the initial feedback of those on the receiving end—local teachers, students, and administrators—crucial to providing insights on possible directions for reform as well as how to design future evaluations.

In this section, we will use the results of an independently conducted, small-scale qualitative survey of participants in CSR distance learning programs at rural schools to assess their strengths and weaknesses. To do so, we first will describe how technology is currently being integrated into the classroom in these CSR programs. We also will analyze the initial opinions of stakeholder groups on the feasibility and sustainability of the program. The section ends by using the results of the qualitative survey to provide suggestions to give direction for future research and evaluations. We hope the data collected can serve as an initial step in designing programs suitable for quantitative and statistical evaluation.

A. Survey Methodology

In the summer of 2019, a team of enumerators conducted the survey in three rural elementary schools in southwestern China. These schools were located in three counties between 50 and 300 km southwest and northwest of Chengdu, the capital of Sichuan province. The schools were participants in pilot CSR programs aiming to teach English through distance learning. Earlier that spring, the authors had met several times with the different EdTech companies who organized these programs to gain an understanding of their platforms. The CSR representatives helped the research team to connect with and gain permission from the school administrators to conduct the survey visit. Though the sample is small, these rural schools share many characteristics with rural schools throughout China.

In each of these schools, the pilot had already been implemented for close to one academic year, and the model used in each was more or less the same. The programs all used the synchronous "dual-teacher" model described in Johnston and Ksoll (2017), with a company-employed distance teacher lecturing over live transmission while a local teacher acted as a facilitator by managing and monitoring the class. Each class session took place twice a week for approximately forty minutes each session. The classes supplemented (rather than replaced) the normal English class time. The structure of each class was similar as well: the LDL teacher first introduced the topic and then allowed students to practice the material through call-and-response, games, and hand gestures. Over the video transmission, the LDL teacher taught 10 to 15 classes of students simultaneously (including the class that we visited), calling on each group of students in succession to participate in the activities.

Over a two-week period, the field team conducted interviews of relevant stakeholders in the program, including two principals, three teachers, and 18 students. In order to understand the perspectives of students across ability level, the team acquired information on student rank from teachers to identify students with low, middle, and high academic performance relative to their peers. Ultimately, we interviewed ten high-performing, six middle-performing, and two low-performing students.[1] In addition, we interviewed the CSR program managers prior to the survey and observed two sample distance learning classes and one lesson preparation meeting between the local and distance teachers.

The interviews were semi-structured and based on interview guides prepared prior to the survey. When creating the interview protocols, the field team focused on seven key areas of understanding based on a casual chain which were used to structure the interview guides: willingness to adopt, infrastructure, teacher training, class preparation, in-class dynamics, post-class assessments, and program sustainability. After transcribing all the interviews, during data analysis, we then created new codes or categories that identified challenges during implementation that were either stated directly by the interviewees or apparent during observations.

B. Survey Results

In the following sub-section, we describe the major themes derived from the interviews and observations at three schools participating in the CSR distance learning programs. In total, we identified seven obstacles that may hinder the successful roll-out and upscaling of these programs: lack of administrative support; poor maintenance of infrastructure; absence of teacher training; insufficient inter-teacher communication; resistance of local teachers to change; disparities in student engagement; and the incompatibility of curricula.

Lack of administrative support. One takeaway from the interviews was the importance of support from school administration for the long-term success of these programs. In one school, despite the one participating teacher's enthusiasm, he stated that the school administrators and

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[1] We grouped students according to academic performance by using the percentile rank of a student relative to his or her class: those above the 85th percentile were classified as high-performing; those in the 40-85th percentile range were classified as middle-performing; and those below the 40th percentile were classified as low-performing.

his colleagues did not become involved at all, and he alone took on the implementation of the program. In this school, participation in the distance learning program was optional and not mandated from above. Therefore, he speculated that the distance program would end at his school after he left the following year. In rural schools, where there is often a high turnover rate for teachers, these programs cannot rely solely on the backing of a small subset of individual teachers and instead need schoolwide support.

Based on our interviews, however, we found that this one example was not universal among the program participants. In general, we found that schools were enthusiastic about the new initiatives. In fact, our interview results showed that when stakeholders were initially introduced to the two-teacher model, most were generally supportive of the adoption of the LDL program. The teacher and principal interviewees all stated that they believed the LDL program would grant their students access to quality education similar to that received by their urban peers. Likewise, 61% of students stated that they were in favor of the program.

Poor maintenance of infrastructure. Another obstacle closely related to administrative support that may decrease the sustainability of such programs is negligence to properly maintain the technological equipment. In all three schools, the infrastructure—webcams, computers, projectors, microphones, and a reliable Internet—were either already owned by the school or supplied by the companies. While the equipment and software were relatively new, none of the schools had protocols or designated staff assigned to the upkeep of this infrastructure. Without proper upkeep and updating, infrastructure may become brittle and eventually break down. This lack of infrastructural maintenance was also a challenge in implementing the MDEPRS project during the 2000s.

Absence of teacher training. In general, the local administration and staff lacked the proper preparation and training needed to successfully carry out the programs. According to interviewee responses, none of the teachers or principals in the pilot received any program-specific training prior to implementation. This was manifested in a number of ways. First, according to our observations, at times teachers seemed to be unfamiliar with the curriculum and the lesson plan for that day, which may have made it more difficult for them to actively participate during class. Second, teachers were incapable of troubleshooting technical issues and—as mentioned in the previous section—did not engage in regular maintenance of the software. In one of the schools the team visited, the microphone stopped functioning properly and nobody could fix it. For the remaining duration of the semester, the distance teacher received no audio input from the students in that class. (It was later discovered that the microphone had simply run out of battery.) Simple problems such as these can significantly hinder the teaching and learning process and could be easily prevented with proper training and instructions.

Insufficient inter-teacher communication. Closely related to the lack of adequate training was insufficient communication between the distance and local teachers prior to class time. This problem is inherently specific to a dual-teacher distance learning model, in which it would seem that the classroom facilitator and the distance lecturer should closely cooperate in order for each lesson to proceed smoothly. The interviews, however, reflected clear differences in teaching quality and student engagement between those classes in which the local teachers reported close and frequent contact with the distance teachers and those who reported little contact. For example, one local teacher interviewee claimed to regularly update the urban teacher on student progress and communicate 10-20 minutes before each session. During classroom observations, this teacher appeared well-prepared and actively managed the class. In contrast, a second teacher stated that he only communicated with the distance teacher for one to two minutes before each class. In our observation of his class, this teacher clearly was less knowledgeable about the class curriculum and was also less engaged while facilitating the lesson, taking on a more passive role.

Ultimately, these differences were also reflected in student-related data. Interviews and observations revealed that students in the class of the teacher that had closer contact with the urban teacher (and prepared more completely) had more positive viewpoints towards the program than those in the less-engaged teacher's class. Perhaps unsurprisingly, these results suggest that when local teachers communicate more with the distance teachers, students may benefit more from the program.

Resistance of local teachers to change. Another issue specific to a dual-teacher model is the potential of classroom teachers to resist the program due to a (at least perceived) undesired shift in their role and responsibilities. Although this was not apparent during interviews or observations at the schools, anecdotes provided by individuals who had experience in organizing dual-teacher programs revealed that some rural teacher participants may have feelings of inadequacy or inferiority in relation to the distance teacher, who generally takes over the role as the main lecturer while the classroom teacher shifts to the role of facilitator. This may lead to a lack of attention to or breaking of the program protocol. At the extreme, rural teachers have even been known to try to undermine the efficacy of the dual-teacher program. For example, there was a story of a local teacher who actively undermined the program because they felt their role and status were being challenged. Another anecdote cited an example of a case of a school whose local teacher frequently cancelled the class due to "technical issues." It was later found that this teacher was taking action to "protect his turf" by interrupting the internet or unplugging the white board screen. Clearly, this could be an ongoing problem in any intervention where the role of a classroom teacher changes to become more supportive in nature. As these claims are based purely on anecdotal evidence, however, they certainly require further corroboration.

Disparities in student engagement. Although interviews and class observations showed that students were overall fairly engaged during class, they also revealed that there was uneven student participation. Several students said they almost never asked the LDL teacher any clarifying questions, attributing this to intimidation to speak out in front of not only their classroom teacher and peers but also the distance teacher and peers. Teaching so many classes of students simultaneously, the distance teachers are also unable to engage in much one-to-one interaction with individual students. Perhaps at least partially due to these factors, we observed that it was usually the same group of students who called out answers during class (which was an encouraged form of participation) while other students remained more reserved.

Therefore, due to the particular set-up of these programs, it may be easier for struggling students to blend into the background, especially when the classroom teacher does not take on a more active role in engaging with students individually. One of the principals that we interviewed stated that, although he believed the LDL system would benefit the top students, it had the potential of leaving struggling students behind. Of course, it can also be argued that this problem can exist with any type of teaching—involving technology or not—in which there is not proper scaffolding of instruction. Again, identifying heterogeneous impacts on different subsets of students should be included in any effort to rigorously evaluate an LDL program.

Incompatibility of curricula. Finally, one of the most fundamental challenges we discovered was the incompatibility of the curricula taught in the distance class with the local curriculum of the school. We found that the English taught during regular class time was not the same as that taught during the supplementary distance class. The curriculum taught in the local

English classes was the content assessed during the high school and college entrance exams, whereas the LDL curriculum was based on a different textbook. The local teachers and students thus had to alternate between the two different curricula throughout the week.

The teachers identified a number of disadvantages to the lack of uniform curricula. First, they expressed worry that students may become confused between the different material and that it would take time away from preparing for standardized examinations. Although we did not hear such feedback from students, these worries were apparent in school policy. The administration did not allow sixth grade classes to participate in the LDL classes, as schools expected the attention of older students to be focused on solidifying their mastery of material on their high school entrance exams. Second, teachers reported an increased workload for themselves. Not only did they need to become familiar with the new curriculum, but they also were expected to prepare review materials and homework for the LDL classes in addition to their regular classes. All in all, while the supplementary nature of the LDL curricula allowed students exposure to new material, for the most part this incompatibility seemed to reduce the teacher and administration's enthusiasm towards the program.

C. Key Takeaways from the Survey

The themes outlined above suggest that despite adequate infrastructure, there are potential challenges that may hinder the successful execution of technology-assisted instruction interventions in rural China. The lack of overall support from the administration may reduce the sustainability of such programs, especially due to the high turnover rate of individual rural teachers. Several of those challenges identified deal with the preparation of classroom teachers. Our data show how insufficient training and a lack of communication with the distance teacher can affect the quality of their participation in class and their ability to deal with day-to-day technical issues. Teacher resistance to change—particularly in regard to those changes that involve new teaching methods or roles—was another potential challenge. As for the students, while most seemed to enjoy this new form of instruction, some may find it difficult to actively participate in such a setting where much of the interaction takes place over a screen and they must share the distance teacher with other classes, especially when the classroom teacher does not take on a more active role to scaffold instruction. Finally, the degree to which the educational content delivered during such interventions fits the existing content already taught also seems to be an important factor. Many of these issues have previously appeared in other studies outlining the challenges of technology integration in education (Keengwe, Onchwari, and Wachira, 2008; Sharma, 2003; Yu and Wang, 2006; Hannum et al., 2009).

Despite these identified challenges, however, we can only treat the material discussed in this section as preliminary evidence. First of all, in all of the pilot schools the field team visited, the LDL program had only been implemented for one academic year and many students were learning English for the first time. Therefore, the program was still in its infancy and there had not been enough time for the full effects of the program to surface. Additionally, due to the small sample and qualitative nature of our study, it is hard to make any definitive causal claims or conclusions about representativeness. The findings from the interviews and observations need to be considered suggestive at best. Thus, there obviously is a huge need for more rigorous quantitative and qualitative research.

VI. Conclusion

By drawing from the existing academic literature, reports from the public and private sectors, and independently acquired data from the field, we have explored the potential of using technology-assisted instruction to improve teaching in China's rural areas. Like in other contexts, teaching quality may be a major determinant of children's schooling outcomes in China, and regional disparities in teacher quality may have exacerbated the urban-rural education gap. As traditional methods to improve teaching—including student migration to the cities, attracting quality teachers to rural areas, and teacher training—appear to have fallen short, it is possible that a significant role for technology exists. Although prior research has not confirmed (or disconfirmed) the effectiveness of technology-assisted instruction, and very few rigorous evaluations have been conducted in developing countries, there is reason to believe that China is uniquely positioned to successfully implement and scale up technology-assisted interventions. China has tens of millions of students in remote, rural schools that receive poor teaching. On account of ambitious policy initiatives and a large EdTech market the country also has the basic resources (hardware, software, and content) to become the first nation to evaluate and scale technology solutions to address problems of equity in education.

We have also discussed some of the challenges that China might encounter in this regard. As seen from the literature, and as past policy attempts in China have revealed, having the necessary infrastructure and content is not enough. During the course of implementation, there are a number of barriers that EdTech interventions will face, including those that involve the engagement of stakeholders and the maintenance of equipment (Yu and Wang, 2006). The results of a small-scale qualitative survey conducted at rural schools participating in a synchronous distance learning program support this idea. Despite overall positive feedback from the stakeholders involved, a number of potential challenges became apparent during the interviews and observations—the lack of administrative support, inadequate maintenance of infrastructure, the absence of training, poor inter-teacher communication, local teacher opposition to shifts in teaching methods and roles, uneven student participation, and the incompatibility of curricula. Future research involving rigorous quantitative analysis is needed to determine whether such programs can improve student academic performance, which kinds of models work the best, and which sub-sets of students benefit the most. Impact evaluation, as well as cost-effectiveness analyses, will be necessary to gain a clearer picture of the future of EdTech interventions (in the form of technology-assisted instruction) in rural China.

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