

# Secondary School Expansion through Televised Lessons: The Labor Market Returns of the Mexican Telesecundaria

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## Abstract

In areas where there is an insufficient supply of qualified teachers, delivering instruction through technology may be a solution to meet the demand for education. This paper analyzes the educational and labor market impacts of an expansion of junior secondary education in Mexico through *telesecundarias*—schools using televised lessons, currently serving 1.4 million students. To isolate the effects of telesecundarias, I exploit their staggered rollout from 1968 to present. I show that for every additional telesecundaria per 50 children, ten students enroll in junior secondary education and two pursue further education. Using the telesecundaria expansion as an instrument, I find that an additional year of education induced by telesecundaria enrollment increases average income by 17.6%. This increase in income comes partly from increased labor force participation and a shift away from agriculture and the informal sector. Since schooling decisions are sequential, the estimated returns combine the direct effect of attending telesecundarias and the effects of further schooling. I decompose these two effects by interacting the telesecundaria expansion with baseline access to upper secondary institutions. Roughly 84% of the estimated returns come directly from junior secondary education, while the remaining 16% are returns to higher educational levels.

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# 1 Introduction

After steadily increasing for 15 years, the worldwide secondary school enrollment rate has stagnated at about 66% since 2013 ([The World Bank, 2019](#)). This leaves more than 200 million children of secondary-school age out of school ([UNESCO, 2017](#)). Providing post-primary education requires teachers specialized in subjects at advanced levels, but such teachers are in short supply in rural and marginalized areas worldwide, especially in developing countries ([Banerjee et al., 2013](#)). Given this constraint, delivering content through information and communication technologies (ICT) as a substitute for face-to-face instruction has the potential to help expand post-primary education around the world.

This paper investigates the educational and labor market impacts of a large-scale expansion of secondary education in Mexico through schools using televised lessons, called *telesecundarias*. Telesecundarias are a type of junior secondary school<sup>1</sup> that delivers all lessons through television broadcasts in a classroom setting, with a single support teacher per grade. The televised content follows the national curriculum and is complemented with learning guides and in-classroom work and discussions. They started in 1968 and by 2016, 18,754 telesecundarias served 1.43 million students, representing 21.4% of all junior secondary students. This is not an isolated program: A dozen low- and middle-income countries started using televisions in education between 1950 and 1970 ([Calixto Flores and Rebollar Albarrán, 2008](#)), and many more have implemented similar programs since then.<sup>2</sup> Interactive televised lessons have recently been introduced in rural schools in Brazil, Ethiopia, and Ghana ([Assefa, 2016](#); [Johnston and Ksoll, 2017](#)).

The Mexican telesecundaria expansion has three features that make it useful for examining the labor market impacts of secondary schools with remote lessons. First, the 50-years history of telesecundarias allows me to investigate very long-run effects of providing access to secondary education in general, and through schools using remote lessons in particular. This feature overcomes the difficulty of documenting the long-run effectiveness of using technologies in the classroom due to the short track record of most of these initiatives. Second, the country-wide scope of telesecundarias provides additional geographic variation in access to upper secondary institutions. This enables the study of the differential impacts of telesecundarias depending on the availability of further schooling in the local area. Third, many developing countries today face similar educational challenges to those faced by Mexico during the 1960s. As such, studying the long-term effects of telesecundarias may inform other governments currently considering the large-scale use of remote lessons in the classroom.

Exploiting the staggered rollout of telesecundarias across different geographical areas and

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<sup>1</sup>The typical ages for junior secondary education are 12 to 14.

<sup>2</sup>Besides telesecundarias, some of the most well-known and successful examples are the Telecurso in Brazil (1978) and the National Open School of India (1989) ([The World Bank, 2005](#)).

over time, I find that a high density of telesecundarias significantly increases educational attainment, long-run employment, and average income among individuals who could have attended them. I then use the staggered rollout to estimate the labor market returns to pursuing secondary education through telesecundarias. Since schooling is cumulative, the long-run income premiums combine the direct returns of attending telesecundarias with the continuation returns of pursuing further education afterward. Hence, in contexts where upper secondary schooling is limited, the benefits of telesecundarias may be lower. Disentangling these two effects is crucial for policymakers interested in implementing similar programs in other settings. To do so, I exploit the variation in access to upper secondary institutions,<sup>3</sup> finding that the direct effects of enrolling in junior secondary education account for most of the combined returns.

In the first part of the paper, I estimate the causal effects of the telesecundaria expansion on long-run education and labor market outcomes. Given that telesecundaria students come from relatively disadvantaged backgrounds, a simple comparison between individuals with differential telesecundaria access would likely underestimate the true effects of the program. I exploit the quasi-exogenous variation in telesecundaria availability generated by the gradual expansion of telesecundarias by using a difference-in-differences approach. Intuitively, it compares the labor market outcomes of individuals with access to different densities of telesecundarias, net of cohort and locality averages. To do so, I combine school-level construction data for all secondary schools in Mexico from the Ministry of Education with detailed individual-level data from the Employment and Occupation National Survey (ENOE) on labor market outcomes and working conditions for almost 900,000 individuals. I find that for every additional telesecundaria per 50 school-aged children in a locality, ten students enroll in junior secondary education and two students continue to pursue upper secondary education. This results in an average increase of an additional year of education. Additionally, there is a significant reduced-form increase in hourly income, partly driven by increased labor force participation, a shift away from the agricultural sector towards services, and a transition to the formal sector.

In the second part of the paper, I use the gradual telesecundaria expansion to estimate the returns to enrolling in junior secondary education—through telesecundarias—on earnings. A simple theoretical framework of sequential schooling choices highlights the main identification challenges when estimating the returns to secondary education in a dynamic setting. An important concern is that unobserved factors affecting labor market outcomes may be correlated with the decision to enroll in a telesecundaria. To address it, I implement an instrumented difference-in-differences approach, using the intensity of telesecundaria expansion as an instrument for junior secondary enrollment. An additional year of education

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<sup>3</sup>The typical ages for upper secondary education are 15 to 17.

after enrolling in a telesecundaria increases income on average twenty years after attending secondary education by 17.6%.<sup>4</sup> However, as recently highlighted in Heckman et al. (2016) and Heckman et al. (2018), the estimated impact of educational interventions is a combination of the direct effects of the program and of all subsequent schooling.

In this context, it is unclear ex-ante which of the two channels—junior secondary education or subsequent schooling—accounts for the majority of the returns to telesecundarias. On the one hand, telesecundarias may provide large payoffs in the labor market through increased productivity after the acquisition of human capital, consistent with the seminal work of Becker (1964) and Mincer (1970). This may be because telesecundarias solve two prevalent problems in developing countries: The supply constraint of trained secondary education teachers, and high rates of teacher absenteeism (Banerjee and Duflo, 2006; Duflo et al., 2012). With the appropriate infrastructure, telesecundarias offer timely lessons conducted by remote lecturers selected for their professional excellence (Martinez Rizo, 2005). On the other hand, even if telesecundarias are not rewarded in the labor market, students may still use them as a pathway to further education. Upper secondary or college education, vocational or technical training can provide large returns in the labor market, especially in developing countries.<sup>5</sup>

I isolate the direct returns of attending junior secondary education through telesecundarias by exploiting the differential proportion of individuals pursuing further education in localities with and without nearby upper secondary schools. I show that, under certain assumptions, the presence of upper secondary schools allows separate identification of the two sequential effects. I implement this identification strategy by exploiting as an additional instrument the interaction between telesecundaria expansion and the presence of nearby upper secondary institutions. I find that attending a telesecundaria accounts for almost 84% of the total returns; the remaining 16% are returns to higher educational levels.<sup>6</sup> Taken together, these findings indicate that attending junior secondary education through telesecundarias has large returns, even when no further education is available or pursued afterward.

**Contributions to the literature.** This paper relates to several strands of the literature. First, it relates to the body of research studying the impacts of technology in education (see

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<sup>4</sup>Estimates of the private rate of secondary education worldwide through Mincerian regressions are about 7.2%, and the rate of return to tertiary education is about 15.2% (Montenegro and Patrinos, 2014).

<sup>5</sup>The evidence on the effectiveness of vocational training programs in developing countries is mixed. While many programs have at best modest impacts (see McKenzie (2017) for a recent review), vocational training may yield positive returns in certain circumstances (Alfonsi et al., 2019).

<sup>6</sup>The estimated returns to attending further education are significantly *larger* than for attending junior secondary education. However, the proportion of individuals pursuing upper secondary education after a telesecundaria construction is small, so the returns to higher education make a limited contribution to the overall income premium.

Bulman and Fairlie (2016) and Escueta et al. (2017) for surveys).<sup>7</sup> Most of the research on remote lessons evaluates them as complements to formal schooling and face-to-face instruction in developed countries, focusing on Massive Open Online Courses (MOOCs) and college online classes (Figlio et al., 2013; Banerjee and Duflo, 2014; Alpert et al., 2016; Bettinger et al., 2017; Goodman et al., 2019) or early childhood educational TV programs (Kearney and Levine, 2015a). Recent work in developing countries shows that remote lessons deliver gains in student achievement (Johnston and Ksoll, 2017; Beg et al., 2019) and, in combination with a computer-assisted learning program, they additionally improve labor market outcomes and mental health (Bianchi et al., 2019). In contemporaneous work, Fabregas (2019) investigates the long-run effects of telesecundarias, finding increases in educational attainment, fertility reductions, and no significant effects on labor market outcomes.<sup>8</sup> Overall, most of these papers focus on understanding the effects of using technologies to deliver remote lessons in an educational context. My paper is distinct to this work, since its objective is to understand the impacts of *providing access* to secondary education through schools that use low-cost technology as a substitute for in-person instruction.

In fact, my work is closely related to the large literature investigating the labor market returns to secondary education, focusing mainly on developed countries (see, for example, the literature surveyed in Card (1999) and Gunderson and Oreopoulos (2010)). Previous research has also documented the impacts of expanding access to primary education in the developing world on education and labor market outcomes, many using large school construction projects as sources of variation (Duflo, 2001; Duflo, 2004; Kazianga et al., 2013; Akresh et al., 2018; Karachiwalla and Palloni, 2019; Delesalle, 2019). Yet, few papers rigorously document the long-run labor market returns to secondary education in developing countries (Spohr, 2003; Ozier, 2016). Duflo et al. (2017) is the first evidence on the returns of free access to secondary education, using a randomized experiment providing scholarships in Ghana. To the best of my knowledge, this is the first paper computing the long-run returns to secondary education using a large country-wide schooling expansion as a natural experiment. I also contribute to this literature by explicitly separating the direct returns to secondary education from the returns to further schooling.

This paper also relates to work estimating dynamic treatment effects in schooling deci-

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<sup>7</sup>In a broad sense, the paper relates to the studies investigating the effectiveness of mass entertainment media programs on educational attainment and labor market outcomes (Gentzkow and Shapiro, 2008; Kearney and Levine, 2015b) and on changing perceptions of social norms and shaping behaviors (Chong and La Ferrara, 2009; La Ferrara et al., 2012; Berg and Zia, 2013; Kearney and Levine, 2015b; Banerjee et al., 2019). It contributes to the entertainment education literature by investigating the long-run impacts of televised content designed to cover a formal education curriculum.

<sup>8</sup>Differences in the labor market findings between Fabregas (2019) and this paper could be attributed to effects heterogeneity, since Fabregas (2019) exploits a different source of variation—the 1993 policy change making junior secondary education compulsory—and uses coarser treatment data at the municipality level.

sions. As previously argued in Heckman et al. (2016) and Heckman et al. (2018), standard instrumental variable estimands in settings with dynamic choices can be a combination of the direct and continuation effects of the program, both of which analyze different economic objects of interest. I show how the variation of an instrument interacted with a baseline covariate can be used to separately identify the direct and continuation effects of the intervention in a dynamic treatment effects setting. These identification arguments exploit previous ones from Kirkeboen et al. (2016), Kline and Walters (2016) and Hull (2018), who develop methods to account for related problems in settings with multiple simultaneous alternatives. My results show that these tools can be appropriately modified to account for dynamic treatment effects.<sup>9</sup>

The rest of the paper is organized as follows. Section 2 describes the institutional background of junior secondary education in Mexico and provides details on telesecundarias and their rollout. Section 3 describes the data sources. Section 4 presents the empirical strategy. Section 5 provides estimates of the reduced-form effects of telesecundaria on educational attainment and labor market outcomes. Section 6 develops a theoretical framework of schooling with sequential choices, provides reduced-form evidence on the model results, computes the combined returns to secondary education and empirically investigates the proportion of the returns attributed to telesecundarias and to further education. Section 7 concludes.

## 2 Background

In this section, I outline the education system in Mexico and describe the specific characteristics and rollout process of telesecundarias.

**Secondary education in Mexico.** Compulsory basic education encompasses preschool education (ages 3 to 5), primary education (grades 1 through 6, ages 6 to 11), and junior secondary education (grades 7 to 9, ages 12 to 14). There are three junior secondary education modalities: General schools (*secundaria general*), technical schools, offering a combination of general subjects and technical subjects, and telesecundarias, schools providing the junior secondary content through televised lessons complemented with in-class support.<sup>10</sup> In 2016, there were 6.71 million junior secondary students in Mexico: 50.6% and 27.1% attended general and technical schools, respectively, and 1.43 million attended telesecun-

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<sup>9</sup>Research on dynamic complementarities (e.g., Malamud et al., 2016; Johnson and Jackson, 2018) examines the returns of combining two sequential interventions in addition to the separate returns of each one. In contrast, in this context individuals need to complete junior secondary education before completing upper secondary, so the individual effect of higher schooling levels cannot be estimated.

<sup>10</sup>The residual junior secondary school modalities are community secondary schools (0.6%) and secondary education for workers (0.3%) (INEE, 2017).

darias, representing 21.4% of the total. Out of the 39,265 junior secondary schools, 47.8% were telesecundarias (INEE, 2017). Throughout my paper, “brick-and-mortar schools” denotes all junior secondary schools with face-to-face instruction, including general secondary schools and junior technical schools, and “higher education” denotes any educational levels beyond junior secondary education, including upper secondary and tertiary education. After finishing junior secondary education, students receive a certificate of completion that is required to enroll in higher education. The administration of basic educational services is decentralized and is the responsibility of state authorities.<sup>11</sup>

**The telesecundarias.** Telesecundaria is a junior secondary school modality that provides all lessons through television broadcasts in a classroom setting. Telesecundarias are small schools, usually with only one class per grade and between 15 and 30 students per class. There is typically a single teacher per grade or even per school, the *maestro monitor* (supervisor teacher).<sup>12</sup> In contrast, brick-and-mortar schools have on average 11 or 12 teachers specialized in different subjects. Supervisor teachers are specially trained for this position and their duties are supervising the classroom, answering students’ questions and grading homework and exams. They have teaching guides for all the subjects covered in the televised lessons. Daily classes are a combination of remote instruction and in-class work: Students watch a 15 minute televised lesson, followed by 35 minutes of class discussion and homework, guided by the *maestro monitor* and by basic concept books and learning guides (INEE, 2005). The televised lessons follow the national curriculum, are designed by pedagogical experts, and are recorded in a television studio in Ciudad de Mexico by teachers selected for their communication skills, the *telemaestros*. Lessons are simultaneously broadcasted to all telesecundarias in the country following a pre-established schedule. When the program was first introduced, transmission was through microwaves and TV antennas and, later, satellite technology, supplemented with videotapes and recordings. Telesecundarias’ average administrative cost per student is half the cost of brick-and-mortar schools: In 2002, telesecundarias cost 6,811 pesos per student, compared to 12,460 pesos for general junior secondary schools and 14,572 for junior secondary technical schools (Martinez Rizo, 2005). Telesecundarias were initially designed to provide education in rural and isolated areas but, due to the lower administrative cost, they were later also introduced to urban areas, especially in marginalized locations with teacher supply constraints. As a result, telesecundaria students tend to come from families with a lower socioeconomic background than those attending brick-and-

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<sup>11</sup>In particular, 84% of basic education students are the responsibility of the state educational authorities, less than 7% are the direct responsibility of the federal government and 9% are in private schools (SEP, 2014).

<sup>12</sup>In 2008, 20% of telesecundarias had only one or two teachers managing the three grades (SEP, 2014).



mortar schools,<sup>13</sup> and there is a wide range in the adequacy of infrastructure and quality of education services in telesecundarias.<sup>14</sup>

**Telesecundaria introduction and rollout.** Telesecundaria was created in 1968 to solve challenges related to the provision of secondary education. At the end of the 1950s, Mexico had very low literacy and school attendance rates,<sup>15</sup> but a successful initiative to expand access to primary education raised the number of primary school students from 4.1 million to 6.6 million in 10 years ([Secretaría de Educación Pública, 2010](#)). This accelerated increase in primary school completion led to a sudden increase in demand for secondary education, exceeding by far the existing capacity, particularly in rural and isolated areas.<sup>16</sup> Telesecundarias were a solution to the inadequate supply of secondary education and two specific challenges of constructing brick-and-mortar secondary schools: The shortage of qualified secondary school teachers willing to work in remote rural areas ([Calderoni, 1998](#)), and the scattered distribution of primary education graduates wanting to continue their studies. Telesecundarias were an attractive alternative because they could support smaller school and class sizes, and needed fewer qualified teachers.

Figure 2 shows the temporal and spatial distribution of telesecundaria construction. Many northern states have less than 10% of junior secondary students enrolled in telesecundarias, whereas the highest concentrations of telesecundaria students are between 39% and 45% of the total enrollment in Zacatecas, Veracruz, Hidalgo and Puebla ([INEE, 2005](#)). Figure 3a reports the distribution of the imputed school construction dates for all schools constructed in Mexican localities with fewer than 100,000 inhabitants. Telesecundarias have been continuously and gradually constructed during 50 years, although there were two major waves of telesecundaria construction. In 1981, an expansion of telesecundarias to new states increased the number of telesecundarias from 694 to 3,279 ([Martinez Rizo, 2005](#)). In 1993, junior secondary education became compulsory, and telesecundarias—cheaper and requiring fewer teachers than brick-and-mortar schools—became an attractive option in places without access to junior secondary education, leading to a significant expansion in the years after the

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<sup>13</sup>For example, in 2016-2017, only 37% of telesecundaria students had mothers with secondary education or higher, and almost 60% benefited from the Prospera/Oportunidades conditional cash transfer (CCT) program, whereas the proportions were respectively 63% and 23% for brick-and-mortar students ([INEE, 2016](#)); ([INEE, 2017](#)).

<sup>14</sup>In 2001, a survey revealed that 10.3% of telesecundarias didn't have electricity, 35% didn't have a television and 17% had one in bad shape, 25% had low reception signal, and 22% didn't have the introductory textbooks. ([Martinez Rizo, 2005](#)). Supervisor teachers and students had to adapt the lessons and classes to these precarious circumstances.

<sup>15</sup>In the 1950s, forty-two percent of children between the ages of 6 to 14 were not attending basic education. Among those enrolled, only one third finished 6<sup>th</sup> grade in urban areas and only 2% in rural areas ([Secretaría de Educación Pública, 2010](#)).

<sup>16</sup>In 1965, the number of primary school graduates unable to enter secondary school in Mexico was about 37% of the number of previous year's 6<sup>th</sup> graders ([Mayo, 1975](#)).



new legislation. I exploit this country-wide variation in the timing and location of telesecundaria constructions over 50 years to investigate the causal effects of telesecundarias.<sup>17</sup>

### 3 Data

In this section, I describe the main features of the data I use to measure the construction of telesecundarias and the long-run education and labor market outcomes. Additional details are provided in Appendix A.

**School construction data.** I examine the effects of telesecundaria expansion by using information on secondary schools from the *Secretaría de Educación Pública* (Ministry of Education). I use two different sources of junior secondary school data: The 2015-2016 school directory of all junior secondary schools in Mexico, and yearly school records of all junior secondary schools for the 1990-2014 period. Each dataset includes the school’s unique identifier, address, geographical coordinates and school modality. The school directory contains information on the foundation date, date registered on the system, and closing and reopening dates. The annual records additionally include the total number of enrolled students by grade. The upper secondary school data comes from the 2016-2017 school directory, with the same features as the junior secondary school directory.

The identification strategy relies on comparing outcomes of cohorts from the same locality with different levels of telesecundaria exposure, which requires knowing the exact year each telesecundaria was constructed. Given that there are differences between the three sources of information for school construction dates—foundation date, date registered into the system, and yearly records—I combine the three variables and impute the school construction date for 19% of telesecundarias.<sup>18</sup> Mexico City is completely excluded from the analysis given its particular status as a federal district during part of the period of interest. Although telesecundarias were initially intended to provide secondary education in rural and isolated areas where it was not feasible to construct brick-and-mortar secondary schools, they were later introduced in urban localities, especially in marginalized neighborhoods. Given this, the analysis focuses on the effects of telesecundarias in low urbanization localities, defined as the localities with less than 100,000 habitants by the Statistics and Geography National Institute (INEGI).<sup>19</sup> The results are robust to restricting the analysis to smaller localities,

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<sup>17</sup>Other work investigates the impacts of telesecundaria using observational and descriptive techniques (e.g., Mayo, 1975; Calderoni, 1998; Santos, 2001), or exploiting the 1993 compulsory schooling law change (Fabregas, 2019).

<sup>18</sup>75% of the differences between telesecundaria construction date sources are within two years or less. The technical details of the imputation procedure of the school construction date are in Appendix A.2. The main results are robust to alternative imputation procedures.

<sup>19</sup>The INEGI denotes the localities with less than 2,499 habitants as “rural localities”, those with between

and are not driven by the inclusion of urban areas.<sup>20</sup> Of the 6,296 localities in the sample, 82% are rural localities and 14% are sub-urbanization localities.

Figure 3b reports the cumulative number of open schools by year in all localities in Mexico with fewer than 100,000 habitants, and Figure 4, only those localities used in the analysis. Both figures show a gradual construction of telesecundarias over time, with particularly rapid increases in 1982 and 1993, consistent with the telesecundaria rollout history. Due to concerns related to measurement error with the 1982 construction dates, I exclude from the analysis localities with the first telesecundaria construction imputed in 1982. The results are robust to this exclusion. Table 1 reports descriptive statistics related to schooling access for individuals in localities with less than 100,000 habitants (Columns 1 and 2). For completeness, I also report the same statistics for all individuals in the sample (Columns 3 and 4). 67% of individuals in the sample had access to some type of secondary education in their locality after they finished primary school: 58% had access to brick-and-mortar schools and 21% to telesecundarias.

**Education and labor market outcomes.** Individual education and labor market outcomes are constructed using data from the *Encuesta Nacional de Ocupación y Empleo* (ENOE, Employment and Occupation National Survey), administered by the *Instituto Nacional de Estadística y Geografía* (INEGI, Statistics and Geography National Institute). The ENOE is a quarterly household survey on the labor market characteristics of the population and is administered as a five-quarter rotating panel.<sup>21</sup>

The policy-relevant treatment is the intensity of telesecundaria exposure when the individual was 12 years-old, so it is relevant to identify the localities in which individuals resided during their school-age years. A limitation of the ENOE is that it doesn't record the locality of birth, only the state of birth and the locality of residence at the time of the survey. I define the measure of telesecundaria exposure for the individual's locality of residence, assuming they did not move from the locality after reaching school-age. However, migration in Mexico is a common phenomenon:<sup>22</sup> If migration decisions were uncorrelated with access to secondary schools, this approach would just introduce measurement error in

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2,500 and 14,999 habitants as “sub-urbanization localities” and those with between 15,000 and 100,000 habitants as “low urbanization localities”.

<sup>20</sup>Appendix B.1 reports the main reduced-form estimates restricted to rural localities (Panel A) and to rural and sub-urbanization localities (Panel B).

<sup>21</sup>The survey is representative at the national and state levels, and for localities with less than 100,000 habitants. Although it is not representative at the locality-cohort level—the level of treatment—the distribution of individuals by year of the first telesecundaria construction in the ENOE sample is roughly similar to the distribution of construction dates for all schools in Mexico, mitigating the concerns of having a highly selected sample (Figure 3a Panel (a) and Figure 4a Panel (a)).

<sup>22</sup>Just in the 2005-2010 period, 1.1% of the Mexican population were international migrants, 3.1% intrastate migrants, and 3.5% interstate migrants (CONAPO, 2014).

the estimates, attenuating the effects towards zero. However, education opportunities and schooling choices in the location of origin influence migration decisions, which could bias the estimates in either direction. To mitigate this concern, I restrict the sample to individuals born in the same state they were living during the survey year, excluding from the analysis interstate and international migrants. I further discuss the extent of the migration concerns in Section 7.

I use all ENOE waves from the 2005-2016 period, keeping only the first observation for each unique individual to avoid non-random attrition in subsequent survey waves. The sample includes only individuals aged over 15 at the time of the interview, born later than 1948—in an attempt to keep the comparison groups relevant—and, as explained above, living in the same state they were born in and in localities with less than 100,000 inhabitants. The final sample consists of 896,274 individuals, 40% of them living in rural localities and almost 30% in sub-urbanization localities. Within these localities, I exploit the construction of 3,132 telesecundarias in 2,110 different localities, more than 80% being constructed in rural areas.

Table 1 reports descriptive statistics related to education and labor market outcomes of the individuals in the sample (Columns 1 and 2). Based on a discrete educational level variable, I define four indicator variables for whether the individual enrolled in junior secondary education, graduated from junior secondary education, enrolled in upper secondary education, and enrolled in tertiary education.<sup>23</sup> The average individual in the sample completed 8.6 years of schooling: 66% of individuals completed some junior secondary grades, 33% some upper secondary grades, and 12% completed some years of college or a technical qualification.

Regarding the long-term labor market outcomes, I investigate the individual’s labor market participation, unemployment status, weekly hours worked, hourly income, labor market sector and occupation informality. The labor market participation identifies economically active individuals, either working or actively looking for a job.<sup>24</sup> Among individuals in the analysis, there is a labor force participation rate of 63% and there is a low unemployment rate of only 5%. The average number of hours worked in a week is 41, and the average income earned per hour worked among workers is 19.8 Mexican pesos (MXN). 20% of individuals work in the agricultural sector, over 30% in manufacturing and commerce, and 36% in the services sector. Separating workers by their type of employers, 48% work in formal companies or institutions, 28% in informal businesses—with no separation between household

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<sup>23</sup>Note that the dataset does not include information on the type of junior secondary school attended—telesecundarias or brick-and-mortar schools—only on whether individuals enrolled in junior secondary education.

<sup>24</sup>The ENOE defines workers as individuals engaged in an economic activity in the week prior to the interview—either working in a formal job, earning some income informally, or helping in land work or in the family business—individuals temporarily not working (e.g., for a strike) or absent but with a secured job after the temporality finishes.

and business income and assets—20% in subsistence agriculture, and 4% are paid domestic workers.<sup>25</sup> Vulnerable and precarious labor market conditions are prevalent among workers in the sample: Almost 40% of individuals work in an informal occupation, and 30% do not have health care benefits through their jobs.

## 4 Empirical strategy

**Treatment.** The main source of identifying variation is the staggered expansion of telesecundarias across Mexico over almost 50 years. The gradual process of school construction naturally leads to variation in the availability of telesecundarias across regions and across cohorts. I measure the intensity of exposure to telesecundarias through a variable identifying the telesecundaria density at the cohort-locality level:

$$TS_{lc} = \frac{\text{Number of telesecundarias}_{lc}}{\text{Population ages 12 to 14}_l} \times 50$$

Thus,  $TS_{lc}$  is the number of telesecundarias available in locality  $l$  when individuals from cohort  $c$  were 12 years-old, scaled by the total population of individuals targeted by the program.<sup>26</sup> The main treatment is a binary measure of intensity to telesecundaria exposure,  $AboveTS_{lc} = 1[TS_{lc} \text{ above median}]$ , identifying individuals with access to a density of telesecundarias above the sample median.<sup>27</sup> For tractability purposes, the binary treatment is the preferred measure of telesecundaria exposure in the effects decomposition in Section 6.4. To keep the analysis cohesive across sections, I use  $AboveTS_{lc}$  as the main measure of telesecundaria exposure in the reduced-form analysis as well. Among individuals with access to a high density of telesecundarias ( $AboveTS_{lc} = 1$ ), the average and the median telesecundaria densities are one telesecundaria per 62 and per 92 junior-secondary-aged children, respectively.<sup>28</sup>

**Reduced-form effects.** Telesecundarias are not constructed at random: their expansion follows geographical, economic and social criteria.<sup>29</sup> Since telesecundaria construction is cor-

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<sup>25</sup>See the Data Appendix A.1 for details on the definitions of labor market informality.

<sup>26</sup>The normalization of the number of schools with the targeted population size mitigates the imprecision in the measurement of the intensity of telesecundaria exposure. I use 50 as the scaling factor to approximate the number of seats available in a newly created telesecundaria.

<sup>27</sup>The density median among exposed individuals is one telesecundaria per 700 school-aged children. This cutoff is not restrictive, since it re-classifies as “untreated” only individuals in large localities with hardly any telesecundarias and, hence, exposed to a very low treatment intensity.

<sup>28</sup>Appendix A.3 reports the main results using the continuous measure of telesecundaria exposure,  $TS_{lc}$ . The results are robust to using the continuous measure as alternative treatment.

<sup>29</sup>In the early days of telesecundarias, government agencies nationally planned school allocations based on “geographical and urban conditions, economic, cultural, social and hygienic factors” (SEP, 1967). More

related with unobserved factors that can directly influence labor market outcomes, a simple comparison of mean outcomes between individuals from localities with different telesecundaria exposure may lead to biased estimates of the program effects with ex-ante unknown direction. On the one hand, if telesecundarias are constructed in underdeveloped regions in need of other public investments, the results would likely underestimate the true impacts of telesecundarias. On the other hand, if telesecundarias are built in areas where they are likely to be successful, the true effects would be overestimated. A comparison of mean outcomes between old and young cohorts from the same locality with different telesecundaria exposure would likely overestimate the impacts as well, since education attainment tends to increase over time for a given population.

A difference-in-differences strategy addresses the identification challenge outlined above by comparing the mean outcomes of individuals with different telesecundaria exposure, net of locality and cohort averages. Intuitively, it compares the difference in outcomes of individuals living in the same locality from cohorts with different levels of telesecundaria exposure due to the timing of telesecundaria construction, with the difference in outcomes between individuals from the same cohorts in localities that did not experience a change in telesecundaria exposure. I implement this using a two-way fixed-effects difference-in-differences regression (DiD), an ordinary least squares (OLS) regression of the outcome on the telesecundaria exposure measure at the locality-cohort level, and on locality and cohort fixed effects. Formally, for individual  $i$  from cohort  $c$  living in locality  $l$ :

$$Y_{ilc} = \alpha + \beta \text{AboveTS}_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc} \quad (1)$$

where  $Y_{ilc}$  is the outcome of interest (educational attainment, labor market participation, income, ...),  $\text{AboveTS}_{lc}$  is defined as above,  $\gamma_l$  and  $\lambda_c$  are locality and cohort fixed effects,  $\mathbf{X}_{ilc}$  is a vector of individual characteristics, and  $\varepsilon_{ilc}$  is the error term. To account for the presence of heteroskedasticity and serial correlation, standard errors are clustered at the locality level.

The estimates of equation (1) measure the reduced-form difference in outcome  $Y_{ilc}$  associated with having access to a high density of telesecundarias. In a framework with 2 localities and 2 periods,  $\beta$  would capture the average treatment effect on the treated (ATT). In this setting—with multiple localities and cohorts—the treatment effect  $\beta$  is a weighted average of ATTs obtained from all possible two-by-two DiD estimators across all localities and cohorts, where the weights on the two-by-two DiDs are proportional to the group sizes and the treatment variance within each pair (de Chaisemartin and D Haultfoeuille, 2018;

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recently, the Ministry of Education has decided school allocations based on, among other things, an algorithm that determines the unmet demand for each education level in every locality (SEP, 2012).

Goodman-Bacon, 2018).<sup>30</sup>

The main assumption needed to be able to interpret the estimated  $\beta$  as the reduced form effect of telesecundaria exposure is a common trends assumption, which requires that the potential growth path of the outcomes is independent from the actual treatment assignment.<sup>31</sup> In other words, had a high telesecundaria density area remained low density, treatment and control groups would have experienced the same trends on mean outcomes. Since the regression relies on group sizes and treatment variances weighting up the two-by-two DiD estimates, the appropriate identifying assumption is a variance-weighted version of the common trends assumption between all groups (Goodman-Bacon, 2018). Section 5.1 provides descriptive evidence in favor of the parallel trends assumption by reporting raw average outcomes by age at telesecundaria introduction, and discusses potential concerns. Sections 5.2 and 5.3 additionally support the parallel trends assumption by reporting the estimated DiD effects by age at telesecundaria construction.

Because the specification has multiple localities and periods, the DiD setting also requires a treatment monotonicity assumption and a stable treatment effect over time assumption (de Chaisemartin and D Haultfoeulle, 2018). The first automatically holds if the treatment is constant within each locality  $\times$  period cell. Hence, it holds for the reduced-form effects of telesecundaria construction, where the treatment is defined at the locality-cohort level, but not for the returns to education estimates, since the secondary education varies within locality and cohort. The second allows for treatment effect heterogeneity across localities but not over time. An additional concern in two-way fixed-effects settings is the potential existence of negative weights on the weighted average, which are only a concern when treatment varies within locality and cohort (de Chaisemartin and D Haultfoeulle, 2018). Goodman-Bacon (2018) shows that these only occur when treatment effects vary over time, and that they tend to bias the DiD estimates away from the sign of the true effect.

**Returns to junior secondary education.** A popular metric to measure the effectiveness of educational interventions is the estimation of labor market returns as the average monetary returns of an extra year of schooling. A limitation of the measure when evaluating interventions with knock-on effects is that it assumes that the returns to an additional year of

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<sup>30</sup>Note that, for some comparison pairs, one locality-cohort group will be treated and the other locality-cohort group untreated. For other comparison pairs, one locality-cohort group already treated will act as control for another locality-cohort group receiving treatment in a given period.

<sup>31</sup>Following de Chaisemartin and D Haultfoeulle (2018), it can be formalized as follows: Let  $L \in \{0, 1, \dots, \bar{L}\}$  denote the locality, and let  $C \in \{0, 1, \dots, \bar{C}\}$  denote the cohort the individual belongs to. Let  $Y(0)_{ilc}$  denote the potential outcome of individual  $i$  without any telesecundaria constructed. The observed outcome is  $Y(TS_{lc})_{ilc}$ . The common trends assumption requires that the mean of  $Y(0)$  follows the same evolution over time in every group, i.e.,  $E[Y(0)|L, C = c] - E[Y(0)|L, C = c - 1]$  does not depend on  $L$ , for all  $c \in \{1, \dots, \bar{C}\}$ .



schooling are constant, regardless of the completed educational level.<sup>32</sup> Given this fact, the main treatment of interest is enrolling in junior secondary education, rather than an additional year of schooling. However, I also report the estimates of the returns to an additional year of schooling to facilitate the comparison with the returns to other interventions.

In the telesecundaria setting, an OLS estimation of the effect of attending junior secondary education on labor market income is subject to two potential biases: First, a bias related to unobserved differences correlated with the access to education, explained above. Second, a selection bias if individuals decide to enroll in secondary education based on some unobserved characteristics correlated with their future labor market outcomes, like their academic ability. I use an instrumented difference-in-differences (IV-DiD) approach to overcome these identification challenges. Let  $Y_{ilc}$  be the long-run labor market income, and  $D_{ilc}^S \in \{0, 1\}$  be a binary variable indicating whether the individual enrolled in junior secondary education. The equation of interest is:

$$Y_{ilc} = \alpha + \beta D_{ilc}^S + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc} \quad (2)$$

with all parameters defined as in equation (1). I use the indicator of high telesecundaria exposure as the instrumental variable for junior secondary education enrollment,  $Z_{lc}^T = \text{Above}TS_{lc}$ . Then, the first-stage and the reduced-form equations are:

$$D_{ilc}^S = \pi_0 + \pi_1 Z_{lc}^T + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \nu_{ilc} \quad (3)$$

$$Y_{ilc} = \phi_0 + \phi_1 Z_{lc}^T + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\varphi + v_{ilc} \quad (4)$$

with all parameters defined as in equation (1).

Three assumptions are needed to interpret the estimated coefficients as local average treatment effects (LATE): The exclusion restriction and the monotonicity assumption, standard in the IV literature, and the common trends assumption, which has to be satisfied for both the treatment and the outcome.<sup>33</sup> The plausibility of these assumptions is discussed in Section 6.3. If all assumptions hold,  $\beta^{LATE}$  identifies weighted sums of the LATEs of the switchers in each group and period, where switchers are the units that experience a change in their treatment status between two consecutive periods. In other words,  $\beta^{LATE}$  estimates the effect of enrolling in junior secondary education through telesecundarias on long-run out-

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<sup>32</sup>Yet, recent empirical evidence reports that returns to schooling differ by educational level (e.g., see [Montenegro and Patrinos \(2014\)](#)).

<sup>33</sup>Instead of the IV independence assumption, the exogeneity of the instrument in the IV-DiD relies on the common trends assumption. As above, this two-way fixed-effects specification also requires a stable treatment assumption and a monotonicity of treatment assumption ([de Chaisemartin and D Haultfoeuille, 2018](#)).

comes for the complier subpopulation, i.e., those individuals induced to enroll in secondary education because they had access to a high telesecundaria density area ( $Z_{lc}^T = 1$ ) who would have not enrolled otherwise ( $Z_{lc}^T = 0$ ). The estimated coefficient can be expressed as a Wald estimator, writing it as the ratio of the reduced form and the first stage coefficients,  $\beta^{LATE} = \phi_1/\pi_1$ . For simplification purposes, consider the case where there are only two periods, 0 and 1.<sup>34</sup> Then,

$$\beta^{LATE} = \frac{E[Y_{i1} - Y_{i0} | Z_{lc}^T = 1] - E[Y_{i1} - Y_{i0} | Z_{lc}^T = 0]}{E[D_{i1}^S - D_{i0}^S | Z_{lc}^S = 1] - E[D_{i1}^S - D_{i0}^S | Z_{lc}^T = 0]} \quad (5)$$

Intuitively, this empirical strategy scales the DiD effect of telesecundaria exposure on the labor market outcome by the DiD effect on the share of individuals enrolled in secondary education.

## 5 Effects of telesecundaria construction

In this section, I examine the reduced-form effects of telesecundaria exposure on long-run education and labor market outcomes. Figure 5 provides evidence in favor of the common trends assumption. Tables 2, 3, and 4 show the estimated results of the DiD equation (1) using as treatment the high telesecundaria intensity indicator,  $AboveTS_{lc}$ . The regressions include individual-level controls (gender, age,  $age^2$  and interactions between them). All standard errors are clustered at the locality level. Figures 6 and 7 investigate the DiD effects heterogeneity by age at the first telesecundaria construction in the locality.<sup>35</sup> The estimates suggest that high telesecundaria exposure significantly increases enrollment junior secondary and higher educational levels, raising the average years of education by almost one. The results also show a significant rise in the average hourly income, partly due to an increase in the extensive margin of the labor supply and a shift away from the agricultural and informal sectors.

<sup>34</sup>Formally, let  $D^S(Z^T)_{ilc}$  denote the potential secondary education enrollment status of individual  $i$  given her telesecundaria exposure level,  $Z_{lc}^T$ . Let  $Y(d, z)_{ilc}$  identify the potential outcome of individual  $i$  given  $D_{ilc}^S$  and  $Z_{lc}^T$ . Then,  $\beta^{LATE} = E[Y(d, 1)_{ilc} - Y(d, 0)_{ilc} | D^S(0)_{ilc} < D^S(1)_{ilc}]$ .

<sup>35</sup>All the reduced-form results hold restricting the sample to only rural localities (<2,500 habitants), and rural and suburbanization localities (<15,000 habitants), with only small decreases in the effect magnitudes (see Table B.1 in the Appendix). Additionally, all the reduced-form results hold when using the continuous telesecundaria density measure  $TS_{lc}$  as alternative treatment, also separating it by smaller locality sizes (see Table B.2 in the Appendix.).

## 5.1 Descriptive evidence

Before discussing the reduced-form results, this section reports evidence in favor of the validity of the parallel trends assumption, necessary to interpret the estimates from equation (1) as the causal effects of telesecundaria expansion. In particular, Figure 5 presents descriptive trends using raw averages of the junior secondary enrollment rate, years of education and hourly income in localities with and without telesecundaria presence over the entire period. The averages are computed with respect to the age of individuals the year the first telesecundaria was constructed in their locality, or with respect to a randomly assigned placebo year if they never had a telesecundaria constructed. The vertical axis shows the raw average of the outcome, normalized to zero for the first year in the graph—the 27 relative age—for comparison purposes, and the horizontal axis shows the age at the construction of the first telesecundaria in the individual’s locality. The cohort outcome averages follow the same trends in localities with and without telesecundaria construction for all cohorts too old to benefit from the telesecundaria expansion. The outcome averages start to diverge for the cohorts that had access to telesecundarias in their locality, while the averages for the same cohorts without access maintain the same trend. I consider the cohorts aged 13 to 16—highlighted with a grey band in Figure 5—as partially treated, either because they may have started school at later ages or have repeated some grades,<sup>36</sup> or because there may be one or two year discrepancies during the imputation of construction date, incorrectly classifying slightly older cohorts as untreated. Overall, these figures suggest that the common trends assumption is likely to hold in this setting.

In a DiD setting, a common concern related to the exogeneity assumption is the simultaneous introduction of other policies that can confound the effect estimates of the program of interest. In contrast to DiD designs exploiting a one-time policy change as main source of identification, I use the construction of more than 3,000 telesecundarias across Mexico over 50 years as the identifying variation. It is unlikely that other policies introduced at the federal, state or local level systematically coincide with the construction of telesecundarias. However, a telesecundaria expansion could be accompanied by infrastructure investment—for example, roads, electricity, or TV antenna installation—needed to construct a telesecundaria. If these public investments have constant direct effects on labor market outcomes for all cohorts in a given locality, the DiD strategy rules out these confounding factors as well. If, instead, these infrastructure improvements differentially affect younger cohorts, the reduced-form estimates would likely overestimate the true effects of the telesecundaria expansion. Although this is a confound I cannot completely rule out, the analysis by cohort in Figures 5, 6 and 7—displaying clear trend breaks for cohorts around 12 to 15 relative age—mitigates the

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<sup>36</sup>As a reference, in 2016, 13% of 9<sup>th</sup> graders in telesecundarias were 17 or older. Additionally, 17% had repeated some grades since primary school (INEE, 2017).

extent of this concern.

## 5.2 Telesecundaria effects on education

Table 2 presents the estimates of the DiD specification (1) on enrollment in different schooling levels and Figure 6 reports the DiD effects by age at the first telesecundaria construction. I estimate that the construction of an additional telesecundaria per 50 children encourages 10 individuals to enroll in junior secondary education, causing an average increase of one additional year of education among individuals that could have attended it. There are also statistically significant effects on the probability of enrolling in upper secondary education, suggesting that telesecundarias have knock-on effects beyond the targeted education level.

**Junior secondary enrollment.** Having access to a high density of telesecundarias after finishing primary school increases the average junior secondary enrollment rate by 13.5 percentage points, and it is statistically significant at the 1% level (Column 1). This is an economically meaningful change, representing a 20% increase from the mean enrollment rate of 66%. A similar increase in junior secondary graduation rate (Column 2) suggests that the completion rate in this type of schools is quite high, consistent with the Ministry of Education reports (SEP) of a 8.7% dropout rate in telesecundarias (Secretaría de Educación Pública, 2010). The positive effects of telesecundaria exposure on enrollment confirms that interventions providing access to junior secondary education through investments in school construction can successfully raise educational achievement at the targeted level.

I now investigate the heterogeneity of the DiD effects by age at the first telesecundaria construction. Let  $AboveTS_l$  denote whether locality  $l$  has a telesecundaria density above median at some point, and let  $\tau$  denote the individual's age when the first telesecundaria was constructed in their locality. Then, the DiD equation (1) becomes

$$Y_{ilc} = \alpha + \sum_{\tau \in [27, -3], \tau \neq 17} \beta_{\tau} AboveTS_l \times 1[Age \text{ at TS constr}_l = \tau] + \gamma_l + \lambda_c + \mathbf{X}_{ilc} + \varepsilon_{ilc} \quad (6)$$

where all other parameters are defined as in equation (1).  $\beta_{\tau}$  is the DiD effect estimate of the exposure intensity to telesecundarias at age 12 as a function of the individual's age when the first telesecundaria was constructed in their locality.<sup>37</sup>

Figure 6a and Figure 6b report the estimates from equation (6) on junior secondary enrollment and graduation rates. The horizontal axis shows the age at the construction of the first telesecundaria in the individual's locality, and the vertical axis the DiD estimated

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<sup>37</sup>All effects are relative to the effect for individuals age 17 at the time the first telesecundaria was introduced, which is set to zero.

effect for the given age group,  $\beta_\tau$ , with a 95% confidence interval. Each point estimate can be interpreted as the causal effect of having access to a high density of telesecundarias for each age group, relative to the same effect for 17 year-olds in a given locality.

When the first telesecundaria was constructed in a locality, individuals aged 17 to 27 were too old to attend it. The estimated effects of high telesecundaria exposure on junior secondary enrollment for this age range are indistinguishable from zero. This suggests that exposure to telesecundarias is not correlated with secondary school enrollment decisions for individuals too old to benefit from them, providing additional evidence that the parallel trends assumption is likely to be satisfied. Among individuals younger than age 12 at the first telesecundaria construction in their locality, the estimated effects are positive and statistically significant. The effects are also larger in magnitude for younger treated cohorts, suggesting that students were systematically more likely to pursue secondary education some years after telesecundaria was first introduced in an area, compared to the cohorts first exposed to the program. This may reflect the fact that additional secondary education institutions were constructed over time in the same locality, so a larger proportion of individuals enrolled in them, or that other factors correlated with the timing of the telesecundaria construction made it more attractive to enroll in secondary education. Lastly, the estimated effects of telesecundaria for individuals ages 13 to 16 are smaller but statistically distinguishable from zero, gradually increasing for the younger cohorts. These partially treated individuals are classified as untreated in the reduced-form effects, so the estimates are lower bounds of the true effects.

**Enrollment in higher education.** Explicit evidence on the causal telesecundaria effects on student learning is beyond the scope of this paper due to lack of data availability. As a first step, I provide evidence on the positive effects of high telesecundaria exposure on enrollment in higher education institutions. In particular, I find that having access to a high density of telesecundarias increases the likelihood of pursuing upper secondary education by 1.5 percentage points (Column 3), representing a 5% increase and being statistically significant at the 1% level. Estimates also report an increase of 0.4 percentage points on tertiary education enrollment rate, although not statistically significant at conventional levels (Column 4).<sup>38</sup> The effects are not significant for individuals too old to benefit from the telesecundaria expansion, and they are positive and increasing over time after the first telesecundaria construction (Figures 6c and 6d). This implies that the first cohorts being exposed to telesecundarias were more likely to attend junior secondary education than older cohorts, but equally likely to pursue higher education. After a few years, junior secondary

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<sup>38</sup>Spillover effects on enrollment in education levels higher than those targeted by the program have also been documented by [Duflo et al. \(2017\)](#) and [Akresh et al. \(2018\)](#).

graduates who had access to areas with a high density of telesecundarias started to enroll in higher education institutions in increasingly larger numbers.

A summary measure of the effects on enrollment rates for all education levels is the change in average years of education. Having access to a high telesecundaria density area increases the average years of education by approximately one additional year from a population mean of 8.6, with the effect being statistically significant at the 1% level (Column 5). Figure 6e summarizes the heterogeneous findings on enrollment rates by age at the first telesecundaria construction: For individuals with access to telesecundarias, the average educational attainment gradually increases over time, probably reflecting the fact that more junior secondary and upper secondary institutions become available over time.

### 5.3 Telesecundaria effects on labor market outcomes

In this section, I report the estimated results from the DiD specification (1) on labor market outcomes. The estimates in Table 3 and Figure 7 indicate that having access to a high telesecundaria density area raises the labor market participation rate, decreases the unemployment rate, increases the probability of receiving some economic compensation and raises the average hourly income. Table 4 provides evidence that suggests two channels related to the earnings increase, a sectoral shift away from subsistence agriculture towards the services sector, and less engagement and a decrease in informal occupations.

**Labor market supply.** The labor market participation rate increases by 3.2 percentage points for individuals having access to a high density of telesecundarias. This represents a 5.1% increase in the average labor market participation rate, statistically significant at the 1% level (Table 3, Column 1). The effects are larger for younger cohorts, whereas they are indistinguishable from zero for cohorts too old to have benefited from attending telesecundaria (Figure 7a).

This result is important when interpreting the labor market returns of the program, since the new workers are likely not a random sample of the population.<sup>39</sup> Because of the endogenous compositional change of the workers' pool, I provide two distinctive sets of labor market results. Panel A in Table 3 reports the effect estimates of telesecundaria exposure on labor market outcomes for all individuals in the population, with zeros for individuals not engaged in an economic activity. These are the causally interpretable reduced-form results. Panel B in Table 3 reports the effect estimates of telesecundaria exposure on labor market outcomes for the workers' subpopulation. Although these estimates are not causally interpretable, they are still informative for understanding the type of individuals likely affected

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<sup>39</sup>Following the ENOE definition, I identify as a worker any individual conducting some type of work in the formal or informal market and either receiving or not receiving economic compensation for it.



by the telesecundaria expansion.

Among individuals participating in the labor market, the increase in telesecundaria density is associated with a 1.3% percentage point decrease in the unemployment probability (Table 3, Column 2). There is also a statistically significant increase of 15.8% in the hours worked among individuals with access to telesecundarias (Panel A in Table 3, Columns 3 and 4), all coming through the increase in labor force participation. The effects heterogeneity by age at telesecundaria introduction displays similar patterns, with no significant impacts for cohorts too old to benefit from it, and significantly positive and increasing effects for younger cohorts (Figures 7b through 7d). Within the subsample of workers, there are no changes in the hours worked, likely due to the fact that the hours are highly clustered around 40. The absence of pretrends for labor market outcomes mitigates the concerns related to the systematic construction of telesecundarias in localities prioritizing economic development, or gradually improving the labor market prospects of their inhabitants.<sup>40</sup>

**Labor market income.** Having access to a high telesecundaria density area increases the average probability of being a wage earner by 2.1 percentage points over an average of 45%. (Panel A in Table 3, Column 5). Among workers though, the probability decreases by 2.7 percentage points. Both magnitudes are significant at the 1% level. The main income variable is the inverse hyperbolic sine transformation of hourly income (Table 3, Column 8).<sup>41</sup> For completeness, I also report the estimated hourly income effects in Mexican pesos (MXN) (Column 6) and on the logarithmic transformation (Column 7). Having access to a high density of telesecundarias increases the average hourly income of the exposed cohorts by 16.9%. The effects heterogeneity by age at the first telesecundaria construction in Figure 7e and Figure 7e reveals the same pattern as in previous figures: No effects for individuals too old to benefit, and positive and increasing effects for individuals young enough to benefit from the telesecundaria expansion.

**Potential channels.** Table 4 reports the estimated effects related to two mechanisms that contribute to the positive labor market effects of telesecundaria expansion for the full population (Panel A), and for the subpopulation of workers (Panel B): A shift in labor market occupational sectors, and a decrease in the participation in the informal sector. Unless stated

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<sup>40</sup>Note that, even if this was the case, educational outcomes could still display no pretrends even if labor market outcomes did, given that it is difficult to improve educational attainment without access to nearby schools.

<sup>41</sup>The hourly income variable displays a long thick upper tail, common in wealth data, which would skew the estimates due to extreme values. With an average labor market participation of 63%, the income variable also has many zeros, making the logarithmic transformation an imperfect choice. I address both issues by using the inverse hyperbolic sine transformation (IHS). The inverse hyperbolic sine transformation is  $\log(y + (y^2 + 1)^{1/2})$  (Burbidge et al., 1988), deals with extreme values and solves the problem of  $\log(0)$  being undefined.

otherwise, the estimates reported below are for the full population. Figure 8 shows the point estimates and the 95% confidence interval for the effects of telesecundaria availability on the outcomes.

Individuals with access to a high density of telesecundarias experience a 3 percentage point net decrease in the probability of working in agriculture, and a 5.2 percentage point net increase in the probability of working in the services sector, with both magnitudes significant at the 1% level (Columns 4 and 5).<sup>42</sup> The small increase in the share of individuals working in construction, manufacturing and commerce likely reflects the overall increase in labor force participation. Among workers, there is a decrease in the probability of working in agriculture and commerce, and an increase in the probability of working in services, all significant at the 1% level (Panel B, Columns 3 through 5). This reinforces the evidence suggesting that the telesecundaria expansion caused a sectoral shift in workers' occupations, decreasing the proportion of individuals working in subsistence agriculture, shifting them towards the services sector.<sup>43</sup>

A relevant indicator for understanding the working conditions is the type of economic unit individuals work for. Among individuals with access to a high density of telesecundarias, there is an average 4.6 percentage point increase in the probability of working for formal companies or institutions (Column 6), and a 3 percentage point decrease in the probability of working in subsistence agriculture (Column 8). Interestingly, there is a 1.5 percentage point net *increase* in the probability of working in informal businesses (Column 9), defined in the ENOE as “those operating using household resources without being a formal business, so that income and economic resources used in the business are not independent from the ones in the household” (INEGI, 2010). All the effect estimates are highly significant. This last result suggests a significant increase in the proportion of individuals engaging in entrepreneurial economic activities and the creation of small businesses.

Two additional outcomes provide suggestive evidence of a decrease in the proportion of individuals working under vulnerable and insecure labor conditions. Having access to a high density of telesecundarias increases the probability of having health care benefits through their employers by 3.8 percentage points (Column 11), which is statistically significant and economically meaningful, representing a 21% increase from the baseline. Additionally, there is an overall 1.6 percentage point decrease in individuals working in informal occupations (Column 10), defined as the occupations “with vulnerable conditions due to the nature of the economic unit they work for, and those whose relationship with the economic unit is not

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<sup>42</sup>The services sector includes jobs in the hospitality industry, government, education, health and professional services, among others.

<sup>43</sup>This sectoral shift is consistent with evidence that large primary school construction programs raise the likelihood of being employed outside the agricultural sector (Karachiwalla and Palloni, 2019). In contrast, Delesalle (2019) provides evidence of an *increased* likelihood of working in agriculture.

formally recognized by the employer” (INEGI, 2010). Although statistically significant at the 1% level, this effect is economically small and represents only a 4% overall decrease.

The effects of having access to a high density of telesecundarias on labor market outcomes show a strong persistence over time, given that they are captured on average 18 years after the potential enrollment in junior secondary education.<sup>44</sup> To my knowledge, this is one of the first papers to capture such long-run effects of secondary school expansion on labor market outcomes in a developing country context.

## 6 Returns to secondary education

One of the purposes of post-primary education is to provide the skills and resources students need to become productive workers. Following the pioneering work of Becker (1964) and Mincer (1970), in this section I argue that an important mechanism by which telesecundaria construction affects labor market outcomes is through human capital accumulation, which increases workers’ productivity.<sup>45</sup> In particular, in a setting where individuals optimize their schooling decisions through cost-benefit calculations, it is important to understand the returns to education: What is the average additional increase in income for staying an extra year in school? Although the estimated worldwide return to education is around 10%, this varies across educational levels and settings (Montenegro and Patrinos, 2014). Given that there are few causal estimates of the long-run returns to secondary education in low and middle income countries, there is little evidence of the effectiveness of post-primary education investment in a developing country context.

In this section, I use the variation in telesecundaria exposure to estimate the income returns to enrolling in junior secondary education through telesecundarias. I first lay out a stylized theoretical framework of sequential schooling choices to highlight the main identification challenges when estimating the returns to secondary education in this context. The main challenges are the multiple counterfactuals, and the continuation effects of further schooling influencing the telesecundaria enrollment decision. Hence, the estimated income returns of 17.6% combine the direct effects of junior secondary education, and the continuation effects of higher education. Ex-ante, it is not clear which component accounts for the majority of the estimated returns: On the one hand, telesecundarias may provide large payoffs in the labor market by increasing workers’ productivity through human capital acquisition.<sup>46</sup> On

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<sup>44</sup>The median age in the sample is 30 years-old, with an interquartile range of 21 to 42 years-old.

<sup>45</sup>See Heckman et al. (2018) for a recent overview on the evolution of the research studying the relationship between education and human capital accumulation and labor market outcomes.

<sup>46</sup>Even if telesecundarias do not increase productivity, there could still be positive returns if there are “sheepskin” or signaling effects (Spence, 1973). Although plausible in theory, there is limited empirical evidence on signaling mechanisms of high school diplomas (Clark and Martorell, 2014; Jepsen et al., 2016).

the other hand, telesecundarias may not be rewarded in the labor market, but they could be a door to upper secondary education, vocational training or college degrees, which could provide large returns.

Decomposing the combined returns into the direct and continuation effects of telesecundarias allows for a more informed assessment of the policy implications of constructing telesecundaria-like schools in other settings: Small direct and large continuation effects would suggest that upper secondary institutions are complementary investments, needed to achieve persistent positive returns. On the other hand, large direct effects could justify expanding access to junior secondary education in a developing country context without needing to simultaneously invest in higher education institutions. I empirically decompose the direct and continuation effects of junior secondary education by exploiting variation in access to nearby upper secondary institutions, finding that the direct effects of attending junior secondary education account for 84% of the combined returns.

## 6.1 Theoretical framework of sequential educational choices

This section develops a simple model of schooling choices, based on sequential models of educational choices (Heckman et al., 2016; Heckman et al., 2018) and on models with choices between schooling substitutes (e.g., Kline and Walters, 2016; Mountjoy, 2018). The purpose of this stylized framework is to identify important forces at play in the schooling decision problem. Following Charles et al. (2018), I derive a set of sufficient conditions on the utility functions that guarantee unique thresholds consistent with the empirical patterns. I then describe two results important for understanding the main challenges to identification of the returns to telesecundarias. Appendix C provides further details on the model and the associated derivations.

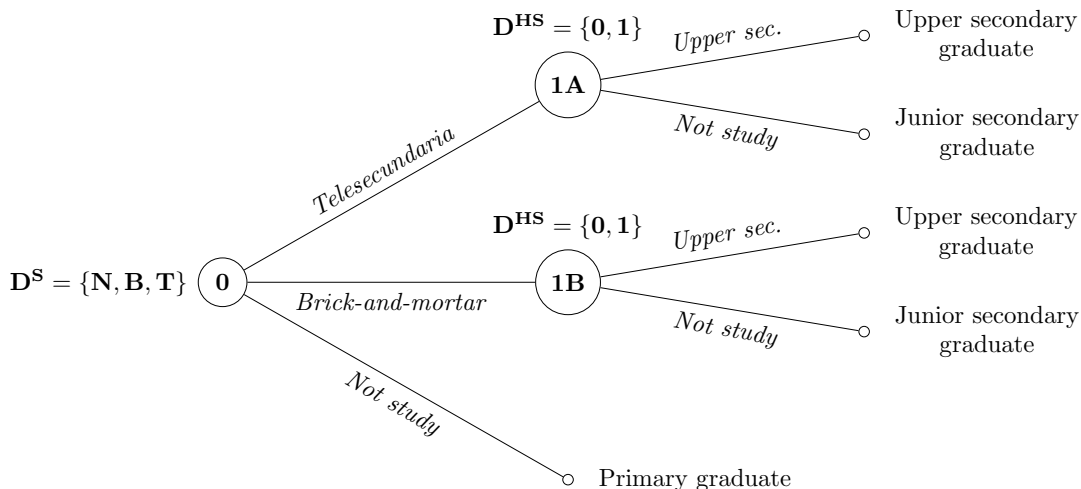
**Model setup.** Individuals indexed by  $i = 1, \dots, I$  have completed primary education and face a set of sequential choices related to their education. First, individuals choose whether to stop studying and enter the labor force or stay at home ( $N$ ) or to attend junior secondary education by enrolling into a brick-and-mortar school ( $B$ ) or into a telesecundaria ( $T$ ). Let  $D_i^S \in \{N, B, T\}$  identify the choice between these three alternatives. In a second stage, individuals that have completed junior secondary education choose whether to pursue further education by attending upper secondary education (1) or whether to stop studying (0),  $D_i^{HS} \in \{0, 1\}$ .<sup>47</sup> Figure 1 is a decision tree showing the two stages of these sequential schooling decisions and the five potential outcomes associated with them.<sup>48</sup>

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<sup>47</sup>I do not explicitly model the choice between upper secondary education modalities or for higher educational levels, combining them in the  $D_i^{HS}$  decision.

<sup>48</sup>Although the choice between junior secondary education modalities  $T$  and  $B$  can be thought of as a middle step between the choice of studying secondary education and the choice of studying upper secondary

Figure 1: Sequence of schooling decisions



**Notes:** This figure shows the two stages of the sequential schooling decision, and the five potential terminal nodes: Primary graduate, junior secondary graduate (either through brick-and-mortar or telesecundaria schools), and upper secondary and beyond graduate (either through brick-and-mortar or telesecundaria schools).

Individuals choose the alternative that maximizes their long-run utility. In the model, I assume that the benefit from attending upper secondary school after going through either junior secondary education modality is the same, and that the benefits of all alternatives are homogeneous across all individuals,  $B_i^s = B^s$ , for every  $s \in \{N, T, B, HS\}$ .<sup>49</sup> I additionally assume that attending a brick-and-mortar school has higher benefits than attending a telesecundaria for all individuals. With the benefit of not studying normalized to zero ( $B^N = 0$ ),  $B^B$ ,  $B^T$  and  $B^{HS}$  are the income premium of attending each type of school compared to just finishing primary education.

The direct cost of attending a brick-and-mortar or an upper secondary institution is the distance to the nearest school, which is constant for all individuals in a given locality  $l$  ( $k_l^m$  for every  $m \in \{B, HS\}$ ). The direct cost of telesecundaria is zero. However, individuals only consider attending a telesecundaria if it is built in the same locality they live in.<sup>50</sup> The indirect cost of post-primary education is a stochastic cost ( $c_i \sim U[0, 1]$ ) and reflects the individual opportunity cost of enrolling in school. In this setting, it may capture whether students are required to help in the fields or in the family business, or social norms and family pressures to stay at home.

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education, I model it simultaneously with the decision of studying or not.

<sup>49</sup>This simplification, which rules out a mechanism of selection based on underlying ability or motivation, is not needed for the empirical estimation, but it facilitates the illustration of the model dynamics.

<sup>50</sup>This assumption is based on the fact that telesecundarias are schools with very limited capacity (between 15-30 students), mainly serving individuals from the same locality. I assume distance to schools is the only direct cost, ruling out tuition costs and other schooling expenses, since private schools are not common in the period of interest.

Individuals optimally choose the schooling path that provides the highest long-run utility:

$$D_i(c_i) = (D_i^S(c_i), D_i^{HS}(c_i)) = \begin{cases} \arg \max_{s \in \{N, B, T\}, h \in \{0, 1\}} U_i^s(k_l^B, k_l^{HS}, c_i) & \text{if } TS \text{ in locality} \\ \arg \max_{s \in \{N, B\}, h \in \{0, 1\}} U_i^s(k_l^B, k_l^{HS}, c_i) & \text{otherwise} \end{cases}$$

where

$$\begin{aligned} U_i^B(k_l^B, k_l^{HS}, c_i, h = 0) &= B^B - k_l^B - \eta c_i \\ U_i^B(k_l^B, k_l^{HS}, c_i, h = 1) &= B^B - k_l^B - \eta c_i + \rho \cdot (B^{HS} - k_l^{HS}) \\ U_i^T(k_l^B, k_l^{HS}, c_i, h = 0) &= B^T - c_i \\ U_i^T(k_l^B, k_l^{HS}, c_i, h = 1) &= B^T - c_i + \rho \cdot (B^{HS} - k_l^{HS}) \\ U_i^N(k_l^B, k_l^{HS}, c_i, h) &= 0 \end{aligned}$$

The parameter  $\eta > 1$  captures the fact that the opportunity cost for attending brick-and-mortar secondary schools is higher than for attending telesecundarias,<sup>51</sup> and  $\rho$  is the probability of enrolling in upper secondary education, which is assumed to be the same whether individuals graduate from telesecundarias or brick-and-mortar schools.

When individuals only have access to brick-and-mortar schools, a single-crossing condition between  $U_i^B$  and  $U_i^N$  is a sufficient condition to obtain a unique threshold of opportunity cost identifying the individual indifferent between attending a brick-and-mortar school or not studying ( $c_{SN}^o$ ), which separates individuals into two groups: Those with lower opportunity costs ( $c_i < c_{SN}^o$ ) will choose to attend brick-and-mortar schools, whereas those with higher opportunity costs ( $c_i > c_{SN}^o$ ) will prefer not to enroll in secondary education. See Figure 9a for a stylized example displaying the threshold  $c_{SN}^o$ .

After telesecundarias are constructed in the individual's locality, attending them becomes a feasible option. Two sufficient conditions are needed to obtain two unique thresholds of opportunity costs ( $c_{BT}^*, c_{SN}^*$ ), which generate positive shares in the three post-primary alternatives: (1) Single-crossing conditions between  $U_i^N$  and  $U_i^T$  and between  $U_i^N$  and  $U_i^B$ , and (2)  $U_i^B$  and  $U_i^T$  crossing only once in the positive utility area. Figure 9a shows a stylized example with the utility functions satisfying these two conditions. Among those children enrolled in junior secondary education, students with moderate opportunity costs ( $c_i \in [c_{BT}^*, c_{SN}^*]$ ), will choose to attend telesecundarias, whereas those with lower stochastic costs ( $c_i < c_{BT}^*$ ) will choose to attend brick-and-mortar schools.<sup>52</sup> Shifts in the opportunity

<sup>51</sup>This is consistent with a setting where brick-and-mortar schools only have a full-time option, whereas telesecundarias offer a more concentrated schedule.

<sup>52</sup>I assume that individuals at the thresholds will choose to attend telesecundarias. This assumption is without loss of generality because tiebreaking happens with probability zero.



cost of the individual indifferent between attending junior secondary education and not studying ( $c_{SN}^*$ ) reflect changes in the extensive margin of secondary education enrollment, whereas shifts in the opportunity cost of the individual indifferent between enrolling in a brick-and-mortar or a telesecundaria ( $c_{BT}^*$ ) reflect changes in the trade-off between junior secondary school modalities.

Following other literature investigating returns to education in partial equilibrium settings, I assume there are no general equilibrium effects or externalities.<sup>53</sup> This assumption is also necessary for interpreting the empirical estimates as the returns to education. The plausibility of this assumption in the context of the paper is discussed in Section 7.

**Result 1. Compliers come from two counterfactuals.** The construction of telesecundarias only affects the individual optimization problem by adding an additional choice without affecting the utility of the other alternatives. This results in an increase of the threshold opportunity cost between enrolling and not enrolling in secondary education,  $c_{SN}^* \geq c_{SN}^o$ , which leads to an improvement in the access to secondary education. The empirical prediction stemming from this shift is a net increase in the share of individuals enrolled in junior secondary education. Under the assumptions above, there are two types of compliers (i.e., individuals choosing to enroll in telesecundarias after they are constructed): Those that would have attended brick-and-mortar schools otherwise (with  $c_i \in (c_{BT}^*, c_{SN}^o]$ ) and those that would not have studied secondary education otherwise (with  $c_i \in [c_{SN}^o, c_{SN}^*)$ ).

**Result 2. The continuation value influences telesecundaria enrollment decision.** The benefits and costs of attending higher education directly influence the decision about attending junior secondary education by affecting the extensive margin of enrolling in junior secondary education ( $c_{SN}^*$ ). However, they do not affect the trade-off between telesecundarias or brick-and-mortar schools ( $c_{BT}^*$ ), since the utilities of both school modalities incorporate the continuation value of upper secondary schooling in the same way. As a concrete example, Figure 9b shows that a decrease in the distance to the nearest upper secondary institution ( $k^{HS}$ ) shifts  $U_i^B$  and  $U_i^T$  by the same amount, only increasing the threshold opportunity cost between attending or not attending junior secondary education  $c_{SN}^* \leq c_{SN}^{**}$ . Therefore, easy access to upper secondary institutions may increase the enrollment rate in junior secondary education, keeping everything else constant.

Although this prediction is empirically testable, it is not interesting *per se*. However, it highlights the fact that, in a dynamic framework, there may be continuation value of attend-

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<sup>53</sup>In the theoretical framework, this implies assuming that the benefits of attending  $T, B, HS$  do not change when a telesecundaria is constructed, i.e.,  $B^m[A^T = 0] = B^m[A^T = 1]$ , for  $m \in \{T, B, HS\}$ , where  $A^T \in \{0, 1\}$  indicates the telesecundaria availability.

ing a given educational level, even if individuals do not directly benefit from it.<sup>54</sup> Hence, if the continuation value of telesecundarias is large enough, it is possible to observe individuals enrolling in telesecundarias after their construction even if individuals do not obtain any direct benefits from it (i.e.,  $B^T = 0$ ). This prediction highlights the challenge of identifying the effects of the telesecundaria expansion, motivating the empirical investigation of the direct and continuation effects of telesecundaria. Section 6.2 provides reduced-form evidence of the existence of continuation effects, Section 6.3 estimates the combined returns to telesecundarias, and Section 6.4 formally decomposes them into the direct and the continuation returns to telesecundarias.

## 6.2 Reduced-form evidence

This section presents reduced-form evidence testing the two observations from the theoretical model above. I first show that the relevant counterfactual to telesecundarias is not to pursue any type of secondary education. I then provide evidence of effects heterogeneity of telesecundaria exposure by differential access to upper secondary institutions. Having access to a high density of telesecundarias increases junior secondary enrollment rates in junior secondary and hourly income everywhere. However, there are only increases in upper secondary enrollment and labor market participation in places with upper secondary institutions nearby, and there are additional income increases in these places, suggesting the potential presence of continuation effects.

**Result 1.** I test whether the compliers come from two different counterfactuals—not studying or attending brick-and-mortar schools—by examining the changes in aggregate enrollment rates for both school modalities when a telesecundaria is constructed in a locality for the 1990-2010 period.<sup>55</sup> Figure 10 reports the estimated DiD coefficients from equation (6) using as outcomes the share of 7<sup>th</sup> graders enrolled in telesecundarias and enrolled in brick-and-mortar schools in a given locality, as a function of their age when the first telesecundaria was constructed in the locality. Although the proportion of individuals in a cohort enrolled in telesecundarias increases by around 50% after telesecundarias are introduced in a locality, the proportion of individuals enrolled in brick-and-mortar schools barely changes after the construction. This suggests that the relevant counterfactual for the average telesecundaria student would have been to not study secondary education.

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<sup>54</sup>Note that the option value concept is different from continuation effects. With option value effects, students learn about their individual ability through course grades, which could affect their decision of whether to pursue further education (Stange, 2012).

<sup>55</sup>Enrollment numbers at the school-year level for all schools in Mexico are only available for the 1990-2010 period.

This test is not definitive, since it assumes that the only potential switchers were attending brick-and-mortar schools in the same locality. However, following the optimization framework in the theoretical model, it is reasonable to expect that individuals attending brick-and-mortar schools in the same locality are more likely to switch than those attending schools in other localities, which have lower opportunity costs to start with. The ordered utility functions based on opportunity costs also rule out alternative re-optimizing movements where there are some switchers from brick-and-mortar schools, but individuals that would have stayed out of school take their slots in brick-and-mortar schools once telesecundarias are constructed. Hence, Figure 10 provides suggestive evidence that the estimated results are the effects of enrolling in telesecundarias compared to not pursuing secondary education.

**Result 2.** I investigate whether the reduced-form effects of telesecundaria expansion from Section 5 differ depending on whether individuals had close access to upper secondary institutions.

Figure 11 shows a scatterplot with the relationship between distance to the nearest upper secondary institution and upper secondary enrollment rates.<sup>56</sup> The upper secondary enrollment rate monotonically decreases as the distance to the nearest upper secondary institution increases until 10 km. After that, the two variables are uncorrelated. This suggests that the negative relationship between the attractiveness of upper secondary education and the distance to the nearest institution outlined in the theoretical framework holds until 10 km. 10 km is also the radius length specified by the Ministry of Education when identifying “areas of influence” of brick-and-mortar schools in their guide for schooling construction (SEP, 2012). Because of this, I use the 10 km cutoff to identify individuals that had close access to upper secondary education. Figure 11 also shows a bar graph with the share of individuals with access to upper secondary education depending on the distance cutoff used. Using the 10 km cutoff, 63% of the individuals in the sample have access to upper secondary institutions within 10 km of their locality.

Table 6 reports the DiD coefficients from equation (1) separately for individuals with and without access to upper secondary education nearby, and Figure 12 shows the same effects by age at the year of the first telesecundaria construction.<sup>57</sup> Having access to a high density of telesecundarias increases junior secondary enrollment rates in both groups, with no significant differences between them. The average positive effects on upper secondary and tertiary enrollment rates all come from the subsample of individuals with access to higher

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<sup>56</sup>Specifically, I calculate the linear distance from the locality centroid to the nearest open upper secondary institution when the individual was 15 years old, and compute the average enrollment rate for each distance bin.

<sup>57</sup>The interpretation of the graphs is the same as in Figures 6 and 7. Table B.3 and Figure B.5 report the corresponding estimates using the continuous telesecundaria density as treatment. The main results hold and are robust to the treatment definition.

education nearby. Overall, there is an estimated increase of 0.6 in the average years of education for both groups, with an additional 0.36 increase for individuals with access to higher educational institutions. Regarding the labor market outcomes, the telesecundaria expansion increases the hourly income of individuals without nearby upper secondary institutions by 7%, significant at the 5% level, whereas it additionally increases hourly income of those with access to nearby upper secondary institutions by 13.1%. The labor market participation increase mostly comes from localities with upper secondary institutions nearby. These two results suggest that attending junior secondary education through telesecundarias has some direct returns in the labor market, and that they are not only due to changes in the extensive margin of the labor supply.

### 6.3 Combined returns to telesecundarias

This section investigates the combined income returns to enrolling in secondary education through telesecundarias. Table 5 reports the estimates from the IV-DiD equation (2) (even columns). For comparison purposes, I also report the estimated returns using an Ordinary Least Squares (OLS) specification (odd columns). The estimates are computed along two margins: The labor market returns of attending junior secondary education (Panel A), and the returns of an additional year of education (Panel B). The instrument used is the binary measure of telesecundaria intensity  $AboveTS_{ic}$ , defined in Section 4.<sup>58</sup> I report the returns for all individuals in the sample (Columns 1-6), and only for individuals engaged in an economic activity (Columns 7-12). The main dependent variable is the inverse hyperbolic sine transformation of hourly income. For completeness, I also report two additional measures of the returns, in Mexican Pesos, and the corresponding logarithmic transformation.

Enrolling in junior secondary education through telesecundarias increases by 126% the average hourly income for the complier subpopulation (Panel A, Column 6), that is, for those individuals induced to enroll in junior secondary because they had access to a high density of telesecundarias and who would have not enrolled otherwise. This estimated effect is significant at the 1% level, and the results are similar using the logarithmic transformation of income. Restricting the analysis to only the worker subpopulation, there is a 22.5% increase in average hourly income attributed to enrolling in junior secondary education through telesecundarias (Panel A, Column 12), although the magnitude is not statistically significant at conventional levels.<sup>59</sup> An additional year of education after enrolling in telesecundarias increases income by 17.6% (Panel B, Column 6), whereas the return of an extra year of

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<sup>58</sup>Table B.4 in Appendix A.3 shows the returns to education using the density of telesecundarias,  $TS_{ic}$  as the instrumental variable. The results are similar using the continuous measure as instrument

<sup>59</sup>For workers, the estimated effect using the logarithmic transformation of income is 26.8%, and it is significant at the 5% level (Panel A, Column 10).

education after enrolling in telesecundarias among workers is 3.4%.

The estimated returns using the IV-DiD specification are substantially larger than the OLS returns (Table 5, odd columns). While the OLS specification estimates the return of an additional average year of education, regardless of the educational level, the IV-DiD specification estimates the return of an additional year of education *after* enrolling in telesecundarias. OLS estimates for Mexico using Mincerian equations report a return to an extra year of primary education of around 8%, whereas the returns for an extra year of secondary education and of college are around 10% and 11% (Morales-Ramos, 2011).<sup>60</sup> This differential in returns by educational level could contribute to the disparities between the OLS and IV-DiD estimates, but they are not enough to explain all the differences.

A reason often used to explain why the LATEs of interventions targeting disadvantaged subpopulations tend to be larger than the corresponding OLS estimates is that the instrument changes only influence the schooling decision of individuals with high marginal returns (Card, 1995; Ichino and Winter-Ebmer, 1999). In contrast, Oreopoulos (2006) provides evidence that LATE estimates of the returns to schooling are similar to the ATE when using compulsory schooling laws as instruments. The policy of interest in this paper—the telesecundaria expansion—specifically targets individuals in rural and isolated areas, who may have larger returns to post-primary education than the average individual. Following arguments from the theoretical model, if the opportunity costs of schooling in localities with telesecundarias are higher than average, the benefit from attending telesecundarias for the compliers should be bigger than the foregone earnings from work, selecting only the high-return individuals into secondary education. Part of the differences between the OLS and the IV-DiD estimated returns could also be due to measurement error.

The estimated returns of the intervention are in line with other instrumental variable estimates in the post-primary education literature in developing countries. Duflo et al. (2017) find that having access to secondary education increases total earnings by 19%, with the effects coming from the increased probability of working, whereas Bianchi et al. (2019) report a 55% increase in earnings due to a computer-assisted learning program with remote lessons, with the main channel being a shift to occupations focusing on analytical and cognitive skills instead of manual and physical skills. In the telesecundaria context, the reduced-form results from Section 5 suggest that a combination of mechanisms may be responsible for the large returns to secondary education: There is an increase in labor force participation, moving people along the extensive margin of labor supply and from receiving zero income to positive income, and there is a shift away from subsistence agriculture towards the services

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<sup>60</sup>More generally, the worldwide average return to schooling is around 10% an additional year, although they are higher in low or middle income economies. Regarding postprimary education, the private rate of secondary education worldwide is around 7.2%, and the rate of return to tertiary education is around 15.2% (Montenegro and Patrinos, 2014).

sector—either working in formal companies and institutions or becoming entrepreneurs in informal businesses.<sup>61</sup>

**Validity of the estimates.** The main assumptions needed to interpret the estimates from equation (2) as the LATE effects of attending junior secondary education through telesecundarias on labor market outcomes are the common trends assumption (evaluated in Section 5.1), the exclusion restriction, and the monotonicity assumption.

The exclusion restriction requires that the only way the telesecundaria expansion affects labor market outcomes is through its effects on the probability of enrolling in secondary education.<sup>62</sup> The potential confounders have to systematically coincide with the telesecundaria construction in many localities and only affect cohorts young enough to attend them. The construction of higher education institutions satisfy these criteria: A few years after expanding junior secondary education through telesecundarias, the government may construct upper secondary education institutions to serve the junior secondary graduates. The cohorts exposed to telesecundarias would also have access to higher education institutions, confounding the estimated long-run secondary education returns with the returns to upper secondary and beyond. Section 6.4 solves this challenge to the exclusion restriction by decomposing the combined returns to telesecundarias into the direct returns and the continuation returns of the program.

The potential endogenous selection of individuals in or out of sample after the telesecundaria expansion also challenges the exclusion restriction. If individuals with differential returns decided to migrate, the estimated effects would be biased. I address this concern by excluding from the analysis interstate and international migrants, and assuming there is no intrastate migration.<sup>63</sup> I further discuss the migration concerns in Section 7. The presence of switchers from brick-and-mortar schools to telesecundarias would also be a threat to the exclusion restriction, since their labor market returns could change after the construction of telesecundarias without changing their secondary education enrollment status. The analysis presented in Figure 10 mitigates the extent of this particular validity threat.

The monotonicity assumption requires that all individuals are weakly more likely to attend junior secondary education after more telesecundarias are constructed in their locality.<sup>64</sup> Although the assumption is not empirically testable, it intuitively makes sense for the binary treatment of junior secondary enrollment,  $D^S$ , since telesecundaria constructions

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<sup>61</sup>Note that the shift away from subsistence agriculture towards the formal sector could artificially inflate the returns to telesecundarias, since individuals working for formal companies are more likely to be regularly paid a fixed salary. This may improve their record keeping, allowing them to accurately report their earnings during the labor market survey, which could look like an earnings increase.

<sup>62</sup>Formally,  $Y(d, z)_{ilc} = Y(d)_{ilc}$  for all  $d, z$ .

<sup>63</sup>See Section 3 and Appendix A for more details on the migration restrictions.

<sup>64</sup>Formally,  $Pr(D^T(1)_{ilt} \geq D^T(0)_{ilt}) = 1$ .



weakly expand the individuals’ choice sets of available options.

## 6.4 Direct and continuation effects of telesecundarias

In this section, I empirically decompose the combined returns into the direct effects of attending telesecundarias and the effects of pursuing higher education afterward. In particular, I use the variation of telesecundaria expansion interacted with a baseline covariate capturing nearby access to upper secondary institutions to separately identify the direct and continuation effects in a setting with one binary endogenous treatment and one binary instrument. The identification arguments exploit previous ones from Kirkeboen et al. (2016), Kline and Walters (2016) and Hull (2018), who develop methods to account for related problems in settings with multiple simultaneous alternatives. I find that the direct returns to telesecundarias are almost 83.5% of the total estimated returns, whereas the remaining 16.5% are returns to higher educational levels.

Heckman et al. (2016) and Heckman et al. (2018) argue that treatment effects in settings with dynamic choices can be a combination of the effect of moving to the next node of a schooling decision tree (*direct effect*), and the benefits associated with the further schooling that such movement opens up (*continuation effect*). Heckman et al. (2016) prove that the Wald estimator using years of schooling as treatment can be decomposed into a weighted sum of outcome changes for people stopping at different years of schooling. Following arguments from Kline and Walters (2016) and Hull (2018), I show the same decomposition in the specific setting of a binary treatment and binary instrument.

For simplicity, I suppress the individual, locality and cohort indices. The instrument  $Z_{lc}^T \equiv Z^T$  is the binary variable indicating the intensity of telesecundaria exposure for cohort  $c$  in locality  $l$ ,  $AboveTS_{lc}$ . Let  $S \in \{0, 1, 2\}$  denote the three terminal choices of schooling from the theoretical framework: Primary education (0), junior secondary education (1) and upper secondary education and beyond (2). Let  $S(Z^T)$  identify the potential terminal choice of schooling depending on the exposure to telesecundarias, and  $Y(S, Z^T)$  the potential outcome depending on the treatment and instrument status. Assume that the standard IV assumptions of independence, exclusion and monotonicity hold.<sup>65</sup> Given the dynamic setting, I add a “no upper-switchers” assumption, which requires that no individuals who would have stopped in junior secondary education with the instrument switched off pursue upper secondary education with the instrument switched on.<sup>66</sup> As above,  $D^S$  is an indicator for whether the individual enrolled in junior secondary education. Then, the Wald estimator

<sup>65</sup>By the instrument exclusion assumption,  $Y(S, Z^T) = Y(Z^T)$ .

<sup>66</sup>Formally, the “no upper-switchers” assumption requires:  $Pr(S(0) = 1, S(1) = 2) = 0$ . This additional assumption is not necessary to secure identification and cannot be tested, but makes the decomposition easier to interpret and to estimate using the proposed econometric strategy.

of the effect of enrolling in junior secondary education on income can be decomposed as follows:

$$\begin{aligned}
\beta &= \frac{E[Y|Z^T = 1] - E[Y|Z^T = 0]}{E[D^S|Z^T = 1] - E[D^S|Z^T = 0]} \\
&= \underbrace{\frac{E[Y(1) - Y(0)|S(0) = 0, S(1) = 1]}{\text{Direct effect } (\delta)}}_{\text{Direct effect } (\delta)} \\
&\quad + \underbrace{\frac{Pr(S(0) = 0, S(1) = 2)}{Pr(S(0) = 0, S(1) \geq 1)}}_{\mu} \underbrace{E[Y(2) - Y(1)|S(0) = 0, S(1) = 2]}_{\text{Continuation effect } (\kappa)} \\
\beta &= \delta + \mu \cdot \kappa
\end{aligned} \tag{7}$$

See Heckman et al. (2018) for details on the decomposition. For completeness, I provide the proof of the decomposition in Appendix D. With the appropriate modifications of the IV assumptions, an analogous expression can be derived for the IV-DiD case. The direct effect ( $\delta$ ) is the effect of attending junior secondary schooling compared to just finishing primary schooling for the complier subpopulation. The continuation effect ( $\kappa$ ) is the effect of pursuing at least upper secondary education compared to stopping at junior secondary school for the complier subpopulation.  $\mu$  is the fraction of individuals that pursued upper secondary education among the compliers.<sup>67</sup> Hence, equation (7) states that the LATE of attending junior secondary education on earnings is the sum of the direct and the continuation effects, with the latter being scaled by  $\mu$ .

**Econometric specification.** I modify the econometric framework to incorporate the two sequential endogenous choices from the theoretical model in Section 6.1: Enrolling in junior secondary education,  $D^S = \{0, 1\}$ , and enrolling in upper secondary education,  $D^{HS} = \{0, 1\}$ ,

$$Y_{ilc} = \alpha_0 + \alpha_1 D_{ilc}^S + \alpha_2 D_{ilc}^S \times D_{ilc}^{HS} + \gamma_l + \lambda_c + \mathbf{X}_{ilc} \theta + \varepsilon_{ilc} \tag{8}$$

where all other variables are defined as in equation (2). The endogenous variable  $D_{ilc}^S \times D_{ilc}^{HS}$  captures the sequential nature of the two schooling choices.<sup>68</sup> Rearranging the above equation, it is easy to see the relationship between the combined returns to telesecundaria and the decomposition in equation (7) that separates them into direct and continuation

<sup>67</sup>  $\mu \cdot \kappa$  would be the continuation value as defined in Heckman et al. (2016) and Heckman et al. (2018).

<sup>68</sup> An important difference compared to the dynamic complementarities specification (e.g., Malamud et al. (2016); Johnson and Jackson (2018)) is that the dynamic treatment effects specification does not include  $D_{ilc}^{HS}$  as individual parameter in the regression. This is because the only way to attend upper secondary education is by having completed junior secondary school first, so adding  $D_{ilc}^{HS}$  would make it perfectly collinear with  $D_{ilc}^S \times D_{ilc}^{HS}$ .

effects:

$$Y_{ilc} = \alpha_0 + \underbrace{(\alpha_1 + \alpha_2 D_{ilc}^{HS})}_{\equiv \beta} D_{ilc}^S + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc}$$

In words, estimating the above equation using junior secondary enrollment,  $D_{ilc}^S$ , as single endogenous regressor results in equation (2), which estimates the LATE of junior secondary enrollment on income,  $\beta$ . By using two endogenous variables,  $\beta$  can be separated into two different magnitudes,  $\alpha_1$  and  $\alpha_2$ , where the latter is scaled by the proportion of individuals that pursue upper secondary education.

To separately identify the direct and continuation effects of enrolling in secondary education, I use the variation in telesecundaria exposure interacted with a baseline covariate. Intuitively, this strategy uses the first stage effects heterogeneity across the baseline covariate to separately identify the effects of the two endogenous variables. These identification arguments exploit previous ones from Kirkeboen et al. (2016), Kline and Walters (2016) and Hull (2018), who develop these methods to account for related problems in settings with multiple simultaneous alternatives. My results show that these tools can be appropriately modified to account for dynamic treatment effects. I implement this approach by using an instrumental variable specification with two instrumental variables. The baseline covariate, which must generate variation in upper secondary enrollment in response to changes in telesecundaria intensity, is the binary variable indicating whether individuals have access to upper secondary education within 10 km,  $H_{lc} \in \{0, 1\}$ .<sup>69</sup> The two instruments are the binary measure of telesecundaria intensity,  $AboveTS_{lc}$ , and its interaction with  $H_{lc}$ ,  $AboveTS_{lc}^T \times H_{lc}$ . The first stage equations are:

$$D_{ilc}^S = \pi_0 + \pi_T AboveTS_{lc} + \pi_H AboveTS_{lc} \times H_{lc} + \varphi H_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \nu_{ilc} \quad (9)$$

$$D_{ilc}^S \times D_{ilc}^{HS} = \rho_0 + \rho_T AboveTS_{lc} + \rho_H AboveTS_{lc} \times H_{lc} + \varphi H_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \nu_{ilc} \quad (10)$$

Note that this econometric framework does not model the choice between junior secondary school alternatives—telesecundarias and brick-and-mortar schools. This is not an issue in this particular analysis, given the evidence in Figure 10 that suggests that the telesecundaria expansion instrument only draws compliers from the no-schooling counterfactual. Extending the decomposition framework to allow for choices between simultaneous alternatives in addition to the sequential choices to be used in other settings is an avenue for future work.

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<sup>69</sup>This is the variable used in the reduced-form evidence testing the effects heterogeneity by upper secondary school access in Section 6.1.

**Identification.** Let  $H$  be a binary baseline covariate that separates the sample in two groups based on its value. With the appropriate modifications of the assumptions, it is straightforward to show that the decomposition in (7) also holds conditioning on the value of  $H$ ,  $\beta(H) = \delta(H) + \mu(H)\kappa(H)$ . Assume that the treatment effects are homogeneous across all values of  $H$  (i.e.,  $\delta(H) = \delta$  and  $\kappa(H) = \kappa$  for all  $H$ ). Under this assumption, and for two different values of  $H$ ,  $H_0$  and  $H_1$ ,

$$\begin{aligned}\beta(H_0) &= \delta + \mu(H_0)\kappa \\ \beta(H_1) &= \delta + \mu(H_1)\kappa\end{aligned}$$

This is a system of two equations and two unknowns. Taking the difference between both equations and rearranging,

$$\kappa = \frac{\hat{\beta}(H_1) - \hat{\beta}(H_0)}{\hat{\mu}(H_1) - \hat{\mu}(H_0)} \quad (11)$$

where all parameters are identified. In particular, the income returns  $\hat{\beta}(H_0)$  and  $\hat{\beta}(H_1)$  can be empirically estimated using the LATE framework in Section 6 separately for each  $H$  group. The population shares  $\hat{\mu}(H_0)$  and  $\hat{\mu}(H_1)$  can be nonparametrically identified using the first stage results. To secure identification of  $\delta$  and  $\kappa$ , the denominator must be nonzero,  $\hat{\mu}(H_1) - \hat{\mu}(H_0) \neq 0$ .

If the LATE assumptions are satisfied, the share of individuals pursuing upper secondary education among the complier subpopulation is different across both  $H$  groups, and the direct and continuation LATEs are homogeneous across both  $H$  groups, then  $\hat{\alpha}_1$  and  $\hat{\alpha}_2$  are unbiased causal estimates of the direct and continuation effects of telesecundaria, i.e.,  $\hat{\alpha}_1 = \delta$  and  $\hat{\alpha}_2 = \kappa$ .

**Estimates of the decomposition.** Table 7 reports the first stage results. As expected, there is a strong first stage of the binary version of the telesecundaria density treatment, *AboveTS<sub>lc</sub>*, on junior secondary enrollment (Column 1), even after controlling for upper secondary school access. The effect of having access to upper secondary enrollment increasing junior secondary enrollment as well (Column 2 and 3) suggests that a continuation value could be at play. Additionally, there are strong first stage effects of both instruments on upper secondary enrollment as well (Columns 4 through 6).

Table 8 reports the net returns to junior secondary education estimated using the IV-DiD specification in equation (2) (Column 1), and estimated results of the returns decomposition in equation (8) (Column 2). As discussed in Section 6.3, the estimated combined returns are a 126% increase in hourly income for the compliers enrolling in junior secondary edu-

cation through telesecundarias (Table 5, Column 1). The average estimated direct effect of enrolling in junior secondary education through telesecundarias is a 104% increase in hourly income for the complier subpopulation compared to just finishing primary school. This effect is statistically significant at the 1% level. The returns to attending upper secondary education after telesecundaria enrollment are an additional 192% increase in income compared to the returns to just completing junior secondary education. Hence, almost 84% of the net returns of junior secondary education come from the direct effects of enrolling in junior secondary education, and the remaining 16% come from having the opportunity to pursue upper secondary education afterwards. Even though the returns to attending upper secondary education are significantly larger than those to attending junior secondary education, their contribution to the net effects of junior secondary enrollment is only 10%, since the proportion of compliers who continue studying by enrolling in upper secondary education is small.

## 7 Discussion and conclusions

The use of non-traditional methods to solve challenges and constraints in the provision of education often raises concerns about educational quality. One such method is the telesecundarias, schools using televised lessons as an alternative to face-to-face instruction in rural areas. Descriptive evidence—with telesecundaria students consistently performing worse than brick-and-mortar students in standardized assessments<sup>70</sup>—is often used to argue that telesecundarias provide low-quality education, without taking into account the socioeconomic differences across student populations.

The findings in this paper provide evidence that expanding access to junior secondary education in developing countries has large positive returns, even if it requires resorting to non-traditional methods to solve provision challenges, and even if there is no access to nor complementary investments in higher educational levels. In particular, I estimate average increases in hourly income of 125% for individuals induced to enroll in junior secondary education by the telesecundaria expansion. Due to the existence of knock-on effects, these returns combine the direct effects of telesecundarias and the continuation effects of higher educational levels. After decomposing the combined returns, I conclude that the majority of the returns come directly from attending junior secondary education rather than from continuing on to further education.

The policy evaluation of the telesecundaria expansion indicates positive and persistent average educational and labor market effects for individuals with access to a high telesecun-

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<sup>70</sup>For example, in PISA 2003, 94% of telesecundaria students had insufficient competency in math, compared to 58% of brick-and-mortar students and the 21% OECD average (INEE, 2005).

daria density. These reduced-form results are robust to different specifications, and there is convincing evidence supporting the parallel trends assumption on the outcomes. A potential confounder is the Progresa/Oportunidades program, a large conditional cash transfer (CCT) program that began in 1997. It targets poor households in rural communities and, among other things, it conditions monetary transfers on children regularly attending schools.<sup>71</sup> Given that most of the CCT program beneficiaries are telesecundaria students,<sup>72</sup> there could be concerns about which program—telesecundarias or Progresa/Oportunidades—is driving the positive impacts. The main results hold when excluding individuals exposed to telesecundarias after 1997, indicating that the Progresa/Oportunidades program does not account for all the estimated effects.

Interpreting the instrumental variable estimates as the income returns to attending junior secondary education requires assuming that there are no externalities or general equilibrium effects. If there are spillovers during the provision of education or later in the labor market, the estimated impacts might be biased in an unknown direction. First, if the telesecundarias and brick-and-mortar schools are imperfect substitutes, the telesecundaria expansion may raise the competition of existing brick-and-mortar schools. This could improve the overall school productivity in nearby localities (Hoxby, 2000), crowd-out public investment to existing education institutions, or induce selective sorting of students switching school modalities (Hsieh and Urquiola, 2006; Imberman, 2011), which could upward- or downward-bias the estimates of the true effects.<sup>73</sup> Second, if workers with different educational levels are imperfect substitutes in production (e.g., Katz and Murphy, 1992), a significant increase in the supply of junior secondary school graduates in the local labor market could lower average wages of post-primary graduates through conventional supply effects. In contrast, the existence of human capital spillovers—with the presence of educated workers making other workers more productive—could increase overall wages (Moretti, 2004; Ciccone and Peri, 2006). There is limited empirical evidence supporting significant human capital spillovers (e.g., Lange and Topel, 2006), which limits the magnitude of the estimates attributed to general equilibrium effects.

A limitation of this paper is that it focuses on adults living in their state of birth, and assumes they live in the same locality they resided in during their childhood. This assumes the absence of intrastate migration, although around 3% of the total population in Mexico were intrastate migrants in the period of 2005–2010 (CONAPO, 2014). Individuals with the highest returns to education may have migrated from rural to urban areas—with rel-

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<sup>71</sup>This program has been widely studied due to its randomized implementation during the early years. See Parker and Todd (2017) for a recent review of the evidence of the program effects.

<sup>72</sup>In 2015, almost 60% of telesecundaria students benefited from the CCT program, compared to 23% of brick-and-mortar junior secondary students (INEE, 2016).

<sup>73</sup>The no-switchers evidence in Section 6.2 mitigates the concerns related to selective sorting.

atively low density of telesecundarias and, hence, classified as “untreated”.<sup>74</sup> This would lower the average return to education in the locality of origin, while the average return in the locality of destination would change in an unknown direction, upward or downward biasing the estimates. The approach I use for dealing with the lack of migration data also excludes international and interstate migrants from the analysis. Understanding whether the telesecundaria expansion induced some individuals to migrate to other states or countries is a relevant outcome for fully understanding the implications of providing access to education in rural and isolated areas, and it is an avenue for future work. Regarding the effect estimates, if individuals with relatively high returns emigrated internationally or to other states—disappearing from the sample—in order to seek additional education or better work opportunities, the true returns to telesecundarias would be underestimated.

When assessing the magnitude of the estimated returns to secondary education, it is worth highlighting that they are results for the complier subpopulation. As argued above, the estimates for compliers tend to be larger than the corresponding average estimates, since the individuals induced to change their behavior by the instrument are likely the ones with high marginal returns. However, the return estimates in this paper are policy-relevant treatment effects, since they are the returns for individuals who enrolled in secondary education induced by the school construction, which are the returns policymakers should take into account when considering the construction of additional schools.

Lack of empirical evidence on individuals switching from brick-and-mortar schools to telesecundarias after a telesecundaria construction suggests that the counterfactual for the majority of telesecundaria students would have been not to enroll in any type of junior secondary education. Hence, the results in this paper can be interpreted as the effects of attending some type of secondary school compared to only graduating from primary school. An area for future research is to investigate the benefits of telesecundarias compared to brick-and-mortar schools: Given that the cost of telesecundarias per student is half the cost of brick-and-mortar schools, understanding the relative benefits of each modality and the degree of substitutability between both is important for shaping optimal school construction policies worldwide. Relatedly, investigating the effects heterogeneity in places where telesecundarias may be closer substitutes for brick-and-mortar schools is important for identifying potential losers when using alternatives to traditional schools, and for computing the welfare effects of these educational policies.

Given that telesecundarias are schools using televised lessons, this paper provides evidence on the long-run impacts of one of the most primitive versions of technology-aided instruction. Recent surveys report mixed results on the effectiveness of the use of technol-

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<sup>74</sup>The existence of significant migration flows from rural to urban areas is supported by descriptive evidence showing that localities with more than 15,000 habitants receive around 75% of the total migration within Mexico (CONAPO, 2014).



ogy in education (Bulman and Fairlie, 2016; Escueta et al., 2017). The interventions with the largest returns use technology to personalize instruction and to teach at the right level (e.g., Banerjee et al., 2007; Muralidharan et al., 2019). In contrast, the content delivery in telesecundarias diverges significantly from these successful programs, being a one-size-fits-all lesson taught by a single remote teacher and simultaneously retransmitted to all schools. Yet, there seem to be large returns to attending telesecundarias. An important difference that could be key to solving this puzzle is that the televised lessons in telesecundarias completely substitute face-to-face instruction in a school setting, whereas educational technologies have often been evaluated either as complementary tools to face-to-face teaching, or as complete substitutes for formal schooling. Hence, the success of telesecundarias could be due to their “blended environment”, where the benefits of superstar teachers delivering the content (Acmoglu et al., 2014) are combined with in-class support and peer interactions.<sup>75</sup>

All in all, there seem to be large returns to providing access to secondary education using low-cost and low-tech technology to deliver lessons. If the success of interventions using technology to personalize instruction replicate to telesecundaria-like settings, the estimated returns in this paper could be a lower bound for similar programs using more sophisticated technologies, such as the interactive televised lessons recently implemented in Brazil, Ethiopia or Ghana. Identifying the factors that make telesecundarias successful, as well as using the existing evidence on educational technologies and teaching at the right level in contexts similar to telesecundarias, are fruitful areas for future research.

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<sup>75</sup>This hypothesis is in line with Escueta et al. (2017), who reports that “the effects of blended learning are generally on-par with those of fully in-person courses. This suggests that appropriate combination of online and in-person learning may be cost effective”. However, recent evidence in Setren et al. (2019) cautions against using “flipped classroom” models—where students view a video lecture at home and work on exercises during class time—finding fade-out effects and an increase in the achievement gap.

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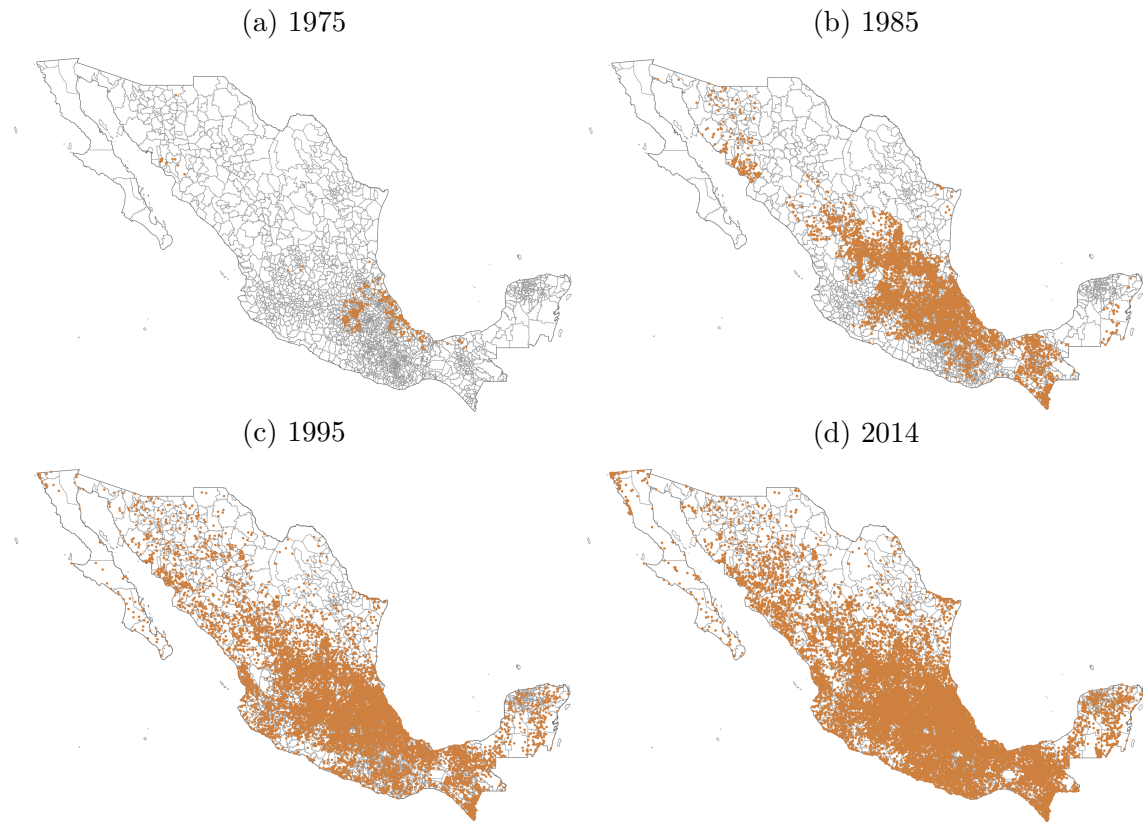
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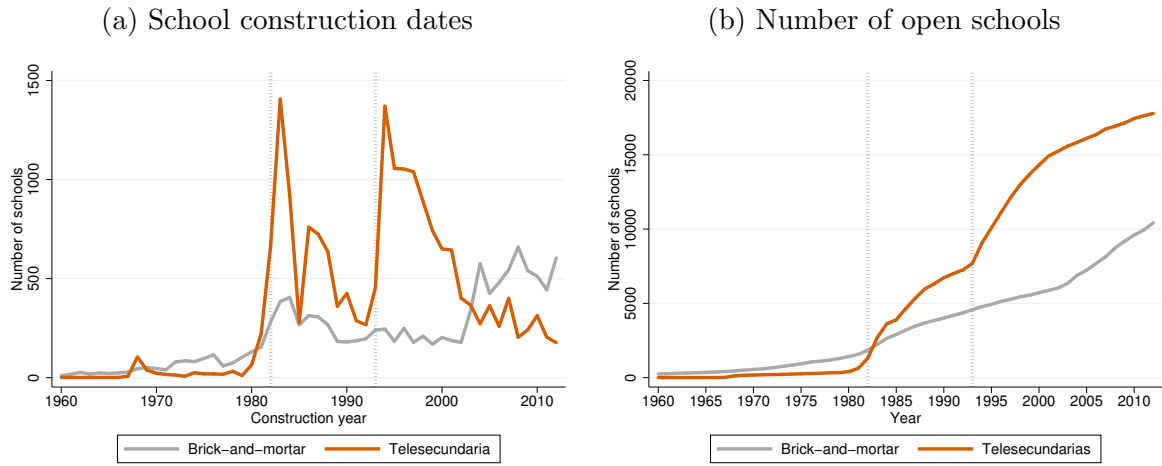
# Figures

Figure 2: Expansion of telesecundarias (1968-2014)



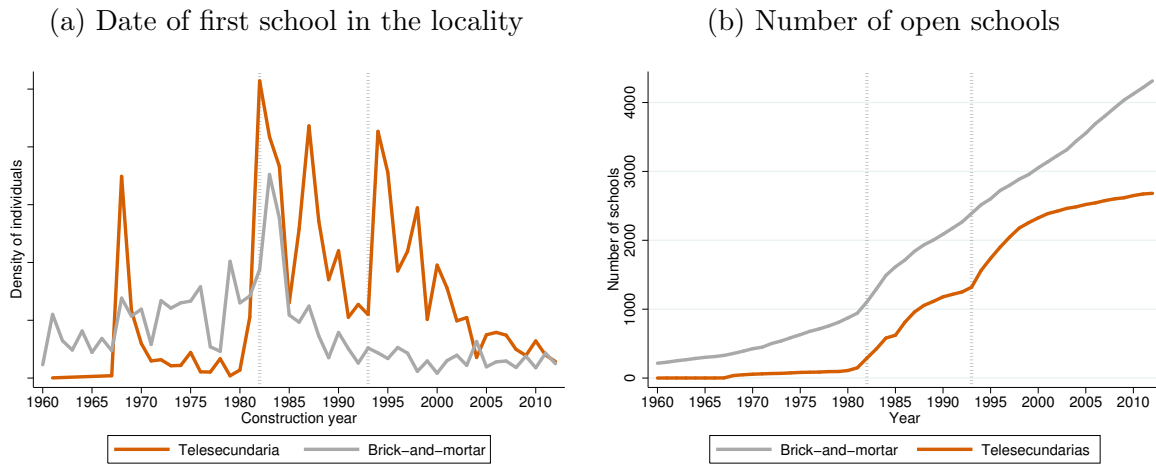
**Notes:** Telesecundaria expansion for the 1968-2014 period. Geographical frontiers correspond to municipalities, and each orange dot to a single telesecundaria. *Source:* Author graphs based on the school registry data from the Ministry of Education in Mexico.

Figure 3: Secondary school construction



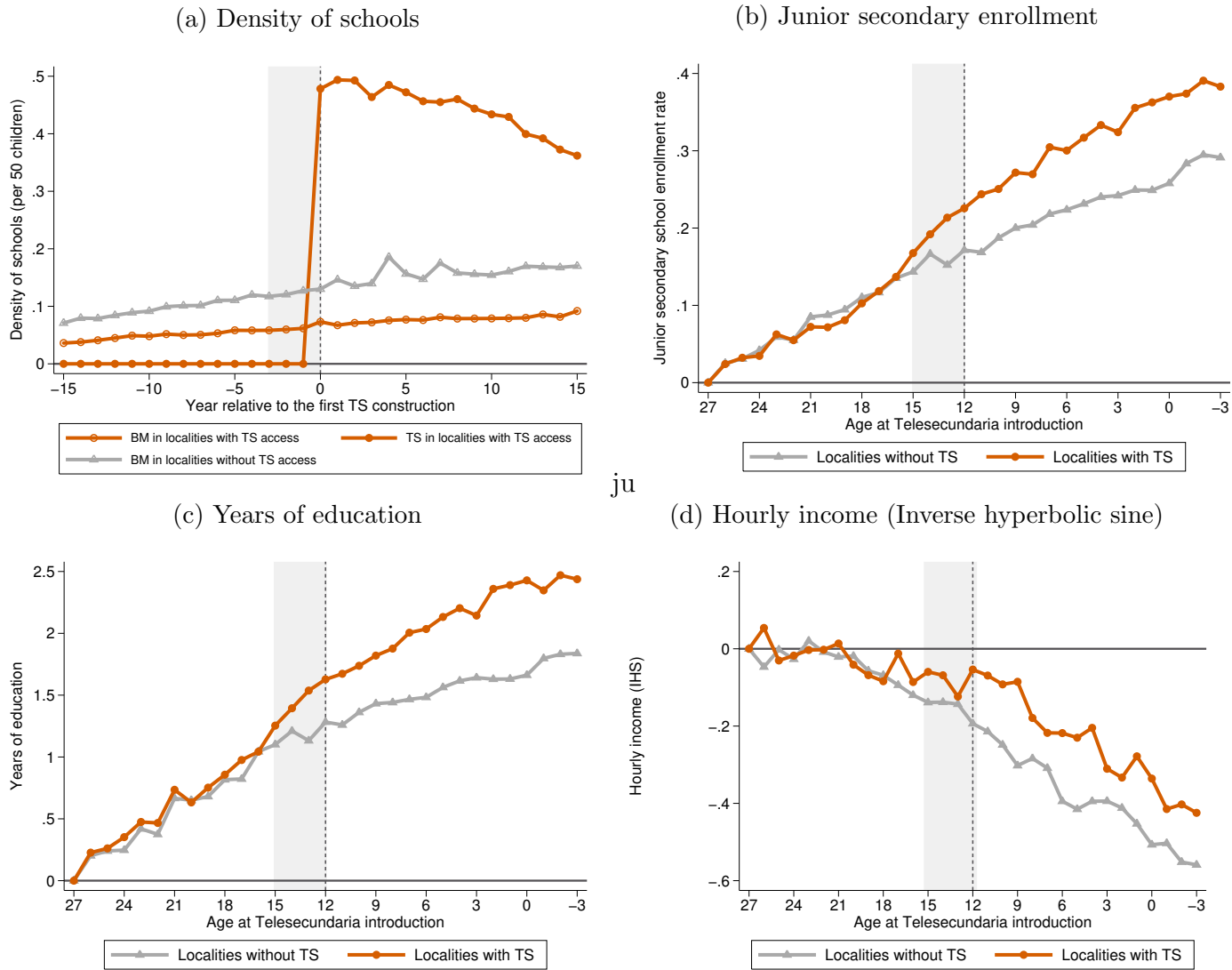
**Notes:** Panel (a) shows the distribution of the imputed construction dates of all junior secondary schools in Mexico, separated by telesecundarias and brick-and-mortar schools. Panel (b) shows the total number of open junior secondary schools in Mexico in a given year, separated by telesecundarias and brick-and-mortar schools. Both panels only include schools constructed in Mexican localities with less than 100,000 habitants during the 1960-2014 period.

Figure 4: Secondary school construction in the ENOE sample



**Notes:** Panel (a) shows the distribution of individuals in the ENOE final sample by dates of the first junior secondary school constructed in their locality, separated by telesecundarias and brick-and-mortar schools. Panel (b) shows the total number of open junior secondary schools in a given year in the ENOE localities, separated by telesecundarias and brick-and-mortar schools. Both panels only include schools constructed in Mexican localities with less than 100,000 habitants during the 1960-2014 period.

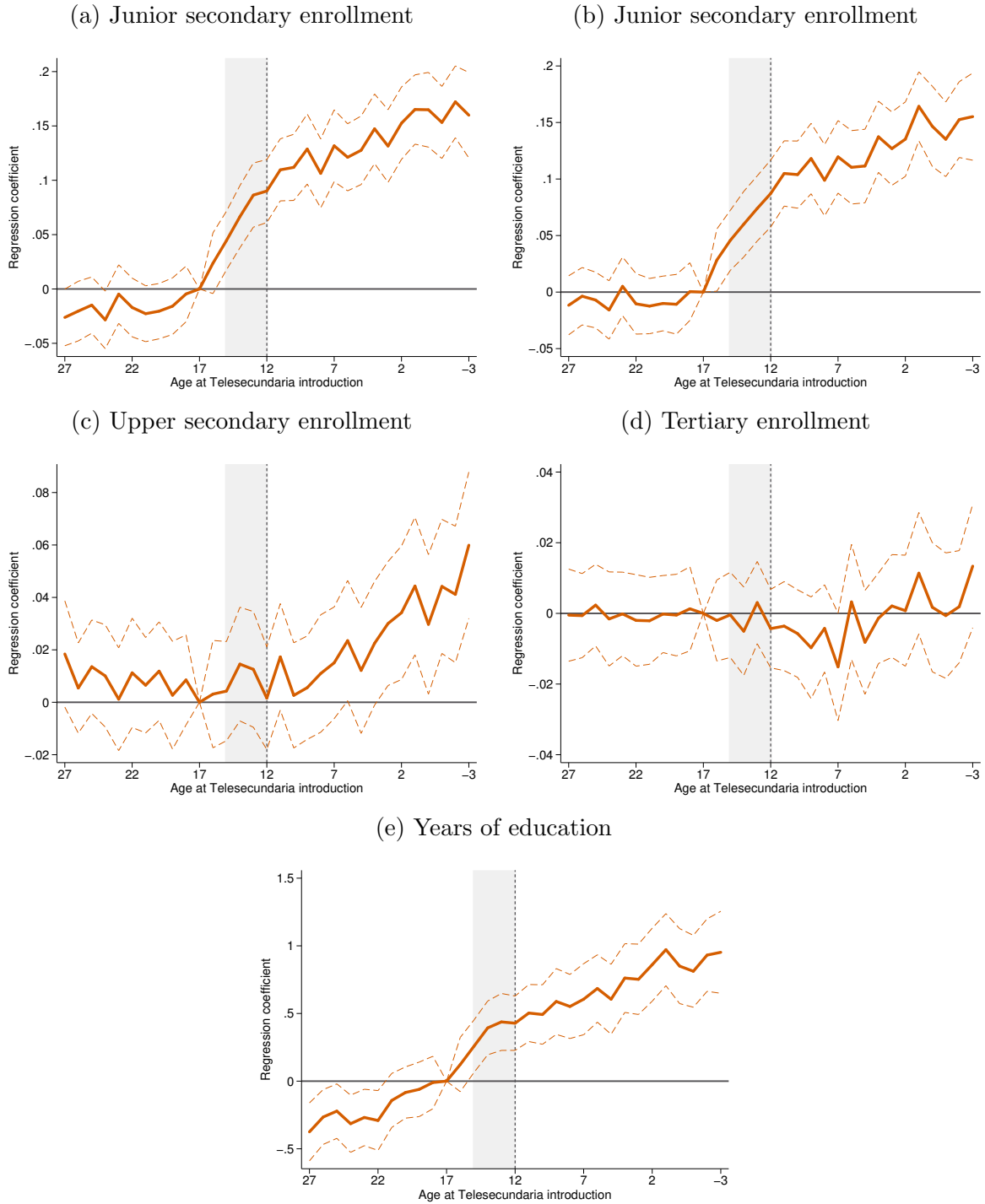
Figure 5: Evolution of outcomes relative to age at telesecundaria introduction



50

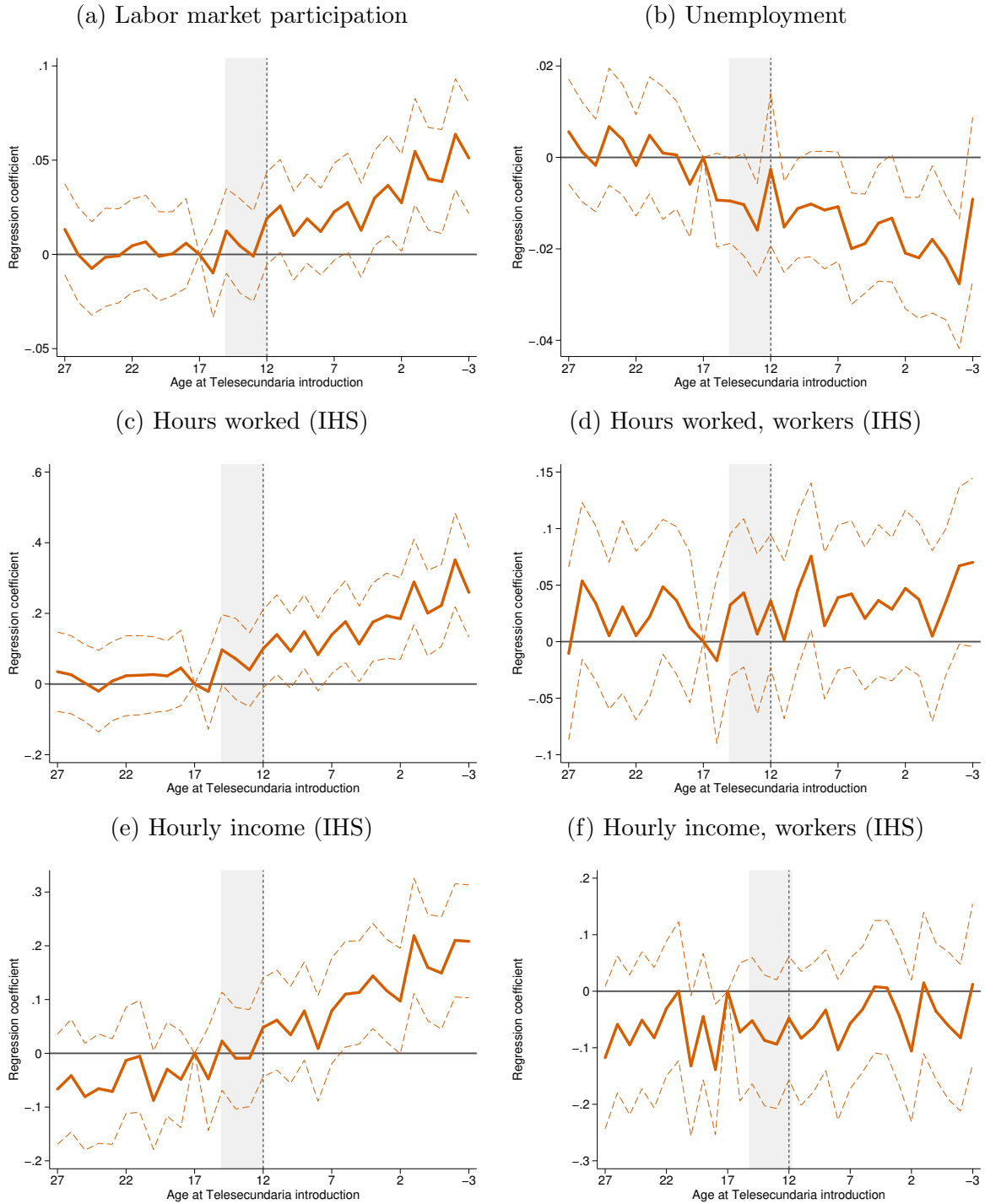
**Notes:** This figure presents descriptive population trends of the average junior secondary enrollment rate (Panel (b)), average years of education (Panel (c)) and average hourly income (Panel (d)) in localities that never had a telesecundaria (blue) and localities that eventually had one (red). The averages are computed with respect to the age of individuals the year the first telesecundaria was constructed in their locality. Localities that never had telesecundarias receive a random placebo year that follows the distribution of construction years in the sample. The mean value of the outcome is normalized at zero at the age of 27 for both groups.

Figure 6: Effects of telesecundaria construction on education outcomes



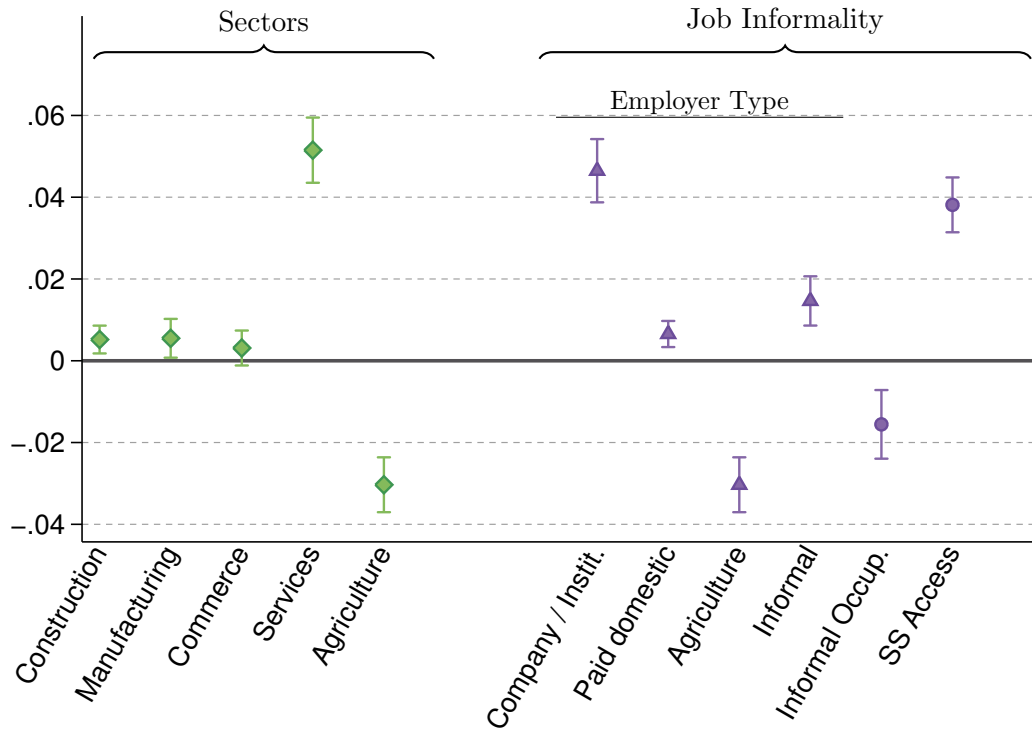
**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for different outcomes, computed by age at the year of telesecundaria construction. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

Figure 7: Effects of telesecundaria construction on labor market outcomes



**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for different outcomes, computed by age at the year of telesecundaria construction. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

Figure 8: Effects of telesecundaria construction on labor market outcomes

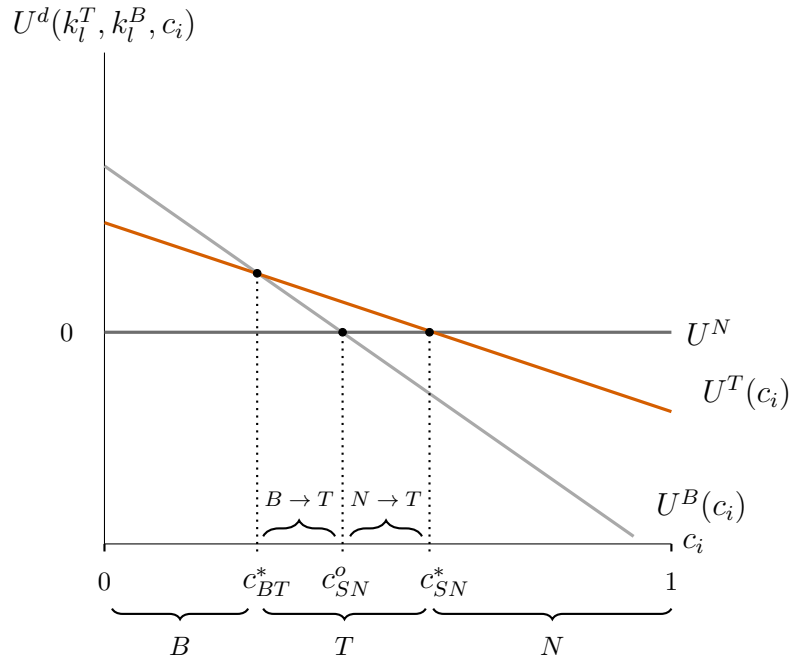


**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification of the effects of having access to a high telesecundaria density area on different outcomes related to labor market sectors and job informality. See equation (1) for details. The vertical axis shows the estimated coefficients with the associated 95% confidence interval.

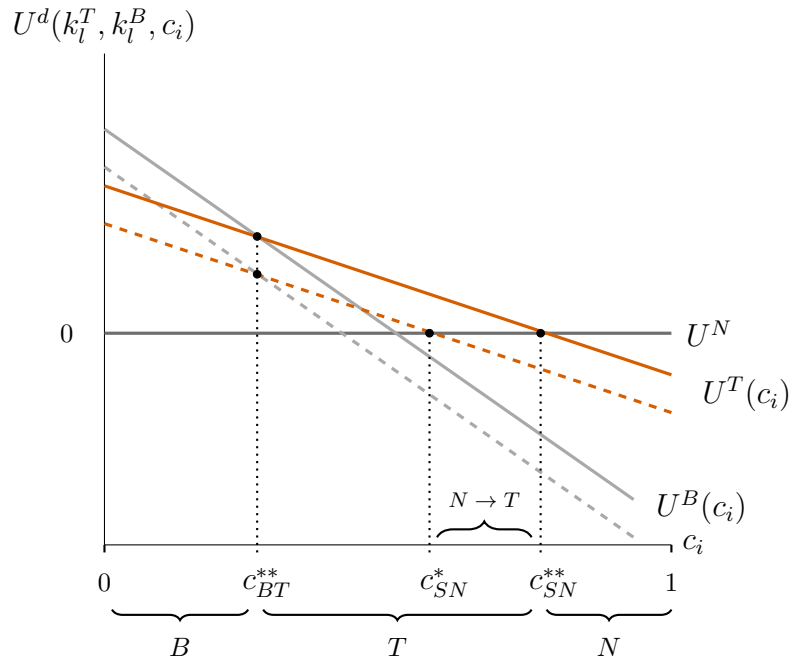


Figure 9: Stylized model of schooling choices

(a) Construction of a telesecundaria

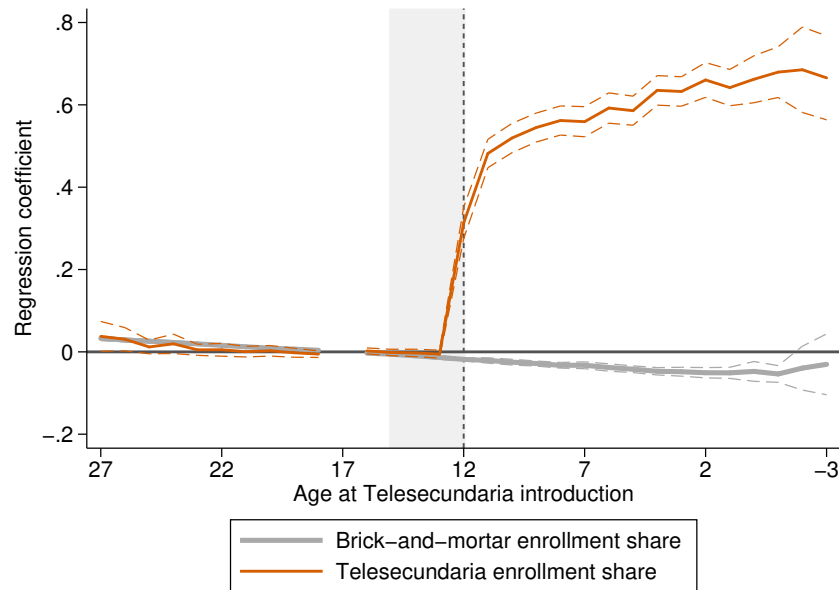


(b) Construction of an upper secondary school



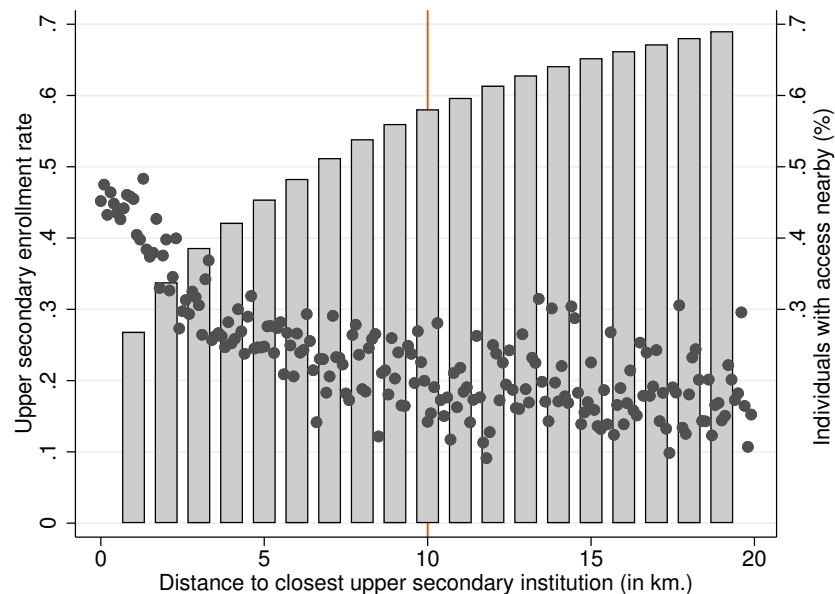
**Notes:** These figures display the utility functions of attending a brick-and-mortar school ( $B$ ), a telesecundaria ( $T$ ) or not to study ( $N$ ). Subfigure (a) shows the opportunity cost cutoffs and the complier shifts when a telesecundaria is constructed in the locality. Subfigure (b) shows the utility and complier shifts, and the new opportunity cost cutoffs when an upper secondary school is constructed nearby (with dashed lines for utilities without upper secondary schools nearby, and solid lines for utilities with an upper secondary school nearby).

Figure 10: Effects of telesecundaria construction on aggregate enrollment shares



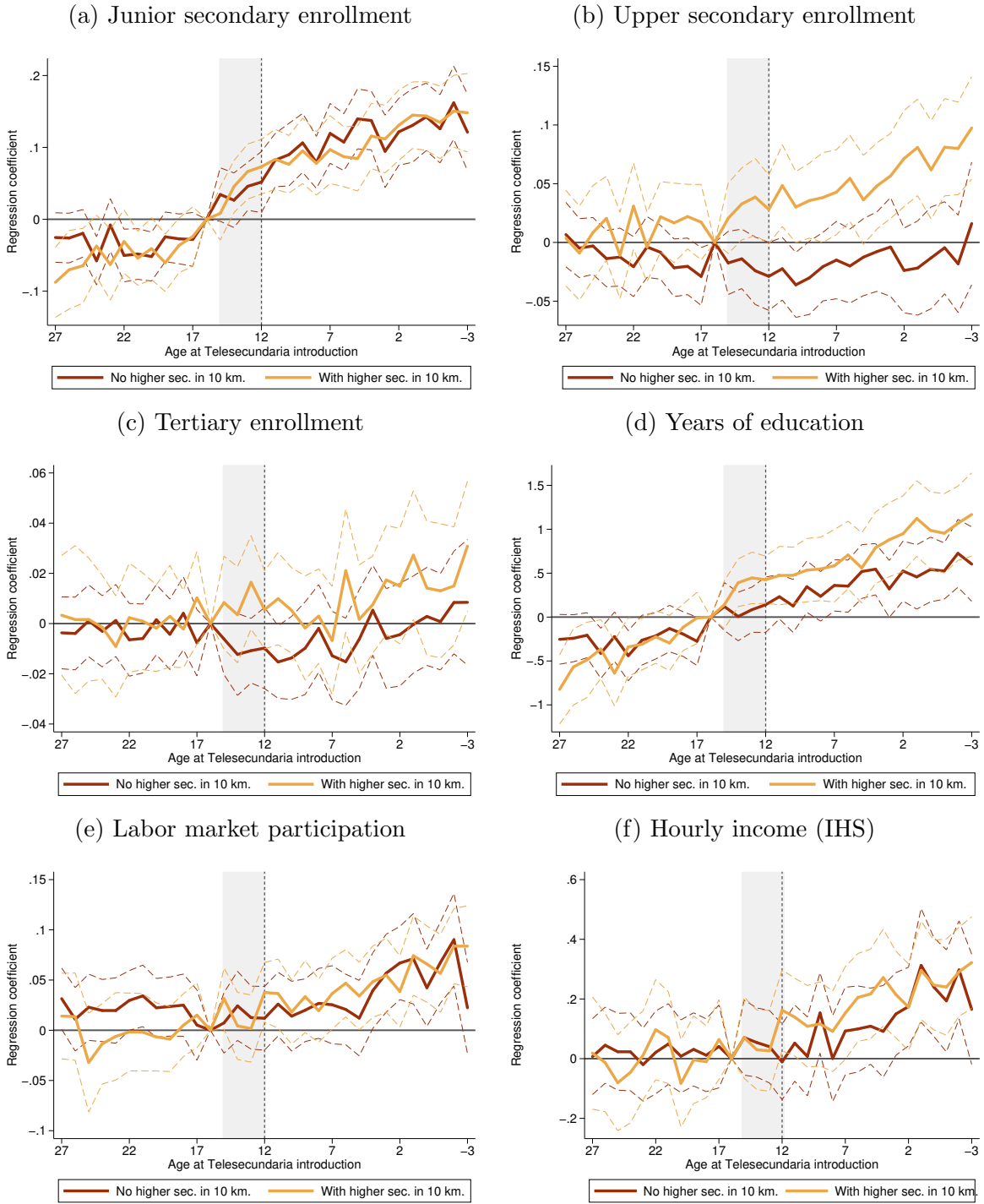
**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for the aggregate enrollment rates in telesecundarias and brick-and-mortar schools, computed by age at the year of the first telesecundaria construction. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

Figure 11: Optimal cutoff for distance to upper secondary school



**Notes:** This figure presents a scatterplot of the correlation between upper secondary enrollment rate (left axis) and the distance to the closest upper-secondary institution (in km.). It also shows a bar graph of the share of individuals with nearby access to upper-secondary education (right axis) if a given distance to closest upper secondary institution (in km.) is used as a cutoff for the definition of "nearby access".

Figure 12: Effects of telesecundaria construction on labor market outcomes, by access to upper secondary institutions



**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for different outcomes, computed by age at the year of telesecundaria construction. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

# Tables

Table 1: Summary Statistics

	< 100,000 hab.		All	
	Mean	SD	Mean	SD
<i>Individual Characteristics</i>				
Female	0.52	0.50	0.52	0.50
Age	32.48	12.78	32.31	12.60
Years of Education	8.62	4.11	9.64	4.12
Junior Secondary Ed. Enrollment Rate	0.66	0.48	0.75	0.43
Upper Secondary Ed. Enrollment Rate	0.33	0.47	0.44	0.50
Tertiary Ed. Enrollment Rate	0.12	0.33	0.19	0.39
Labor Force Participation Rate	0.63	0.48	0.64	0.48
Unemployment Rate	0.05	0.21	0.05	0.22
Weekly Hours Worked	41.06	18.61	41.39	18.02
Hourly Income (MXN pesos)	11.88	27.12	14.14	39.93
Hourly Income of Workers (MXN pesos)	19.81	32.70	23.16	49.01
Sector: Construction	0.09	0.29	0.09	0.28
Sector: Manufacturing	0.16	0.37	0.16	0.36
Sector: Commerce	0.17	0.38	0.19	0.39
Sector: Services	0.36	0.48	0.44	0.50
Sector: Agriculture	0.20	0.40	0.10	0.30
Type: Company/Institution	0.48	0.50	0.60	0.49
Type: Paid Domestic	0.04	0.21	0.04	0.20
Type: Informal Sector	0.28	0.45	0.25	0.43
Type: Subsist. Agriculture	0.20	0.40	0.10	0.30
Informal Occupation Rate	0.39	0.49	0.33	0.47
Social Security Access Rate	0.30	0.46	0.41	0.49
Observations	896274		1794042	
<i>Schooling Access</i>				
Has Access to Secondary Schools	0.67	0.47	0.83	0.38
Has Access to Telesecundarias	0.21	0.41	0.34	0.47
Has Access to Brick-and-mortar Schools	0.58	0.49	0.78	0.41
Number of Secondary Schools (if access)	6.11	7.24	43.40	52.02
Number of Telesecundarias (if access)	1.67	1.14	4.40	4.77
Number of Brick-and-mortar (if access)	6.43	7.05	43.88	50.57
Secondary Schools per 50 Children (if access)	0.30	0.63	0.19	0.41
Telesecundarias per 50 Children (if access)	0.42	0.77	0.14	0.47
Brick-and-mortar per 50 Children (if access)	0.19	0.47	0.14	0.29
Total Population in 1990	20120.33	25899.32	209246.23	259013.59
Observations	896274		1794042	

**Notes:** This table shows summary statistics computed at the individual level for all localities and for localities with less than 100,000 habitants. Variable means displayed to the right of the variable name. Standard deviations displayed next to the mean.

Table 2: Effects of Telesecundaria Construction on Educational Attainment

	Junior Secondary		Higher Education		Years of Education
	Enrollment (1)	Graduation (2)	Upper Secondary (3)	Tertiary (4)	(5)
Above Median TS Density	0.135*** (0.007)	0.118*** (0.007)	0.015*** (0.005)	0.004 (0.002)	0.960*** (0.060)
Dependent Mean	0.66	0.60	0.33	0.12	8.62
Observations	896274	896274	896274	896274	896274

**Notes:** This table illustrates the reduced-form effects of telesecundaria access on educational attainment. The table reports the estimated coefficients of  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), with the specification:  $Y_{ilc} = \alpha + \beta AboveTS_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc}$ . It uses as dependent variable an indicator for enrollment and graduation in junior secondary education (Columns 1-2), for enrollment in upper secondary and tertiary education (Columns 3-4), and total years of education (Column 5). See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{lc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  were 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample includes all individuals living in localities with less than 100,000 inhabitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 3: Effects of Telesecundaria Construction on Labor Market Outcomes

	Labor Supply				Labor Income			
	Active	Unemployed	Hours Worked		Wage Earner	Hourly Income		
	(1)	(2)	(log) (3)	(IHS) (4)	(5)	(Pesos) (6)	(log) (7)	(IHS) (8)
<i>Panel A: All Individuals</i>								
Above Median TS Density	0.032*** (0.005)	-0.013*** (0.002)	0.135*** (0.017)	0.158*** (0.020)	0.021*** (0.005)	2.655*** (0.193)	0.148*** (0.015)	0.169*** (0.018)
Dependent Mean	0.63	0.05	2.12	2.51	0.45	11.88	1.37	1.65
Observations	896274	563401	896274	896274	896274	896274	896274	896274
<i>Panel B: Workers</i>								
Above Median TS Density			0.008 (0.008)	0.008 (0.009)	-0.027*** (0.006)	2.312*** (0.254)	0.037** (0.016)	0.031 (0.020)
Dependent Mean			3.54	4.18	0.76	19.81	2.28	2.76
Observations			537546	537546	537546	537546	537546	537546

**Notes:** This table illustrates the reduced-form effects of telesecundaria access on labor market supply (Columns 1-4) and on labor market income (Columns 5-8). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), with the specification:  $Y_{ilc} = \alpha + \beta AboveTS_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc}$ . It uses as dependent variable an indicator for labor market participation (Column 1), unemployment (Column 2) the log and inverse hyperbolic sine transformations of weekly hours worked (Columns 3-4), an indicator for earning a wage (Column 5), and hourly wage in Mexican pesos, and its log and inverse hyperbolic sine transformations (Columns 6-8). See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{lc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample in *Panel A* includes all individuals living in localities with less than 100,000 habitants, and the sample in *Panel B* includes only workers living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 4: Effects of Telesecundaria Construction on Labor Sectors and Informality

	Labor Market Sectors					Labor Market Informality					
	Construction (1)	Manufact. (2)	Commerce (3)	Services (4)	Agriculture (5)	Types of Employers					
						Company/Instit. (6)	Domestic (7)	Agriculture (8)	Informal (9)	Informal Occup. (10)	SS Access (11)
<i>Panel A: All Individuals</i>											
Above Median TS Density	0.005*** (0.002)	0.005** (0.002)	0.003 (0.002)	0.052*** (0.004)	-0.030*** (0.003)	0.046*** (0.004)	0.007*** (0.002)	-0.030*** (0.003)	0.015*** (0.003)	-0.016*** (0.004)	0.038*** (0.003)
Dependent Mean	0.06	0.10	0.10	0.22	0.12	0.29	0.03	0.12	0.17	0.39	0.18
Observations	896274	896274	896274	896274	896274	896274	896274	896274	896274	896274	896274
<i>Panel B: Workers</i>											
Above Median TS Density	0.003 (0.003)	-0.007 (0.004)	-0.020*** (0.004)	0.040*** (0.005)	-0.020*** (0.005)	0.017*** (0.005)	0.008*** (0.003)	-0.020*** (0.005)	-0.005 (0.005)	-0.047*** (0.005)	0.028*** (0.005)
Dependent Mean	0.09	0.16	0.17	0.36	0.20	0.48	0.04	0.20	0.28	0.65	0.30
Observations	537546	537546	537546	537546	537546	537546	537546	537546	537546	537546	537546

**Notes:** This table illustrates the reduced-form effects of telesecundaria access on the participation on labor market sectors (Columns 1-5) and on labor market informality (Columns 6-8). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), with the specification:  $Y_{itc} = \alpha + \beta AboveTS_{lc} + \gamma_l + \lambda_c + \mathbf{X}_{itc}\theta + \varepsilon_{itc}$ . Columns 1-5 use as a dependent variable an indicator identifying whether the individual work in a given labor market sector: Construction (Column 1), manufacturing (Column 2), commerce (Column 3), services (Column 4) or agriculture (Column 5). Columns 6-9 use as a dependent variable an indicator for whether the individual works for a given type of employer: Formal company or institution (Column 6), paid domestic work (Column 7), subsistence agriculture (Column 8) or informal sector (Column 9). Column 10 uses as a dependent variable an indicator for whether the individual works in an informal occupation, and Column 11 for whether the individual has access to health insurance benefits through their employer. See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{lc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample in *Panel A* includes all individuals living in localities with less than 100,000 habitants, and the sample in *Panel B* includes only workers living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .



Table 5: Labor Market Returns to Junior Secondary Education

	<i>All Individuals</i>						<i>Only Workers</i>					
	Income (Pesos)		Income (log)		Income (IHS)		Income (Pesos)		Income (log)		Income (IHS)	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	OLS (5)	2SLS (6)	OLS (7)	2SLS (8)	OLS (9)	2SLS (10)	OLS (11)	2SLS (12)
<b>Panel A. Treatment: Junior Secondary Education Enrollment</b>												
Enrolled in Junior Sec.	6.590*** (0.168)	19.699*** (1.396)	0.305*** (0.011)	1.099*** (0.106)	0.341*** (0.013)	1.256*** (0.128)	8.737*** (0.232)	16.691*** (1.874)	0.299*** (0.015)	0.268** (0.119)	0.318*** (0.017)	0.225 (0.144)
First-stage F-stat.		392.07		392.07		392.07		317.15		317.15		317.15
Dependent Mean	11.88	11.88	1.37	1.37	1.65	1.65	19.81	19.81	2.28	2.28	2.76	2.76
Observations	896274	896207	896274	896207	896274	896207	537546	537441	537546	537441	537546	537441
Locality FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Cohort FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
<b>Panel B. Treatment: Years of Education</b>												
Years of Education	1.152*** (0.025)	2.764*** (0.194)	0.048*** (0.001)	0.154*** (0.015)	0.053*** (0.002)	0.176*** (0.018)	1.492*** (0.034)	2.492*** (0.281)	0.041*** (0.002)	0.040** (0.018)	0.042*** (0.002)	0.034 (0.022)
First-stage F-stat.		258.54		258.54		258.54		206.94		206.94		206.94
Dependent Mean	11.88	11.88	1.37	1.37	1.65	1.65	19.81	19.81	2.28	2.28	2.76	2.76
Observations	896274	896207	896274	896207	896274	896207	537546	537441	537546	537441	537546	537441
Locality FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Cohort FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

**Notes:** This table illustrates the labor market returns to junior secondary education through telesecundaria enrollment. The table reports the estimated coefficient  $\beta^{LATE}$  from the estimation of the instrumented difference-in-differences equation (2) in even columns, with the specification  $Y_{ilc} = \alpha + \beta D_{ilc}^S + \gamma_l + \lambda_c + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc}$ . In odd columns it reports the estimated coefficient  $\beta$  from an Ordinary Least Squares (OLS) regression with the specification:  $Y_{ilc} = \alpha + \beta D_{ilc}^S + \mathbf{X}_{ilc}\theta + \varepsilon_{ilc}$ , where the parameters are defined as in equation (2). It uses as dependent variable hourly wage in Mexican pesos, and its log and inverse hyperbolic sine transformations (Columns 6-8). See Section 3 for a description of the outcome variables. The treatment in *Panel A* is an indicator for enrollment in secondary education, and the treatment in *Panel B* is the total years of education. The instrumental variable is *AboveTSI<sub>lc</sub>*, and is an indicator capturing the intensity of telesecundaria exposure, identifying the locality-cohort observations with above median telesecundaria density. The telesecundaria density *TSI<sub>lc</sub>* is defined as the number of telesecundarias open in locality *l* when individuals from cohort *c* where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the instrumental variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample in Columns 1-6 includes all individuals living in localities with less than 100,000 inhabitants, and the sample in Columns 7-12 includes only workers living in localities with less than 100,000 inhabitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 6: Effects of Telesecundaria Construction by Access to Upper Secondary Education

	(1)	(2)	(3)	(4)
<b>Panel A: Education Outcomes</b>				
	Junior Sec. Enroll.	Upper Sec. Enroll.	Tertiary Enroll.	Years of Education
Above Median TS Density	0.117*** (0.011)	-0.015** (0.007)	-0.004 (0.004)	0.599*** (0.080)
Above Median TS Density $\times$ Upper Sec. Nearby	0.011 (0.015)	0.061*** (0.010)	0.021*** (0.006)	0.360*** (0.116)
Dependent Mean	0.66	0.33	0.12	8.62
Observations	896207	896207	896207	896207
<b>Panel B: Labor Market Outcomes</b>				
	Active	Unemployed	Hours Worked	Hourly Income
Above Median TS Density	0.008 (0.007)	-0.007** (0.003)	0.039 (0.031)	0.070** (0.028)
Above Median TS Density $\times$ Upper Sec. Nearby	0.043*** (0.010)	-0.004 (0.004)	0.190*** (0.045)	0.131*** (0.038)
Dependent Mean	0.63	0.05	2.51	1.65
Observations	896207	563297	896207	896207

**Notes:** This table illustrates the reduced-form effects of telesecundaria construction by upper secondary school access on education outcomes (Panel A) and labor market outcomes (Panel B). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), all regressors interacted with a binary indicator for whether individuals had access to upper secondary institutions in 10km. See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{lc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample includes all individuals living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 7: First-stage Effects of School Construction on Education Enrollment

	Junior Secondary Enroll.			Upper Sec. Enroll.		
	(1)	(2)	(3)	(4)	(5)	(6)
Above Median TS Density	0.133*** (0.007)		0.149*** (0.009)	0.014*** (0.005)		-0.016** (0.006)
Upper Secondary School Nearby	0.048*** (0.005)	0.036*** (0.005)	0.051*** (0.005)	0.033*** (0.004)	0.029*** (0.004)	0.027*** (0.004)
Above Median TS Density $\times$ Upper Sec. Nearby		0.106*** (0.007)	-0.023** (0.010)		0.028*** (0.006)	0.042*** (0.007)
Dependent Mean	0.66	0.66	0.66	0.33	0.33	0.33
Observations	896274	896274	896274	896274	896274	896274

**Notes:** This table illustrates the first-stage effects of telesecundaria construction on junior secondary enrollment and on upper secondary enrollment. Columns 1-3 report the estimated coefficient from the estimation of the two-way fixed-effects difference-in-differences on junior secondary enrollment, with only one instrument and with both instruments combined, as in equation (9). Columns 4-6 report the estimated coefficient from the estimation of the two-way fixed-effects difference-in-differences on upper secondary enrollment, with only one instrument and with both instruments combined, as in equation (10). See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{lc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  were 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. Upper secondary school nearby is a binary variable  $H_{lc}$  indicating whether individuals have access to upper secondary education in 10 km. See Section 6.4 for details on the instruments. All regressions use sampling weights and include cohort and locality fixed effects. The sample includes all individuals living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 8: Decomposition of the Returns to Lower Secondary Education

	Hourly Income (IHS)	
	LATE	Decomposition
Junior Secondary Enrollment	1.256*** (0.128)	1.049*** (0.153)
(Junior Sec. Enrollment) $\times$ (Upper Sec. Enrollment)		1.922** (0.752)
Instrumental variables	$AboveTS_{lc}$	$AboveTS_{lc}$ $AboveTS_{lc} \times H_{lc}$
First-stage F-stat. (underid)	300.90	36.75
First-stage F-stat. (weak id)	392.07	18.72
Dependent mean	1.65	1.65
Observations	896207	896207

**Notes:** This table illustrates the decomposition of labor market returns into direct and continuation effects. Column 1 reports estimated coefficient  $\beta^{LATE}$  from the estimation of the instrumented difference-in-differences equation (2). Column 2 reports the estimated coefficients  $\alpha_1$  and  $\alpha_2$  from the estimation of equation (8). It uses as dependent variable the inverse hyperbolic sine transformation of the hourly wage. See Section 3 for a description of the outcome variable. The treatment is an indicator for enrollment in junior secondary education. The instrumental variable in the regression in Column 1 is an indicator for having an above median telesecundaria density,  $AboveTS_{lc}$ . See Section 4 for details on the TS density variable. The instrumental variables in the regression in Column 2 are (1)  $AboveTS_{lc}$ , an indicator for having an above median telesecundaria density, and (2)  $AboveTS_{lc} \times H_{lc}$ , an interaction between  $AboveTS_{lc}$  and a binary variable  $H_{lc}$  indicating whether individuals have access to upper secondary education in 10 km. All regressions use sampling weights and include cohort and locality fixed effects. The sample includes all individuals living in localities with less than 100,000 inhabitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## A Data details

### A.1 Education and labor market outcomes

The individual outcome level data comes from the *Encuesta Nacional de Ocupación y Empleo* (ENOE, Employment and Occupation National Survey), administered by the *Instituto Nacional de Estadística y Geografía* (INEGI, Statistics and Geography National Institute). It is a quarterly household survey on the labor market characteristics of the population, and it is constructed as a five-quarter rotating panel. I use all waves from the 2005-2016 period, keeping only the first observation for each unique individual to avoid non-random attrition in subsequent survey waves. The survey is representative at the national level, state level, and for each of the following locality size groups: Localities with 100,000 and more habitants, localities with between 15,000 and 99,999 habitants, localities with between 2,500 and 14,999 habitants and localities with less than 2,500 habitants. All economic characteristics correspond to the week previous to the interview, except income, which refers to the previous month. Below I define the education and labor market outcomes used in the analysis and describe their construction.

**Achievement levels.** I construct the achievement level variables using the ENOE variables education level (*CS\_P13\_1*) and years of education (*ANIOS\_ESC*). The education levels are preschool, primary, junior secondary, upper secondary (*preparatoria* or *bachillerato*), teacher’s degree (*escuela normal*), technical degree, professional degree (*licenciatura*), master or PhD.

**Junior secondary education.** I define junior secondary enrollment as having completed at least some years in junior secondary education, either in lower general secondary school or in technical junior secondary school<sup>76</sup>, which is equivalent at completing at least 7 years of education. I define junior secondary graduation as having completed at least junior secondary school or lower technical secondary school, which is equivalent to at least 9 years of education.

**Upper secondary enrollment.** I define upper secondary enrollment as having completed at least some courses of *preparatoria* or *bachillerato*, or some courses of upper technical education, equivalent of having completed at least 10 years of education.

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<sup>76</sup>There are three types of technical education: A 3 year degree (9 total years of education), a 3+3 year degree (12 total years of education) and a 3+3+3 years degree (15 years of education). I classify the 3 year degree as technical secondary education, the 3+3 years as lower technical education, and the 3+3+3 as higher technical education.

**Tertiary education enrollment.** I define tertiary education enrollment as having completed at least some courses of tertiary technical education, a teacher's degree (*ecuelas normales* or *licenciatura*) or a college degree (either a full degree or a technical degree). It also includes individuals later pursuing a master or a PhD.

**Labor market participation.** The labor market participation is a binary variable classifying the individual as economically active or not. The ENOE defines the economically active population as the sum of working population and the non-working individuals actively looking for a job in the month prior to the interview. The workers are defined as individuals engaged in an economic activity in the week prior to the interview, either working in a formal job, earning some income informally, helping in land work or family business, and individuals temporarily not working (e.g., for a strike) or absent but with a secured job after the temporality finishes. I construct the labor market participation directly using the variable *CLASE1* from the ENOE dataset *SDEMT.dbf*, which classifies the population in Economically Active Population (EAP) and Non-Economically Active Population (NEAP). There are no missing values associated with this variable.

**Unemployment.** Unemployment is a binary variable that indicates whether an individual that actively participates in the labor market (see above) was not involved in an economic activity during the week prior to the interview but was actively looking for work during the last month. The unemployment variable is only defined for the individuals actively participating in the labor market, and has missing values for individuals not participating in the labor market. I construct it using the variable *CLASE2* from the ENOE dataset *SDEMT.dbf*. *CLASE2* classifies the population in employed, unemployed (for those economically active), and available and not available (for those not economically active because, for example, they perform housekeeping duties or are studying).

**Weekly hours worked.** Hours worked are the number of hours worked in a week. I obtain this information from the ENOE variable *HRSOCUP*, constructed from the survey question *P5C\_THRS*. As in the ENOE, I define this variable for all individuals in the sample, with a zero value if the individual is either unemployed or not in the labor force. I winsorize the hours worked at the 99th percentile to exclude extreme and unreasonably large values that could drive the results. Due to its nature, the variable has a highly left-skewed distribution. I minimize the incidence of large values by using two variable transformations. First, I apply a logarithmic transformation of the weekly hours worked, adding a 1 to avoid the logarithm not being defined. Second, I apply an inverse hyperbolic sine transformation of the weekly

hours worked<sup>77</sup>. Both transformations result with a smoother distribution with a spike at 0, with very similar distributions between variables. Two supplementary variables identify the weekly hours worked only for the employed individuals.

**Hourly income.** The hourly income variable identifies the average income per hour worked. I use the ENOE variable *ING\_X\_HRS*, constructed by dividing the monthly income with the weekly hours worked following the formula  $ING\_X\_HRS = INGOCUP / (HRSOCUP * 4.3)$ . I define the variable for all individuals in the sample, imputing a 0 if the individual is not employed. Due to its nature, the variable has a highly left-skewed distribution. I minimize the incidence of large values by using two variable transformations. First, I apply a logarithmic transformation of the weekly hours worked, adding a 1 to avoid the logarithm not being defined. Second, I apply an inverse hyperbolic sine transformation of the weekly hours worked<sup>78</sup>. Both transformations result with a smoother distribution with a spike at 0, with very similar distributions between variables. Two supplementary variables identify the hourly income only for the employed individuals.

**Labor market informality.** The ENOE includes several variables that provide complementary information on the worker's informality level. I define individuals working in informal occupations as the individuals that are working in vulnerable conditions due to the nature of the economic unit they work for, and those whose relationship to the economic unit is not formally recognized by the employer<sup>79</sup>. I construct a supplementary variable on labor market informality based on whether the individual receives health care benefits through the job. I consider the individual to be in the informal sector if the job doesn't provide health care benefits ( $P6D = 6$ ) or they are provided by other medical institutions ( $P6D = 5$ ). Lastly, I follow the ENOE classification of occupations by type of employers: Companies or institutions, subsistence agriculture, paid domestic work, and informal sector. Hence, the workers in the informal sector are the employed population that works in a non-agricultural economic unit that operates using household resources but without being a formal business, so that the income, materials and equipment used for the business are not independent from the ones in the household<sup>80</sup>.

**Labor market sectors.** The ENOE specifies five labor market sectors: Agriculture, construction, manufacturing industry, commerce and services. The agricultural sector includes

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<sup>77</sup> $\log(w\_hours\_worked + \sqrt{(w\_hours\_worked)^2 + 1})$

<sup>78</sup> $\log(hourly\_income + \sqrt{(hourly\_income)^2 + 1})$

<sup>79</sup>This definition corresponds to the *TIL1* variable in the ENOE dataset (see (INEGI, 2010), page 30 for the explanation on the definitions)

<sup>80</sup>This definition corresponds to the *TOSI1* variable in the ENOE dataset (see (INEGI, 2010), page 30 for the explanation on the definitions)



economic activities related to agriculture, farming, logging, fishing and hunting. The services sector includes occupations in restaurants and lodging; transportation, communication and storage; professional, financial and corporative services; social services and government and international organisms.

## A.2 Secondary school construction

The information on secondary school data comes from the *Secretaría de Educación Pública* (Ministry of Education). I use two different sources for junior secondary school data, the 2015-2016 school directory, and yearly school records for the 1990-2014 period. The 2015-2016 school directory is a database of all junior secondary schools in Mexico. Among other information, for each school it includes its unique identifier, address, geographical coordinates, school type, foundation date, date it was registered into the system, and closing and reopening dates, when appropriate. The registration system was created in 1981. All schools that existed prior to 1981 have the same date of registration, which makes the distinction between the foundation date and registration date relevant. The yearly school records are yearly databases of all junior secondary schools opened in a given academic year in Mexico. Among other information, for each school they include the unique school code, address, geographical coordinates, school type and total number of enrolled students by grade. For upper secondary schools, I use the 2016-2017 school directory, a database of all upper secondary schools in Mexico from the *Secretaría de Educación Pública*, with the same features as the junior secondary school directory.

**Creation of the school construction date.** I combine three different sources of information to construct the school construction date: The foundation date and the registration date from the 2015-2016 school directory, and the yearly records, from which I extract the years the schools were actually operating. Although these three variables should result with the same school opening years, they don't always match, and the discrepancy levels between them widely vary depending on the state. I impute the school construction date by combining the three data sources with the following procedure: I first use the foundation year from the school registry as the school construction date. If it doesn't exist, I use the registration year from the same database. Lastly, if neither exist, I assign as the school construction date the first date the school was open according to the yearly records<sup>81</sup>. Since the registry

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<sup>81</sup>I specify eight alternative criteria to check that the results are robust to the criteria used for imputing the school construction date: (1) use the foundation, closure and re-opening dates derived from the yearly records, (2) use the foundation year from the school registry, (3) use the foundation year, closure and re-opening dates from the school registry, (4) use the registration year from the school registry, (5) use the registration year, closure and re-opening dates from the school registry, (6) use the foundation year and, if it doesn't exist, use the registration year from the school registry, (7) use the registration year and, if it doesn't

was created in 1981, any schools constructed prior to this date will have assigned 1981 or 1982 as the construction date. Similarly, since the yearly records started in 1990, any schools constructed prior to this date will have assigned 1990 as the first year the school was opened. When constructing the binary indicator for whether the school was open in a given year, I assign a missing value to all years prior to 1982 or 1990 depending on the case if I use either of these sources. Note that the yearly records are only valid starting in 1990, and the registration dates are only valid starting in 1982<sup>82</sup>. Hence, depending on the data source used, some localities or states will have different sample sizes in the analysis. Any schools without an imputed construction year at the end of the construction date assignment procedure will be categorized as never opened (with a zero for all the sample period), and are not dropped from the sample. Figure A.1 shows the number of schools opened each year by state depending on the data source used to construct the variable. I combine these three sources to impute the school construction date used in the analysis. As a empirical test, I look at school construction trends for telesecundarias and brick-and-mortar schools. The relatively smooth increase of brick-and-mortar schools during the 1993 expansion suggests that the imputed telesecundaria construction dates are capturing real telesecundaria constructions. However, there is a jump in brick-and-mortar schools in 1982 (Figure 4), which raises measurement concerns related to the construction dates around 1982. Additionally, the school registry officially opened in 1982, which could have caused to include backdated information in 1982 as well, causing this artificial jump in school construction. Given this evidence, I exclude from the analysis the localities with the first telesecundaria imputed in 1982.

**Construction of the treatment of telesecundaria exposure.** I identify the schools with unknown start dates, either because either the date is 1990 from the yearly records source, or the date is 1982 from the registration date source. I aggregate the junior secondary school construction dates at the locality and cohort level, also separating them by school type. The year that separates the cohorts as treated or untreated is the year the first telesecundaria was constructed in the locality. I identify the locality as having an unknown start date if at least one school in the locality has an unknown start date. For the difference-in-

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exist, use the construction date derived from the yearly records, and (8) use the foundation year and, if it doesn't exist, use the construction date derived from the yearly records. The main results are quite robust to the criteria used to assign the school construction dates, and are available upon request.

<sup>82</sup>If I use the registration date, I categorize as not usable any school constructed in 1982. Note that this is restrictive, since in 1981-1982 there was a telesecundaria construction boom with the introduction of this modality to new states. As a robustness check, I identify states that have reliable pre-1982 based on the coincidence between the three sources along the years and smoothness of the number of schools pre and post 1982 (see Figure A.1). The states with reliable pre-1982 dates are Aguascalientes, Hidalgo, Mexico, Morelos, Sonora and Veracruz. and use the 1982 construction dates. Results are robust to this modification and available upon request.

differences specification by age at telesecundaria introduction, I compute the average number of schools after the first telesecundaria is constructed, and I assign random construction years to localities that never had a telesecundaria. I assign the random construction dates following the distribution of the real construction dates across time. I do not assign a random construction year to localities with telesecundarias with unknown construction dates. I drop localities with extreme values of the average density of telesecundarias per 50 children, higher than the 99 percent.

**Construction of school coordinates.** I combine several sources of school coordinates to have the maximum coverage. I use the school coordinates from the school directory and the yearly school records, if available. If not, I use the locality coordinates if the locality is rural, and the locality centroid coordinates for urban localities. Lastly, I use the average of primary schools coordinates from the same locality.

### A.3 Supplementary variables

**Aggregate enrollment shares.** To construct the aggregate enrollment shares, I combine yearly secondary school enrollment data from the *Secretaría de Educación Pública* (Ministry of Education) for the period 1990-2014, and population counts from the census. The school records are yearly databases of all junior secondary schools open in a given academic year in Mexico. Among other information, they include the unique school code for each school, address, geographical coordinates, school type and total number of enrolled students per grade. The population counts at the locality level come from the 1990, 2000 and 2010 census and from the 1995 and 2005 population counts, all from the Instituto Nacional de Estadística y Geografía (INEGI).<sup>83</sup> The population counts in each census year are aggregated at the locality-cohort level. For individuals older than 25 years-old, they are also binned in 5-age intervals.

Whenever possible, I split the 5-age population count bins into cohort population counts following the cohort proportions from the 1990 census. If the specific cohorts proportions are not available, and given that there are almost no differences in cohort sizes within a 5-age bin, I divide the population groups into five equally-sized cohorts. I obtain yearly population counts using a cubic spline interpolation across census years.

I aggregate the school-level enrollment data by separately computing the total number of brick-and-mortar and telesecundaria students in a given locality and year. Assuming no individuals leave their locality to attend a school, I use the cohort size from the imputed

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<sup>83</sup>Specifically, the population data come from the following datasets: *XI Censo General de Población y Vivienda 1990*, *I Conteo de población y vivienda 1995*, *XII Censo General de Población y Vivienda 2000*, *II Conteo de población y Vivienda 2005*, and *XIII Censo de Población y Vivienda 2010 Cuestionario Básico*.

population data to compute the enrollment shares in brick-and-mortar and telesecundaria students, and proportion of individuals not enrolled in secondary education. I exclude from the aggregate analysis 17% of the ENOE localities, which have a total number of enrolled students exceeding the total cohort population.

Figure A.1: Number of open schools by data source

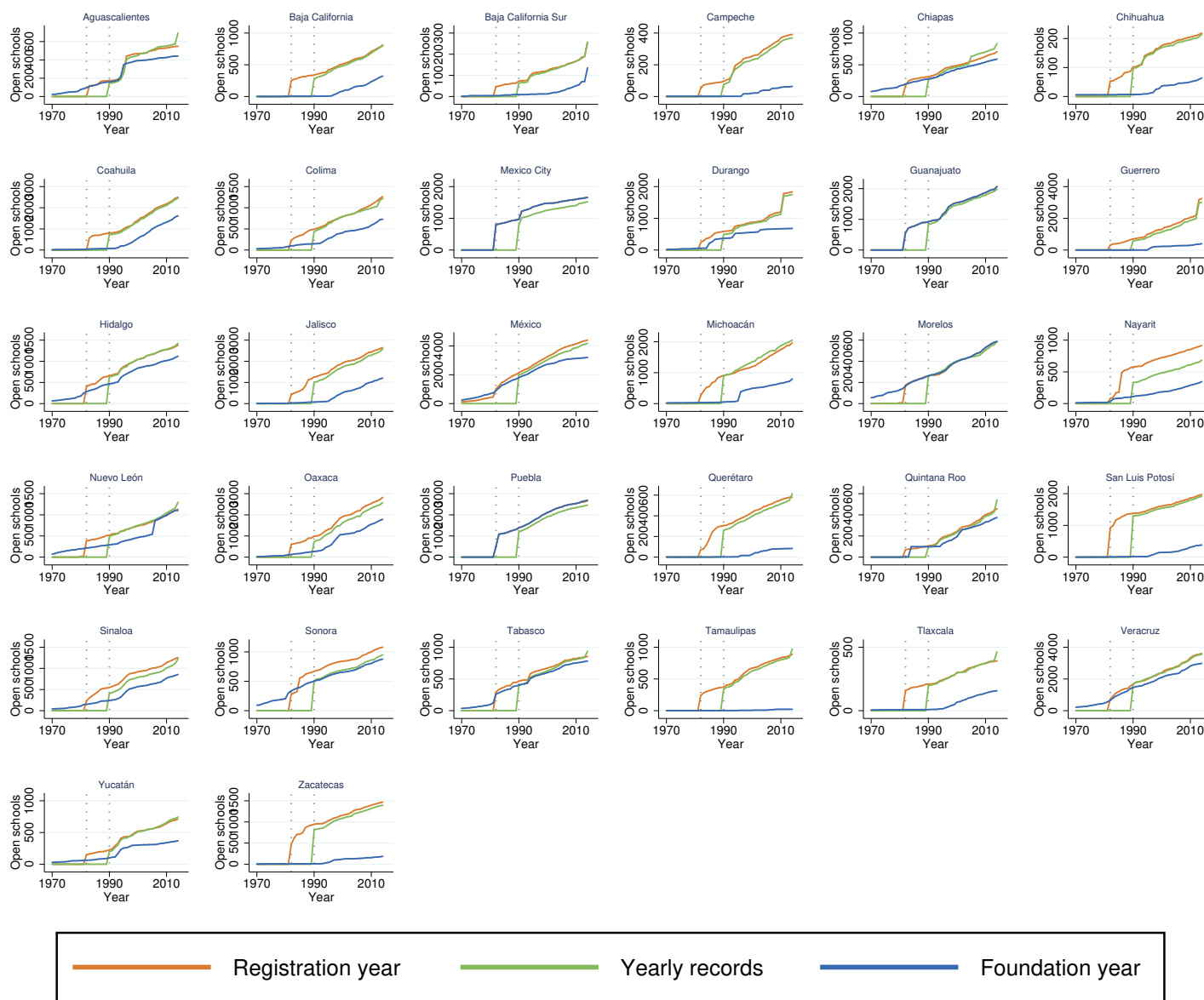


Figure A.2: Final school creation dates (I)

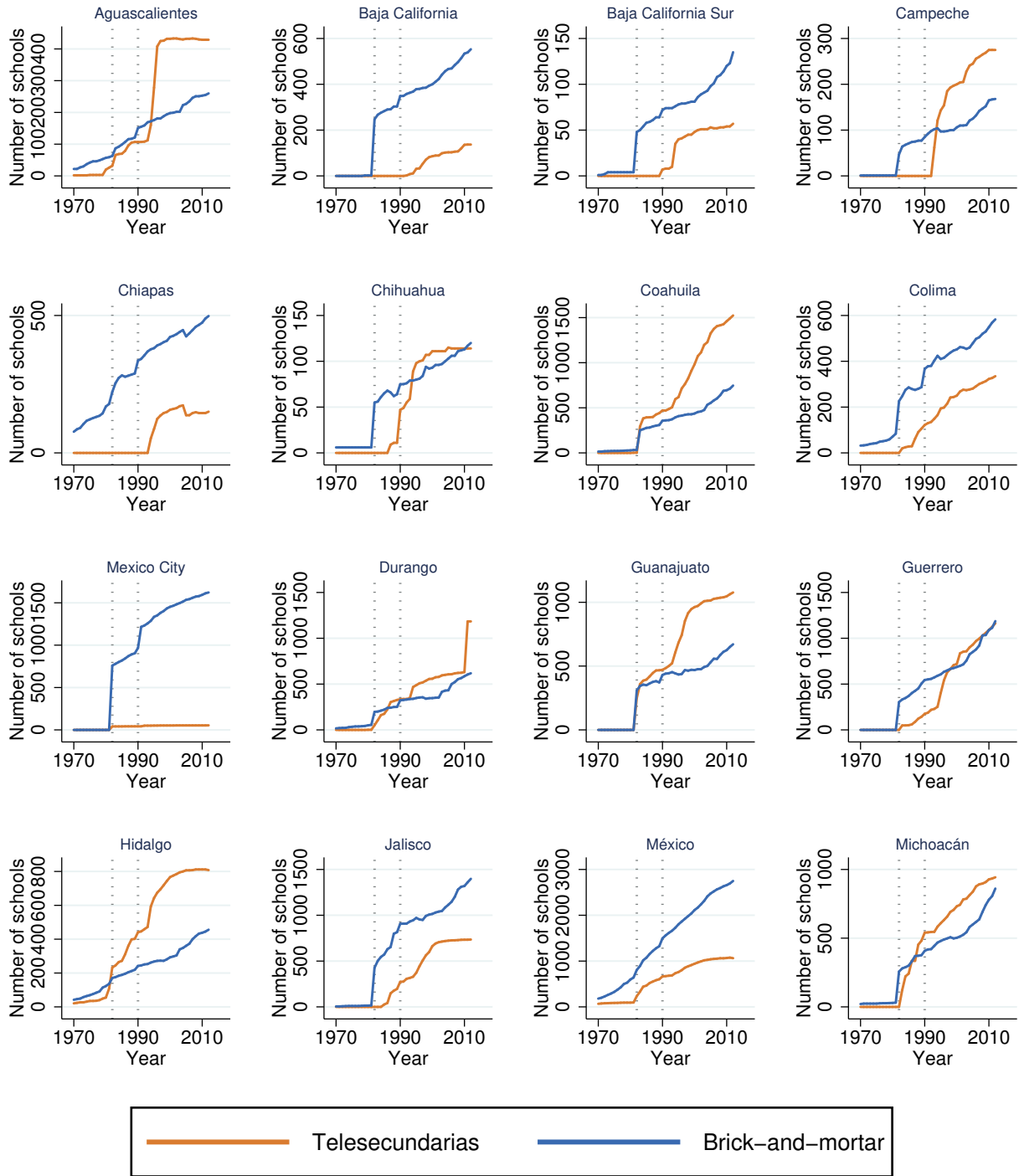
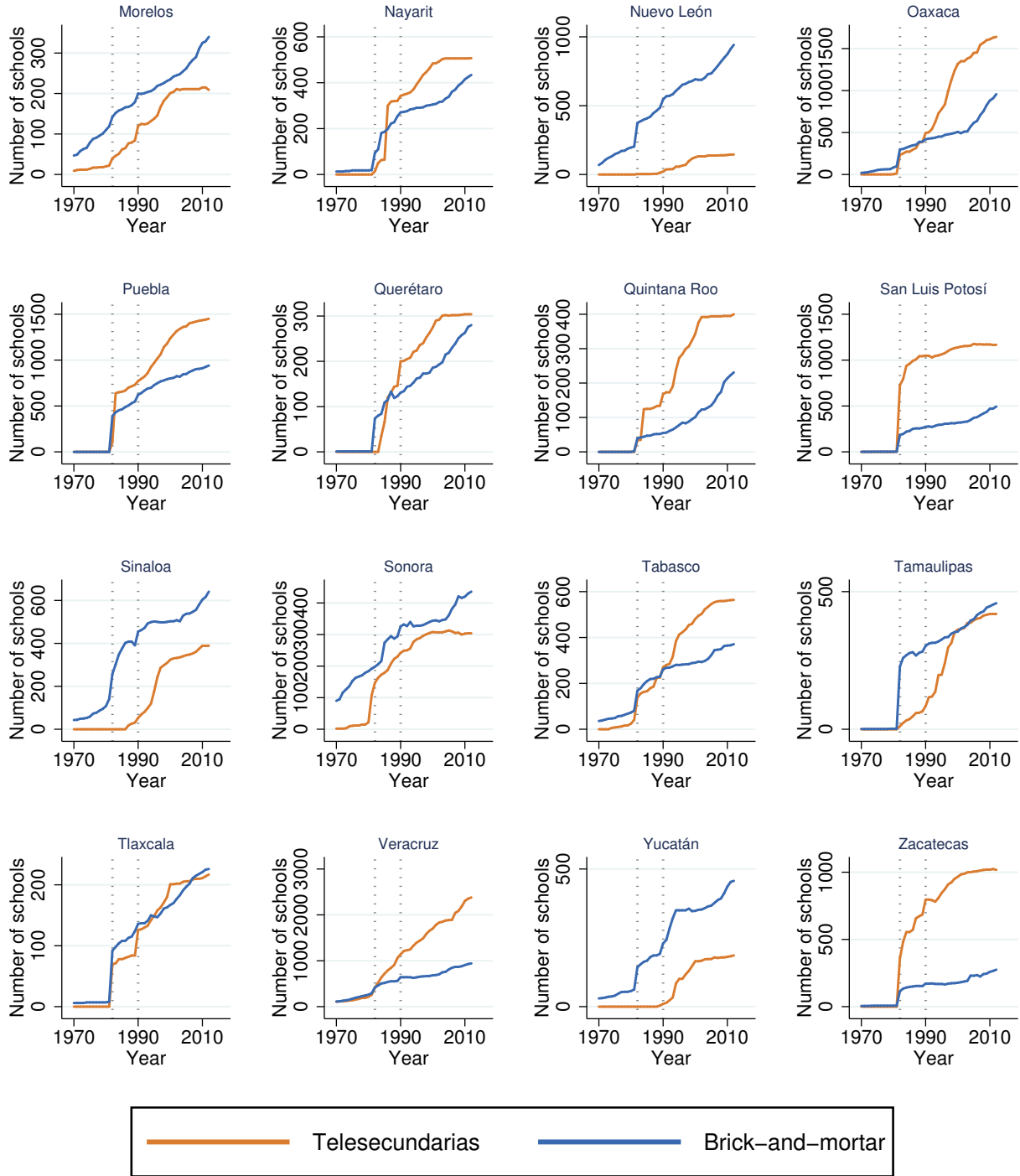


Figure A.3: Final school creation dates (II)



## B Alternative specifications

### B.1 Main results by locality size

Table B.1: Reduced-form Effects of Telesecundaria Construction by Locality Size  
Treatment: Above Median Telesecundaria Density

	Junior Secondary		Higher Education			Labor Supply				Labor Income			
	Enrollment	Graduation	Upper Sec.	Tertiary	Years Educ.	Active	Unemployed	Hours Worked	Wage Earner	Hourly Income			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(log) (8)	(IHS) (9)	(10)	(Pesos) (11)	(log) (12)	(IHS) (13)
<i>Panel A: Rural localities (less than 2,500 habitants)</i>													
Above Median TS Density	0.109*** (0.008)	0.095*** (0.007)	0.010 (0.007)	0.001 (0.002)	0.510*** (0.057)	0.018*** (0.005)	-0.005* (0.003)	0.061*** (0.019)	0.072*** (0.022)	0.011* (0.006)	1.117*** (0.187)	0.080*** (0.017)	0.093*** (0.020)
Dependent Mean	0.53	0.48	0.20	0.05	7.30	0.60	0.04	2.02	2.39	0.42	9.04	1.18	1.44
Observations	355042	355042	355042	355042	355042	355042	212095	355042	355042	355042	355042	355042	355042
<i>Panel B: Rural and low urbanization localities (less than 15,000 habitants)</i>													
Above Median TS Density	0.138*** (0.007)	0.118*** (0.007)	0.007 (0.006)	0.004* (0.002)	0.933*** (0.058)	0.032*** (0.005)	-0.010*** (0.002)	0.126*** (0.018)	0.149*** (0.021)	0.019*** (0.005)	2.362*** (0.182)	0.144*** (0.015)	0.164*** (0.018)
Dependent Mean	0.60	0.54	0.27	0.09	7.98	0.61	0.04	2.08	2.45	0.44	10.50	1.28	1.56
Observations	609232	609232	609232	609232	609232	609232	374230	609232	609232	609232	609232	609232	609232
<i>Panel C: Rural and urban localities (less than 100,000 habitants)</i>													
Above Median TS Density	0.135*** (0.007)	0.118*** (0.007)	0.015*** (0.005)	0.004 (0.002)	0.960*** (0.060)	0.032*** (0.005)	-0.013*** (0.002)	0.135*** (0.017)	0.158*** (0.020)	0.021*** (0.005)	2.655*** (0.193)	0.148*** (0.015)	0.169*** (0.018)
Dependent Mean	0.66	0.60	0.33	0.12	8.62	0.63	0.05	2.12	2.51	0.45	11.88	1.37	1.65
Observations	896274	896274	896274	896274	896274	896274	563401	896274	896274	896274	896274	896274	896274

**Notes:** This table illustrates the reduced-form effects of telesecundaria access on education outcomes (Columns 1-5) and on labor market outcomes (Columns 6-13). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), with the specification:  $Y_{itc} = \alpha + \beta \text{AboveTS}_{itc} + \gamma_l + \lambda_c + \mathbf{X}_{itc}\theta + \varepsilon_{itc}$ . It uses as dependent variable an indicator for enrollment and graduation in lower secondary education (Columns 1-2), for enrollment in upper secondary and tertiary education (Columns 3-4), and total years of education (Column 5). It also uses as dependent variable an indicator for labor market participation (Column 6), unemployment (Column 7) the log and inverse hyperbolic sine transformations of weekly hours worked (Columns 8-9), an indicator for earning a wage (Column 10), and hourly wage in Mexican pesos, and its log and inverse hyperbolic sine transformations (Columns 11-13). See Section 3 for a description of the outcome variables. Above median TS density is an indicator capturing the intensity of telesecundaria exposure, and identifies the locality-cohort observations with above median telesecundaria density. The telesecundaria density,  $TS_{itc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample in *Panel A* includes all individuals living in localities with less than 2,500 habitants, the sample in *Panel B* includes all individuals living in localities with less than 15,000 habitants, and the sample in *Panel C* includes all individuals living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .



## B.2 Density of telesecundarias as alternative treatment

Table B.2: Reduced-form Effects of Telesecundaria Construction by Locality Size  
Treatment: Density of Telesecundarias

	<u>Junior Secondary</u>		<u>Higher Education</u>			<u>Labor Supply</u>				<u>Labor Income</u>			
	<u>Enrollment</u>	<u>Graduation</u>	<u>Upper Sec.</u>	<u>Tertiary</u>	<u>Years Educ.</u>	<u>Active</u>	<u>Unemployed</u>	<u>Hours Worked</u>		<u>Wage Earner</u>	<u>Hourly Income</u>		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(log) (8)	(IHS) (9)	(10)	(Pesos) (11)	(log) (12)	(IHS) (13)
<i>Panel A: Rural Localities (less than 2,500 habitants)</i>													
TS Density (50 ch.)	0.061*** (0.004)	0.053*** (0.004)	0.003 (0.004)	0.001 (0.001)	0.289*** (0.030)	0.010*** (0.003)	-0.003** (0.001)	0.037*** (0.011)	0.044*** (0.013)	0.007** (0.003)	0.623*** (0.102)	0.048*** (0.009)	0.055*** (0.011)
Dependent Mean	0.53	0.48	0.20	0.05	7.30	0.60	0.04	2.02	2.39	0.42	9.04	1.18	1.44
Observations	355042	355042	355042	355042	355042	355042	212095	355042	355042	355042	355042	355042	355042
<i>Panel B: Rural and Low Urbanization Localities (less than 15,000 habitants)</i>													
TS Density (50 ch.)	0.085*** (0.005)	0.072*** (0.005)	0.004 (0.004)	0.003** (0.001)	0.546*** (0.036)	0.024*** (0.003)	-0.007*** (0.001)	0.090*** (0.011)	0.106*** (0.013)	0.015*** (0.003)	1.464*** (0.112)	0.098*** (0.009)	0.112*** (0.011)
Dependent Mean	0.60	0.54	0.27	0.09	7.98	0.61	0.04	2.08	2.45	0.44	10.50	1.28	1.56
Observations	609232	609232	609232	609232	609232	609232	374230	609232	609232	609232	609232	609232	609232
<i>Panel C: Rural and Urban Localities (less than 100,000 habitants)</i>													
TS Density (50 ch.)	0.104*** (0.005)	0.089*** (0.005)	0.012*** (0.004)	0.006*** (0.001)	0.746*** (0.043)	0.032*** (0.003)	-0.010*** (0.001)	0.122*** (0.011)	0.144*** (0.013)	0.019*** (0.003)	2.075*** (0.126)	0.128*** (0.009)	0.147*** (0.011)
Dependent Mean	0.66	0.60	0.33	0.12	8.62	0.63	0.05	2.12	2.51	0.45	11.88	1.37	1.65
Observations	896274	896274	896274	896274	896274	896274	563401	896274	896274	896274	896274	896274	896274

**Notes:** This table illustrates the reduced-form effects of telesecundaria access on education outcomes (Columns 1-5) and on labor market outcomes (Columns 6-13). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), with the specification:  $Y_{itc} = \alpha + \beta TS_{itc} + \gamma_l + \lambda_c + \mathbf{X}_{itc}\theta + \varepsilon_{itc}$ . It uses as dependent variable an indicator for enrollment and graduation in lower secondary education (Columns 1-2), for enrollment in upper secondary and tertiary education (Columns 3-4), and total years of education (Column 5). It also uses as dependent variable an indicator for labor market participation (Column 6), unemployment (Column 7) the log and inverse hyperbolic sine transformations of weekly hours worked (Columns 8-9), an indicator for earning a wage (Column 10), and hourly wage in Mexican pesos, and its log and inverse hyperbolic sine transformations (Columns 11-13). See Section 3 for a description of the outcome variables. The telesecundaria density,  $TS_{itc}$  is defined as the number of telesecundarias open in locality  $l$  when individuals from cohort  $c$  where 12 years-old, scaled by the total population of individuals targeted by the program. See Section 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample in *Panel A* includes all individuals living in localities with less than 2,500 habitants, the sample in *Panel B* includes all individuals living in localities with less than 15,000 habitants, and the sample in *Panel C* includes all individuals living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table B.3: Effects of Telesecundaria Construction by Access to Upper Secondary Education

	(1)	(2)	(3)	(4)
<b>Panel A: Education Outcomes</b>				
	Lower Sec. Enroll.	Upper sec. Enroll.	Tertiary Enroll.	Years of Education
TS Density (50 ch.)	0.079*** (0.006)	-0.011*** (0.004)	-0.001 (0.002)	0.392*** (0.044)
TS Density (50 ch.) $\times$ Upper sec. nearby	0.023* (0.013)	0.058*** (0.008)	0.026*** (0.004)	0.416*** (0.098)
Dependent Mean	0.66	0.33	0.12	8.62
Observations	896207	896207	896207	896207
<b>Panel B: Labor Market Outcomes</b>				
	Active	Unemployed	Hours Worked	Hourly Income
Density TS (num. for 50 child.)	0.010*** (0.004)	-0.004*** (0.002)	0.043*** (0.016)	0.075*** (0.015)
Above avg. TS density $\times$ Upper sec. nearby	0.049*** (0.007)	-0.005* (0.003)	0.208*** (0.030)	0.137*** (0.025)
Dependent Mean	0.63	0.05	2.51	1.65
Observations	896207	563297	896207	896207

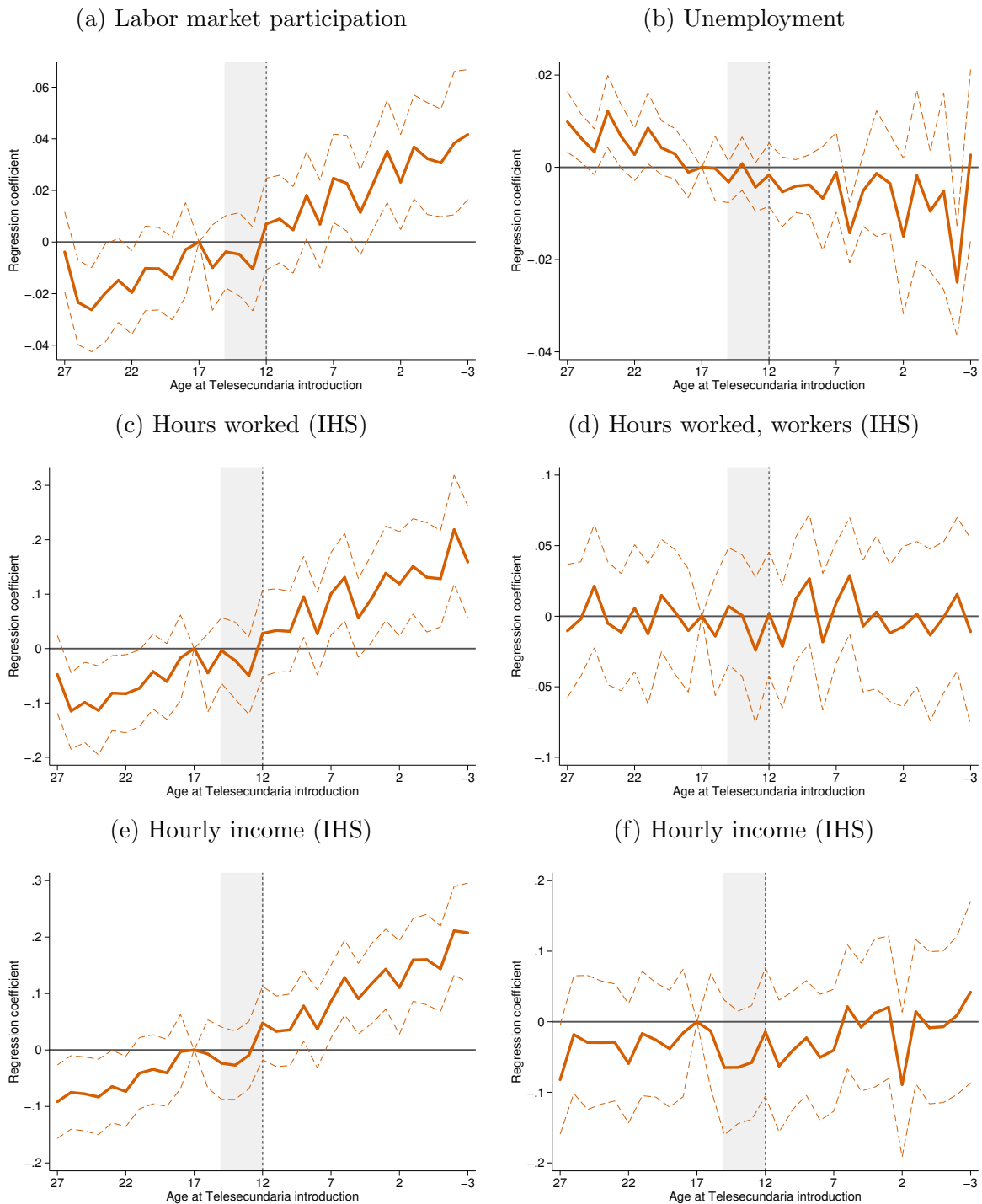
**Notes:** This table illustrates the reduced-form effects of telesecundaria construction by upper secondary school access on education outcomes (Panel A) and labor market outcomes (Panel B). The table reports the estimated coefficient  $\beta$  from the estimation of the two-way fixed-effects difference-in-differences equation (1), all regressors interacted with a binary indicator for whether individuals had access to upper secondary institutions in 10km. See Section 3 for a description of the outcome variables. Above average TS density (50 children) identifies the locality-cohort pairs intensity of telesecundaria exposure, measured by  $TS_{ic}$ , above the sample average. See 4 for details on the treatment variable. All regressions use sampling weights and include cohort and locality fixed effects. The sample includes all individuals living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table B.4: Labor Market Returns to Junior Secondary Education

	<i>All Individuals</i>						<i>Only Workers</i>					
	Income (Pesos)		Income (log)		Income (IHS)		Income (Pesos)		Income (log)		Income (IHS)	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	OLS (5)	2SLS (6)	OLS (7)	2SLS (8)	OLS (9)	2SLS (10)	OLS (11)	2SLS (12)
<b>Panel A. Treatment: Lower Secondary Education Enrollment</b>												
Enrolled in secondary ed.	6.590*** (0.168)	20.014*** (1.157)	0.305*** (0.011)	1.234*** (0.095)	0.341*** (0.013)	1.416*** (0.114)	8.737*** (0.232)	14.873*** (1.498)	0.299*** (0.015)	0.195* (0.109)	0.318*** (0.017)	0.132 (0.133)
First-stage F-stat.		374.49		374.49		374.49		347.96		347.96		347.96
Dependent mean	11.88	11.88	1.37	1.37	1.65	1.65	19.81	19.81	2.28	2.28	2.76	2.76
Observations	896274	896207	896274	896207	896274	896207	537546	537441	537546	537441	537546	537441
Locality FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Cohort FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
<b>Panel B. Treatment: Years of Education</b>												
Years of education	1.152*** (0.025)	2.782*** (0.160)	0.048*** (0.001)	0.172*** (0.014)	0.053*** (0.002)	0.197*** (0.016)	1.492*** (0.034)	2.184*** (0.216)	0.041*** (0.002)	0.029* (0.016)	0.042*** (0.002)	0.019 (0.020)
First-stage F-stat.		309.69		309.69		309.69		299.11		299.11		299.11
Dependent mean	11.88	11.88	1.37	1.37	1.65	1.65	19.81	19.81	2.28	2.28	2.76	2.76
Observations	896274	896207	896274	896207	896274	896207	537546	537441	537546	537441	537546	537441
Locality FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Cohort FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

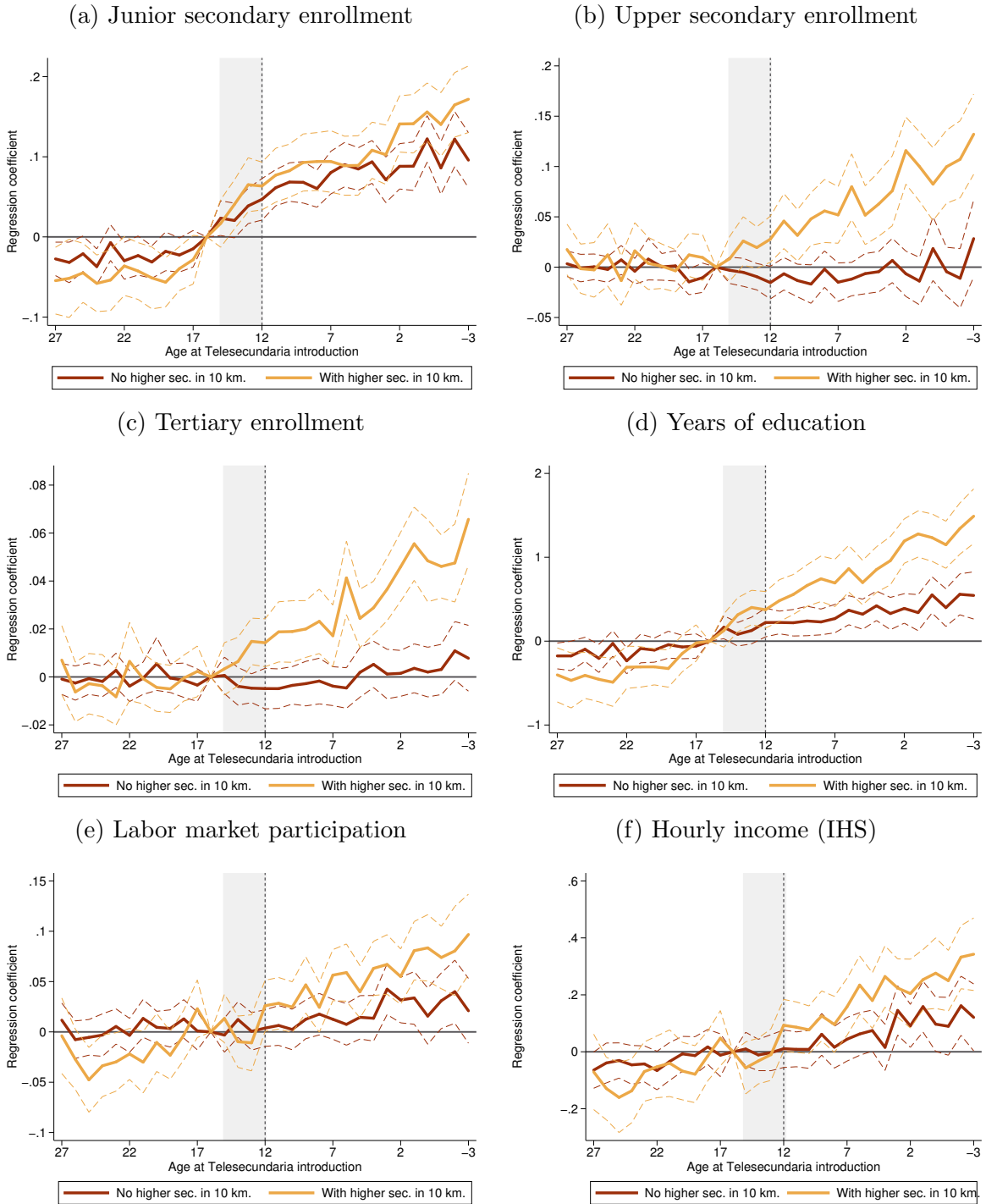
**Notes:** This table illustrates the labor market returns to lower secondary education through telesecundaria enrollment. The table reports the estimated coefficient  $\beta^{LATE}$  from the estimation of the instrumented difference-in-differences equation (2) in even columns, with the specification  $Y_{itc} = \alpha + \beta D_{itc}^S + \gamma_l + \lambda_c + \mathbf{X}_{itc}\theta + \varepsilon_{itc}$ . In odd columns it reports the estimated coefficient  $\beta$  from an Ordinary Least Squares (OLS) regression with the specification:  $Y_{itc} = \alpha + \beta D_{itc}^S + \mathbf{X}_{itc}\theta + \varepsilon_{itc}$ , where the parameters are defined as in equation (2). It uses as dependent variable hourly wage in Mexican pesos, and its log and inverse hyperbolic sine transformations (Columns 6-8). See Section 3 for a description of the outcome variables. The treatment in *Panel A* is an indicator for enrollment in secondary education, and the treatment in *Panel B* is the total years of education. The instrumental variable is *TS density (50 children)*. It captures the intensity of telesecundaria exposure at the locality-cohort level, and is defined as the number of telesecundarias open in locality 1 when individuals from cohort  $c$  were 12 years-old, scaled by the total population of individuals targeted by the program. All regressions use sampling weights and include cohort and locality fixed effects. The sample in Columns 1-6 includes all individuals living in localities with less than 100,000 habitants, and the sample in Columns 7-12 includes only workers living in localities with less than 100,000 habitants. Individual controls include female, age and age<sup>2</sup> and interactions between them. Robust standard errors are shown in parentheses and clustered at the locality level. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Figure B.4: Effects of telesecundaria construction on labor market outcomes



**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for different outcomes, computed by age at the year of telesecundaria construction. The treatment is telesecundaria density per 50 children. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

Figure B.5: Effects of telesecundaria construction on labor market outcomes, by access to upper secondary institutions



**Notes:** This figure presents the reduced-form estimates of the difference-in-differences specification for different outcomes, computed by age at the year of telesecundaria construction. The treatment is telesecundaria density per 50 children. See equation (6) for details. Coefficient estimates are shown with a solid line, and 95% confidence intervals with a dashed line. All effects are computed with respect to age 17, the baseline year.

## C Details on the theoretical framework

This appendix provides the details on the stylized model of schooling choices described in Section 6.1. First, I consider the baseline case where there are only brick-and-mortar schools available. Following Charles et al. (2018), I derive a set of sufficient conditions on the utility functions that guarantee a single equilibrium that is consistent with the empirical patterns. Then, I analyze how the individuals' behavior and the unique thresholds optimally change when a telesecundaria gets constructed and when an upper secondary school becomes available.

**Setup.** Individuals, indexed by  $i = 1, \dots, I$ , have completed primary education and face a set of sequential choices related to their education. First, individuals choose whether to stop studying and enter the labor force or stay at home ( $N$ ) or to attend junior secondary education by enrolling into a brick-and-mortar school ( $B$ ) or into a telesecundaria ( $T$ ). Let  $D_i^S \in \{N, B, T\}$  identify the choice between these three alternatives. In a second stage, individuals that have completed junior secondary education choose whether to pursue further education by attending upper secondary education (1) or whether to stop studying (0),  $D_i^{HS} \in \{0, 1\}$ .<sup>84</sup>

Individuals choose the alternative that maximizes their long-run utility. I assume that the benefit from attending upper secondary school after going through either junior secondary education modality is the same, and that the benefits of all alternatives are homogeneous across all individuals,  $B_i^S = B^S$ , for every  $s \in \{N, T, B, HS\}$ . I additionally assume that attending a brick-and-mortar school has higher benefits than attending a telesecundaria for all individuals. With the benefit of not studying normalized to zero ( $B^N = 0$ ),  $B^B$ ,  $B^T$ , and  $B^{HS}$  are the income premium of attending each type of school compared to just finishing primary education.

The direct cost of attending a brick-and-mortar or an upper secondary institution is the distance to the nearest school, which is constant for all individuals in a given locality  $l$  ( $k_l^m$  for every  $m \in \{B, HS\}$ ). The direct cost of telesecundaria is zero. However, individuals only consider attending a telesecundaria if it is built in the same locality they live in. The indirect cost of post-primary education is a stochastic cost ( $c_i \sim U[0, 1]$ ) and reflects the individual opportunity cost of enrolling in school.

Individuals optimally choose the schooling path that provides the highest long-run utility:

$$D_i(c_i) = (D_i^S(c_i), D_i^{HS}(c_i)) = \begin{cases} \arg \max_{s \in \{N, B, T\}, h \in \{0, 1\}} U_i^s(k_l^B, k_l^{HS}, c_i) & \text{if } TS \text{ in locality} \\ \arg \max_{s \in \{N, B\}, h \in \{0, 1\}} U_i^s(k_l^B, k_l^{HS}, c_i) & \text{otherwise} \end{cases}$$

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<sup>84</sup>I do not explicitly model the choice between upper secondary education modalities, or the choice for higher educational levels, combining them in the  $D_i^{HS}$  decision.

where

$$\begin{aligned}
U_i^B(k_l^B, k_l^{HS}, c_i, h = 0) &= B^B - k_l^B - \eta c_i \\
U_i^B(k_l^B, k_l^{HS}, c_i, h = 1) &= B^B - k_l^B - \eta c_i + \rho \cdot (B^{HS} - k_l^{HS}) \\
U_i^T(k_l^B, k_l^{HS}, c_i, h = 0) &= B^T - c_i \\
U_i^T(k_l^B, k_l^{HS}, c_i, h = 1) &= B^T - c_i + \rho \cdot (B^{HS} - k_l^{HS}) \\
U_i^N(k_l^B, k_l^{HS}, c_i, h) &= 0
\end{aligned}$$

with  $\eta > 1$  capturing the fact that the opportunity cost for attending brick-and-mortar secondary schools is higher than for attending telesecundarias, and  $\rho$  the probability of enrolling in upper secondary education, which is assumed to be the same whether individuals graduate from telesecundarias or brick-and-mortar schools.

**No access to telesecundaria.** I first consider the baseline case where individuals only have access to brick-and-mortar schools. The two sufficient conditions on the utility functions that guarantee a single equilibrium consistent with the empirical patterns are:

1.  $U_i^B(c_i = 0) > 0$
2.  $U_i^B(c_i = 1) < 0$

This single-crossing condition between  $U_i^B$  and  $U_i^N$  is sufficient to obtain a unique threshold of opportunity cost identifying the individual indifferent between attending a brick-and-mortar school or not studying,  $c_{SN}^o$ , where

$$c_{SN}^o = \begin{cases} \frac{B^B - k_l^B}{\eta} & \text{if } h = 0 \\ \frac{B^B - k_l^B + \rho(B^{HS} - k_l^{HS})}{\eta} & \text{if } h = 1 \end{cases} \quad (12)$$

$c_{SN}^o$  separates individuals into two groups — individuals with  $c_i < c_{SN}^o$  will choose to attend brick-and-mortar schools, whereas those with  $c_i > c_{SN}^o$  will not enroll in secondary education. With no telesecundarias in the locality, no individual finds optimal to enroll in one of them. Figure 9a shows a stylized example displaying the threshold  $c_{SN}^o$ .

**Construction of telesecundarias.** The two sufficient conditions needed to obtain two unique thresholds of opportunity costs ( $c_{BT}^*$ ,  $c_{SN}^*$ ) after the construction of telesecundarias are (1) single-crossing conditions between  $U_i^N$  and  $U_i^T$  and between  $U_i^N$  and  $U_i^B$ , and (2)  $U_i^B$  and  $U_i^T$  crossing only once in the positive utility area. Specifically,

1.  $U_i^B(c_i = 0) > U_i^T(c_i = 0) > 0$

$$2. U_i^T(c_i = 1) < U_i^T(c_i = 1) < 0$$

If these two conditions are satisfied, the equilibrium parameters are:

$$c_{SN}^* = \begin{cases} B^T & \text{if } h = 0 \\ B^T + \rho(B^{HS} - k_l^{HS}) & \text{if } h = 1 \end{cases} \quad (13)$$

$$c_{BT}^* = \frac{B^B - B^T + k_l^B}{\eta - 1} \quad (14)$$

Figure 9a shows a stylized example with the utility functions satisfying these two conditions. Among children enrolled in junior secondary education, those with  $c_i \in [c_{BT}^*, c_{SN}^*]$  will choose to attend telesecundarias, whereas those with  $c_i < c_{BT}^*$  will choose to attend brick-and-mortar schools. I assume that individuals at the thresholds will choose to attend telesecundarias without loss of generality, since tiebreaking happens with probability zero. Shifts in  $c_{SN}^*$  reflect changes in the extensive margin of secondary education enrollment, whereas shifts in  $c_{BT}^*$  reflect changes in the trade-off between junior secondary school modalities.

Let  $A^T$  be a parameter measuring the availability of telesecundarias in a locality ( $A^T \in \{0, 1\}$ ). Following other literature investigating returns to education in partial equilibrium settings, I assume there are no general equilibrium effects or externalities. This assumes that the benefits of attending  $T, B, HS$  do not change when a telesecundaria is constructed, i.e.,  $B^m[A^T = 0] = B^m[A^T = 1]$ , for  $m \in \{T, B, HS\}$ . The construction of a telesecundaria improves access to secondary education, resulting in an increase of the binding opportunity cost between working and attending junior secondary school,  $c_{SN}^* > c_{SN}^o$ . This results in an increase in the share of individuals enrolled in junior secondary education, and a decrease of children out of school. Individuals enrolling in junior secondary education with a relatively high opportunity cost ( $c_i \in [c_{BT}^*, c_{SN}^*]$ ), will choose to attend the telesecundaria, whereas those with lower stochastic costs ( $c_i < c_{BT}^*$ ) will choose to attend a brick-and-mortar school.<sup>85</sup>

**Availability of upper secondary education.** This framework accounts for the fact that the benefits and costs of attending higher education directly influence the decision of attending junior secondary education. In particular, they only affect the extensive margin of enrolling in junior secondary education or working,  $c_{SN}^*$ , but do not affect the trade-off between telesecundarias or brick-and-mortar schools ( $c_{BT}^*$ ). Figure 9b graphically shows that a decrease in the distance to the nearest upper secondary institution shifts  $U_i^B$  and  $U_i^T$  by the same amount. Hence, the construction of an upper secondary school nearby results in an overall increase of individuals enrolled in junior secondary education, but does not shift the proportion of individuals attending a brick-and-mortar school. This last result implies

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<sup>85</sup>Note that the model assumes that the benefits of telesecundarias are constant between these two groups of compliers, since the only difference explicitly modeled are differences in opportunity costs.



that easy access to upper secondary institutions may increase the enrollment rate in *junior* secondary education, keeping everything else constant.

## D Proof: Dynamic treatment effects decomposition

Following arguments from Kirkeboen et al. (2016), Kline and Walters (2016), Hull (2018) and Mountjoy (2018), this appendix shows the decomposition of the LATE into direct and continuation effects from section 6.4 using a binary instrument. To simplify the notation, I decompose the Wald estimator using a binary instrument that satisfies the exclusion and independence assumptions:

$$\beta = \frac{E[Y|Z = 1] - E[Y|Z = 0]}{E[D^T|Z = 1] - E[D^T|Z = 0]} \quad (15)$$

The steps of the decomposition still apply to the IV-DiD setting.

Let  $S \in \{0, 1, 2\}$  identify the three terminal choices of schooling from the theoretical framework, observed in the data: Primary education, 0, junior secondary education, 1, and upper secondary education, 2. Let  $D_s$  be an indicator variable for the level of schooling attained, i.e.,  $D_s = 1$  if  $S = s$ , and zero otherwise. Let  $Y_Z^S = Y(S, Z)$  identify the potential outcome if  $S = s$  and  $Z = z$ .

By the instrument exclusion assumption, ( $Y_s^z = Y_s$  for all  $s \in \{0, 1, 2\}$ ), the observed outcome  $Y$  can be decomposed in three potential outcomes:

$$Y = Y_0D_0 + Y_1D_1 + Y_2D_2$$

Then, the first component of the numerator from the Wald estimator can be decomposed in:

$$\begin{aligned} E[Y|Z = 1] &= E[Y_0D_0|Z = 1] + E[Y_1D_1|Z = 1] + E[Y_2D_2|Z = 1] \\ &= E[Y_0|D_0 = 1, Z = 1] + E[Y_1|D_1 = 1, Z = 1] + E[Y_2|D_2 = 1, Z = 1] \end{aligned}$$

Let  $S(Z)$  identify the potential terminal choice of schooling depending on the instrument status. By the independence assumption,

$$= E[Y_0|S(1) = 0]Pr(S(1) = 0) + E[Y_1|S(1) = 1]Pr(S(1) = 1) + E[Y_2|S(1) = 2]Pr(S(1) = 2)$$

Based on individuals' choices depending on the instrument status, we have nine groups of individuals. The monotonicity assumption ( $Pr(D_0(0) \geq D_0(1)) = 1$ ,  $Pr(D_1(0) \leq D_1(1)) = 1$ ,  $Pr(D_2(0) \leq D_2(1)) = 1$ ) eliminates the defiers ( $\{S(0) = 2, S(1) = 1\}$ ,  $\{S(0) = 2, S(1) =$

0} and  $\{S(0) = 1, S(1) = 0\}$ ). The no upper-switchers assumption ( $Pr(S(0) = 1, S(1) = 2) = 0$ ) rules out  $\{S(0) = 1, S(1) = 2\}$ . Then, we have five remaining groups of individuals based on their choices:  $\{S(0) = 0, S(1) = 1\}$ ,  $\{S(0) = 0, S(1) = 2\}$ ,  $\{S(0) = 0, S(1) = 0\}$ ,  $\{S(0) = 1, S(1) = 1\}$  and  $\{S(0) = 2, S(1) = 2\}$ .

Using these groups, we can further decompose the formula as:

$$\begin{aligned}
E[Y|Z = 1] &= E[Y_0|S(0) = 0, S(1) = 0]Pr(S(0) = 0, S(1) = 0) \\
&\quad + E[Y_1|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&\quad + E[Y_1|S(0) = 1, S(1) = 1]Pr(S(0) = 1, S(1) = 1) \\
&\quad + E[Y_2|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&\quad + E[Y_2|S(0) = 2, S(1) = 2]Pr(S(0) = 2, S(1) = 2)
\end{aligned}$$

Following analogous arguments, we can decompose the other part of the numerator as:

$$\begin{aligned}
E[Y|Z = 0] &= E[Y_0|S(0) = 0, S(1) = 0]Pr(S(0) = 0, S(1) = 0) \\
&\quad + E[Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&\quad + E[Y_1|S(0) = 1, S(1) = 1]Pr(S(0) = 1, S(1) = 1) \\
&\quad + E[Y_0|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&\quad + E[Y_2|S(0) = 2, S(1) = 2]Pr(S(0) = 2, S(1) = 2)
\end{aligned}$$

Then,

$$\begin{aligned}
E[Y|Z = 1] - E[Y|Z = 0] &= E[Y_1|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&\quad - E[Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&\quad + E[Y_2|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&\quad - E[Y_0|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2)
\end{aligned}$$

Adding and subtracting  $E[Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2)$ ,

$$\begin{aligned}
&= E[Y_1|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&- E[Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&+ E[Y_2|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&- E[Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&+ E[Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&- E[Y_0|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&= E[Y_1 - Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&+ E[Y_1 - Y_0|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&+ E[Y_2 - Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2)
\end{aligned}$$

Hence, the numerator can be decomposed as:

$$\begin{aligned}
E[Y|Z = 1] - E[Y|Z = 0] &= E[Y_1 - Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) = 1) \\
&+ E[Y_1 - Y_0|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&+ E[Y_2 - Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2) \\
&= E[Y_1 - Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) \geq 1) \\
&+ E[Y_2 - Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2)
\end{aligned}$$

Recall that  $D^S$  is a binary indicator for whether the individual enrolled in secondary education. Then,  $D^S = D_1 + D_2$ . Transforming the denominator using the same arguments as above,

$$\begin{aligned}
E[D^S|Z^T = 1] &= E[D_1|Z = 1] + E[D_2|Z = 1] \\
&= Pr(D_1 = 1, Z = 1) + Pr(D_2 = 1, Z = 1) \\
&= Pr(S(1) = 1) + Pr(S(1) = 2) \\
&= Pr(S(0) = 0, S(1) = 1) + Pr(S(0) = 1, S(1) = 1) \\
&\quad + Pr(S(0) = 0, S(1) = 2) + Pr(S(0) = 1, S(1) = 2) + Pr(S(0) = 2, S(1) = 2) \\
E[D^S|Z^T = 0] &= E[D_1|Z = 0] + E[D_2|Z = 0] \\
&= Pr(D_1 = 1, Z = 0) + Pr(D_2 = 1, Z = 0) \\
&= Pr(S(0) = 1) + Pr(S(0) = 2) \\
&= Pr(S(0) = 1, S(1) = 1) + Pr(S(0) = 1, S(1) = 2) + Pr(S(0) = 2, S(1) = 2)
\end{aligned}$$

Then,

$$\begin{aligned} E[D^S|Z^T = 1] - E[D^S|Z^T = 0] &= Pr(S(0) = 0, S(1) = 1) + Pr(S(0) = 0, S(1) = 2) \\ &= Pr(S(0) = 0, S(1) \geq 1) \end{aligned}$$

The Wald estimator becomes

$$\begin{aligned} \beta &= \frac{E[Y|Z = 1] - E[Y|Z = 0]}{E[D^S|Z = 1] - E[D^S|Z = 0]} \\ &= \frac{E[Y_1 - Y_0|S(0) = 0, S(1) = 1]Pr(S(0) = 0, S(1) \geq 1)}{Pr(S(0) = 0, S(1) \geq 1)} \\ &\quad + \frac{E[Y_2 - Y_1|S(0) = 0, S(1) = 2]Pr(S(0) = 0, S(1) = 2)}{Pr(S(0) = 0, S(1) \geq 1)} \\ &= E[Y_1 - Y_0|S(0) = 0, S(1) = 1] + E[Y_2 - Y_1|S(0) = 0, S(1) = 2] \underbrace{\frac{Pr(S(0) = 0, S(1) = 2)}{Pr(S(0) = 0, S(1) \geq 1)}}_{\mu} \\ &= E[Y_1 - Y_0|S(0) = 0, S(1) = 1] + \mu E[Y_2 - Y_1|S(0) = 0, S(1) = 2] \\ &= DE + \mu CONT \quad \square \end{aligned}$$