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Abstract

Across the world educated women tend to have fewer children than their less-educated peers. This paper provides new stylised facts about the long-run relationship between women's education and fertility at both the national and individual levels. I focus on Colombia, a country that experienced both a rapid fertility decline and fast expansion of education in the mid-20th century and I use data from the censuses of 1973, 1985, 1993, 2005 and 2018. The findings caution that the relationship between fertility and women's education is not always monotonic and this relationship changes significantly depending on the aggregation of the data. At the individual level, the relationship between education and fertility holds strongly and education increases the probability of remaining childless, reduces the total number of children and the likelihood of having a birth at a younger and older age, suggesting a strong trade-off between education and fertility. Peer effects, such as the percentage of peers with secondary education, are ruled out, which suggests that the externalities of education had a moderate effect on uneducated women. On the other hand, at the national level, the fertility decline cannot be explained by education as fertility has fallen continuously in all educational groups since 1965.

Keywords: fertility, education, Colombia, census data
JEL Classification: J11, J13, I25, N36, O35

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Explorando la relación entre la educación femenina y la disminución de la fecundidad: Una mirada desde Colombia

Juliana Jaramillo-Echeverri*†

Resumen

En el mundo, las mujeres más educadas tienden a tener menos hijos que las menos educadas. Este documento presenta nuevos hechos estilizados sobre la relación a largo plazo entre la educación de las mujeres y la fecundidad, tanto a nivel nacional como individual. El documento se enfoca en Colombia, un país que experimentó una rápida caída en la fecundidad así como una rápida expansión de la educación a mediados del siglo XX. Con los datos de los censos de 1973, 1985, 1993, 2005 y 2018, los resultados advierten que la relación entre la fecundidad y la educación de las mujeres no siempre es estable y por el contrario cambia dependiendo de la agregación de los datos. A nivel individual, la educación aumenta la probabilidad de permanecer sin hijos, reduce el número total de hijos y disminuye la probabilidad de tener un hijo a una edad temprana, lo que sugiere un fuerte *tradeoff* entre educación y fecundidad. Se descartan los efectos de los pares, como el que puede tener el porcentaje de mujeres con educación secundaria, lo que sugiere que las externalidades de la educación tuvieron un efecto moderado en las mujeres no educadas. Por otro lado, a nivel nacional, el declive en la fecundidad no puede explicarse únicamente por el aumento en la educación, ya que la misma ha disminuido continuamente en todos los grupos educativos desde 1965.

Palabras clave: fecundidad, educación, Colombia, datos censales
Clasificación JEL: J11, J13, I25, N36, O35

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1 Introduction

Across the world, educated women tend to have fewer children than their less-educated peers. As the literature has shown, women face a particular trade-off between caring and working (Liu & Raftery, 2020; Frye & Lopus, 2018; Jejeebhoy, 1995; Becker & Lewis, 1973). Increases in female education can then lead to increases in the opportunity costs of having children, as women have to choose between childbearing and rearing (care) and enrolling in education and the labour force (work). Additionally, women's education can translate into lower infant and child mortality rates and this can be associated with fewer total births (Kravdal, 2002; Baudin, De La Croix, & Gobbi, 2015). At the same time, women's education can speed up cultural change, create new cultures and values, and raise the economic aspirations of the population, which in turn can affect fertility rates at the macro level (Caldwell, 1980; Axinn & Barber, 2001). Nonetheless, the empirical evidence testing these mechanisms is limited given that other variables, such as wealth or family preferences, are strongly related both to schooling and fertility, which creates confounding bias. Even more challenging, the simultaneity in the decision-making between childbearing and schooling most of the time limits the causal interpretation of the relationship (Behrman, 2015). Also, the effects of women's education on fertility can change depending on how fertility is defined and the level of aggregation studied, which constrains inter-temporal comparisons. For example, some studies focus on the number of children a woman has (intensive margin) while others analyse the probability of ever having a child (extensive margin). While education almost certainly reduces the number of children a woman has, in some cases, it can also increase the probability of childbearing (De La Croix, Schneider, & Weisdorf, 2019; Aaronson, Lange, & Mazumder, 2014; DeCicca & Krashinsky, 2023).

This paper provides new stylised facts about the long-run relationship between women's education and fertility in Colombia at several levels of aggregation and along the two margins of fertility. I use individual-level data from a 10% sample of the censuses of 1973, 1985, 1993 and 2005 from the Integrated Public Use Microdata Series – IPUMS International (Minnesota Population Center, 2019) and the full count census of 2018.

The case of Colombia is of relevance because during the mid-20th century female education grew rapidly while fertility declined faster than in almost any other country in the world (Flórez-Nieto, 2000; Ramírez-Giraldo & Téllez-Corredor, 2006), although this pattern of rapid fertility decline with an expansion of education also emerged in other Latin American countries. The changes were preceded by a set of liberal reforms in the 1930s, that placed improvements in education as one of the main priorities. These reforms aimed at promoting gender equality by making access to education equal for girls and boys and represented a break with the Catholic traditional views, which dominated the educational system since the late 19th century and limited the participation of women in the labour market (López-Uribe, Quintero, & Gaitán-Guerrero, 2011). Recent research shows however that the reforms did not increase substantially the number of women enrolled in education and that it was only until the 1950s that educational levels started to increase significantly (Iregui-Bohórquez, Melo-Becerra, Ramírez-Giraldo, & Tribín-Uribe, 2020). Furthermore, universal education, both for females and males, has not been achieved today and coverage rates in primary education are above 90% while in secondary education are close to 65%. As for the decline in fertility, the onset coincides with the increase in knowledge, availability, and use of contraceptive methods. Likewise, the decline began just a decade after the introduction of female suffrage. In 2021, the total fertility rate was around 1.7 although in some regions of the country, it was closer to 1.

To observe how fertility and education have been related in the long run at the national level, I estimate the Total Fertility Rate (TFR) by educational level from 1958 to 2017 implementing the Own Child Method (OCM). In 1960 women with no education had on average 7.8 children while women with secondary education had 4.6. Soon after, fertility declined very fast until the mid-1970s and then slowed down. From 1978 to 2003 fertility declined by less than 1 child in all educational groups. I document persistent fertility differentials by education until the early 2000s. However, by 2015, the gap between educational groups was smaller than one child. According to the estimations, in 2015 women with completed primary education had on average 2.4 children while women with secondary education or more had 1.7 children. This means that fertility rates by educational groups are slowly converging over time.

Then I turn my attention to the intensive and extensive margin by studying the fertility outcomes of women with completed fertility (that are between 50 and 60 years) in the 5 censuses. The results show, as in the case of the TFR, a clear educational gradient, especially for women born after 1930. However, the number of children born decreased across all educational groups, and the decline was less pronounced for women with no education. Once again, the results confirm that the fertility gap between uneducated and educated women persisted over time, despite fertility falling across all groups. I find that fewer married women stayed childless over time across all educational groups, which could indicate a generalised increase in living standards, perhaps related to better nutrition over time. Similar to the US case, during the fertility transition women were having fewer children but at the same time, fewer women remained childless in all educational groups. A different pattern emerges for single women. The levels and trend of childlessness were more or less constant for women born before 1935 who remained single. After that, childlessness decreases steadily. It is noticeable that the fertility differentials by education are more pronounced for single women than for married women. Around 90% of single women with secondary education remained childless while 50% of single women with no education were mothers. This characterisation of the fertility transition differs considerably from the European case, as it reveals high levels of illegitimacy for uneducated women (Coale & Watkins, 1986; Guinnane, Okun, & Trussell, 1994).

Finally, I study the relationship between schooling and fertility at the individual level, analysing both margins of fertility and the use of birth control strategies (starting, spacing and stopping) during the onset of the transition. Given that education can potentially create spillovers from educated to uneducated women, I take into account individual as well as peer effects on fertility. The results show that schooling increases the probability of remaining childless (up to 200%), reduces the total number of children (by around 2 children), decreases the likelihood of having a birth at a younger age (up to 71%) and reduces the probability of childbearing at ages older than 40 (by 50%). In all cohorts and in both margins the effect of secondary schooling is stronger than the effect of primary schooling. What is more surprising, the effects are quantitatively similar across most cohorts of women suggesting that the direct effect of education on fertility changes little over time.

Community variables, such as the percentage of peers with secondary education, mostly have a limited effect on the different measures of fertility, including the use of strategies to limit fertility. This means that the externalities of education had a moderate effect on uneducated women. Nonetheless, the relationship started changing for the 1960s cohort, as the individual effect of education became smaller and peer effects became larger, suggesting that the general increase in female education transformed broadly social norms.

Taken together the findings caution that the relationship between fertility and women's education is not always monotonic and, the relationship changes significantly depending on the unit of analysis. At the national level, the fertility decline in Colombia cannot be explained through changes in education. However, at the individual level, the results indicate that access to secondary education was key for fertility outcomes, even before the fertility transition.

The results of this research contribute to several strands of the literature. First, they show that although Colombia passed through the demographic transition, the large fertility differentials between educated and non-educated women changed little during the first years of the transition. Although Potter, Ordoñez, and Measham (1976) showed this for 1973 and Batyra (2020) for 2005, my results provide a long-run view of this relationship using consistent measures of fertility that allow for inter-temporal comparison. The results indicate that women who did not benefit from the education expansion ended up having more children and that fertility outcomes of less-educated women did not match those of their more-educated counterparts.

Second, the Colombian case reveals that the fertility decline happened independently from educational expansion at the national level. The puzzle regarding why fertility changed so fast remains an unsolved question as previous research has cast doubt on the role of contraception (see for example Miller (2010)). Perhaps the decline indicates a rapid transformation in social norms, as fertility levels almost converged by 2015. However, at the individual level, the absence of peer effects also allows us to rule out the diffusion hypothesis from educated to non-educated women at the municipal level during the first decades of the transition. Similarly, the results suggest a moderate importance of other economic transformations, as most of this happens at the municipal level. Nonetheless, it would be crucial for future research to explore fertility preferences instead of completed fertility as some studies find relative convergence in the number of children wanted between 1970 and 1980 (Bongaarts, Mauldin, & Phillips, 1990; Martin & Juarez, 1995). Then, the fertility gap across educational groups could be explained by variations in unwanted fertility rather than by variations in fertility preferences.

Third, the results of the extensive margin in single women deserve attention. For this group of women, the educational gradient is clear and stable during most of the period studied. Although the causes of this pattern are not explored in this paper, it is clear that single women without education and with children represent one of the most vulnerable population groups, as uneducated single mothers generally have less earning power and their children are likely to have worse socioeconomic outcomes (Bernal & Keane, 2011; Esteve, García-Román, & Lesthaeghe, 2012). Understanding why the educational gradient exists for single women and not for married women is crucial to disentangling the mechanisms through which education affects fertility.

The rest of the paper is organised as follows. Section 2 presents evidence of the relationship between female education and fertility in the Latin American context and introduces Colombia as a case study. Section 3 outlines the potential interconnections between education and fertility. Section 4 provides an overview of the data and Section 5 delves into the long-term relationship between fertility and education, considering various levels of aggregation and margins of fertility. Finally, Section 6 offers concluding remarks and proposes future research directions.

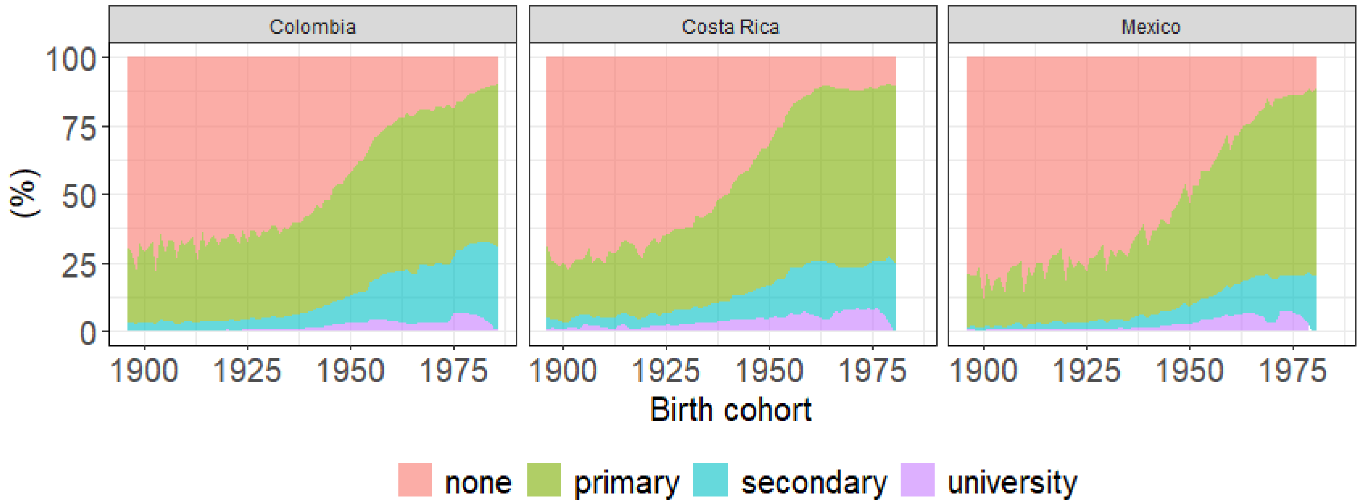
2 Education and Fertility in Colombia

Latin American countries offer a compelling context for exploring the relationship between women's education and fertility. As shown in Fig. 1 and Fig. 2, the rapid expansion of education coincided with declines in fertility rates in Colombia, Costa Rica, and Mexico, while other countries such as Brazil, Dominican Republic, Ecuador, and Trinidad and Tobago, followed similar trajectories. Across the region, educational attainment surged in the latter half of the 20th century, paralleled by declining fertility rates in the 1960s and 1970s.

Numerous studies have examined this relationship in Latin America, particularly in the decades following the fertility decline (Martin & Juarez, 1995; Weinberger, 1987; Heaton & Forste, 1998; Rios-Neto, Miranda-Ribeiro, & Miranda-Ribeiro, 2018). Research reveals significant fertility differences between educated and non-educated women during the 1970s, primarily attributed to varying access to contraception (Bongaarts et al., 1990). For example, Martin and Juarez (1995) found homogeneous desired family sizes across educational levels in nine Latin American countries during the 1980s, despite educated women ultimately having four fewer children compared to their less educated counterparts. Additionally, researchers noted a narrowing of fertility disparities across educational groups from the 1980s onward. However, the long-term fertility differentials across education levels remain relatively underexplored, with some notable exceptions, such as Esteve, Castro-Torres, and Becca (2023) although their focus primarily centres on family formation.[1]

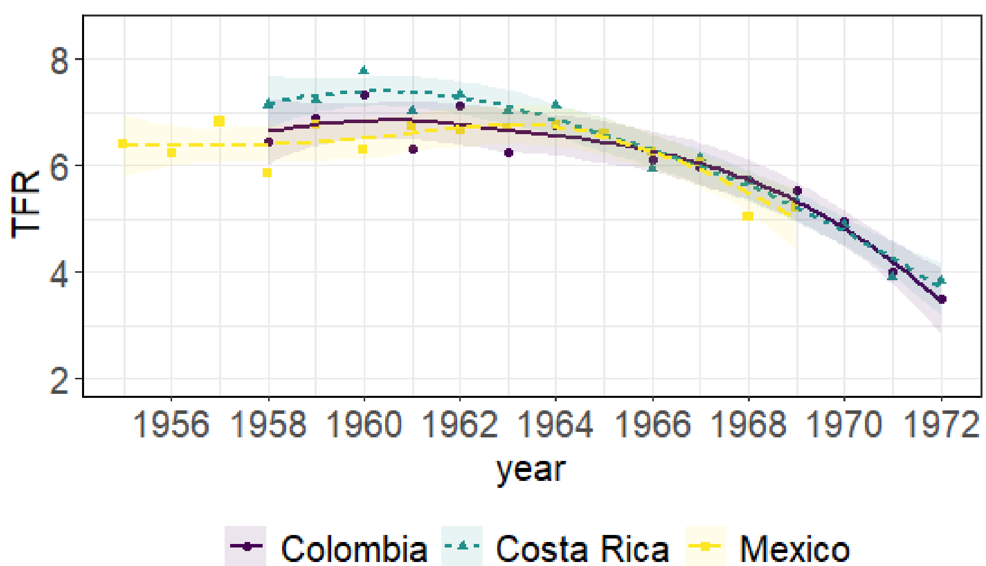
[1]See also Bongaarts, Mensch, and Blanc (2017) for an analysis of education's impact on first sexual intercourse, first marriage, and first birth in 43 countries, including eight Latin American countries.

Figure 1: Women's education by cohort, 1895-1985



Notes: The graph shows the proportion of women older than 18 years in each educational category by the year of birth. Sources: Authors' calculations based on census samples from IPUMS-International (Minnesota Population Center, 2019). The years of the censuses are 1973, 1985, 1993 and 2005 for Colombia, 1970, 1990 and 2000 for Mexico, and 1973, 1984 and 2000 for Costa Rica.

Figure 2: Total fertility rate, 1950-1972



Note: Calculations are made following the Own Child Method. Sources: Authors' calculations based on census samples from IPUMS-International (Minnesota Population Center, 2019), Mortality tables from the Human Life-Table Database from 1970, and data from Colombia from the complete census 1973, National Agency of Statistics (DANE). The years of the censuses are 1970 for Mexico, and 1973 for Costa Rica. I released the implementation of the OCM to construct these fertility rates under an open-source license (`https://github.com/jje90/ASFR_TFR`).

In Colombia, the liberal governments of the 1930s reformed the educational system, expanding the right to access education and promoting universal education.[2] However, these reforms did not alter the number of students enrolled in education and during the first 50 years of the 20th century, the enrolment in primary schooling slowly increased while the students in secondary schooling saw almost no change. But in the second half of the century, the expansion of education finally started and between 1950 and 1970 the century witnessed the sharpest expansion in the number of students at all levels, especially in primary schooling. The sustained enlargement in education after the mid-1950s in Colombia was a result of the plebiscite of 1957 as well as the result of the greater fiscal capacity from economic growth after several coffee booms (Ramírez-Giraldo & Téllez-Corredor, 2006).

By 1970, the proportion of women in education was 49% of the total (Ramírez-Giraldo & Téllez-Corredor, 2006). Nevertheless, women still lagged behind men, especially at the university level. In 1965, females represented no more than 20% of total university enrolment (Iregui-Bohórquez et al., 2020). Access to education continues to be an important issue in Colombia and universal education has not been achieved. Coverage rates in primary education are above 90% and in secondary education are close to 65% (Table 1).

The changes in educational attainment shown in Fig. 1 also reflect the evolving significance and status associated with specific levels of education. Prior to the mid-1940s, when over 50% of women lacked formal education, obtaining primary or secondary education likely signalled wealth or high social status. However, as educational opportunities broadened and more women attained at least a primary education, the link between high social status and primary education began to diminish. Likewise, with the increasing number of women completing secondary education after the 1970s, a parallel trend emerged.

As for fertility, the decline from the 1960s to the 1980s has been extensively studied (Prada & Ojeda, 1987; Prada-Salas, 1996; Batyra, 2016; Flórez-Nieto, 2000). Surveys conducted during this period revealed that the fall began around 1964 and slowed by 1985 (López Toro, 1968; Flórez-Nieto, 2000). Women living in rural and urban areas saw a decrease in fertility rates, narrowing the gap between them from 4 live births in 1969 to 2 live births in 1986. Similarly, most regions in the country experienced a reduction in fertility more or less at the same time and fertility levels halved in less than 25 years (Jaramillo-Echeverri, 2023b).

[2] See Fuentes-Vásquez (2021) for a history of education in the first half of the 20th century and Ramirez-Zuluaga (2016) for the second half of the 20th century. See also Helg (2001).

Although it is challenging to identify one single cause of the fertility decline, the simultaneity of the reduction suggests that rapid changes in social norms could have been fundamental. For example, the decline coincided with the foundation of one of the largest family planning organisations in the world, Profamilia, and the spread and popularisation of modern contraceptive methods (Miller, 2010; Jaramillo-Echeverri, 2023a). Also, during this period, the government established an official population policy aimed at reducing population growth (Ott, 1977), and supported different initiatives to promote the use of family planning. Additionally, as we will see in the next section, educational expansion can affect fertility outcomes through several mechanisms.

3 Potential mechanisms

The negative relationship between fertility and education is well-documented in the literature (Castro Martin, 1995; Caldwell, 1980; Weinberger, 1987).[3] At the cross-country level, more educated countries have lower fertility rates, and at the national level, more educated women tend to have fewer children. Although women's education is considered a crucial factor in the fertility decline reducing the number of births (intensive margin), in some contexts, education can also increase the probability of childbearing (extensive margin) and therefore it is key to study both the intensive as well as the extensive margin of fertility.

Additionally, education can affect fertility at the individual and at the community level. Individual-level education can affect the demand and supply of children as it has the potential to change attitudes towards childbearing (Caldwell, 1980), reduce the economic utility of children (Galor & Weil, 2000; Becker & Lewis, 1973), increase the opportunity cost of women (Becker, 1960) and change their relative autonomy within the family (Jejeebhoy, 1995). Similarly, female education also affects fertility decisions indirectly. As Frye and Lopus (2018) highlight, the social meaning of a woman's educational attainment depends on the educational attainments of her peers which could be of particular importance during a time of women's educational expansion. In this section, I review some channels through which female education can affect fertility decisions.

[3]For the case of Colombia see Heaton and Forste (1998), Potter and Ordoñez (1976) and Batyra (2016). However, see the recent contribution from Doepke, Hannusch, Kindermann, and Tertilt (2022) that argues that this regularity held in the past while it no longer holds universally today. Mainly because in high-income countries this relationship has flattened or even reversed.

3.1 The intensive and extensive margins of fertility

Most research on fertility focuses on the intensive margin, that is the number of children a woman has, however, some attention has been placed on the extensive margin, which is the probability of having or not having children (see for example Anderson (1998); Baudin et al. (2015); De La Croix et al. (2019); DeCicca and Krashinsky (2023)). Studying fertility at both margins is relevant as the potential mechanisms behind these outcomes are different. For example, it has been argued that for Europe and some early transition countries, early stages of fertility decline were associated with an increase in childlessness and very small families (Anderson, 1998), and in particular, the decision to remain childless within the marriage was a key strategy for controlling fertility in pre-industrial societies (De La Croix et al., 2019). However, in other contexts, fertility decline was accompanied by a decline in childlessness (see for example Aaronson et al. (2014)). For the case of Latin America, the extensive margin is crucial as motherhood has been traditionally almost universal and early (Rosero-Bixby, Castro-Martín, & Martín-García, 2009; Poston, Kramer, Trent, & Yu, 1983). What is more, motherhood is largely independent of marital status, and illegitimacy rates (children outside wedlock) have been increasing since the 1960s (Esteve, Saavedra, López-Colás, López-Gay, & Lesthaeghe, 2016).[4]

Both margins are influenced, among other things, by the level of education of the mother (Aaronson et al., 2014; Baudin et al., 2015; De La Croix et al., 2019; Baudin, De la Croix, & Gobbi, 2020; Van Bavel et al., 2018; DeCicca & Krashinsky, 2023). While education almost certainly decreases the number of children it can also result in fewer childless women. On the one hand, the opportunity cost of bearing and rearing a child is higher for higher-educated women, as more-educated women presumably have more labour opportunities than less-educated women, resulting in fewer or no children. On the other hand, couples with more education could have higher incomes, resulting in the possibility of having at least one child. Aaronson et al. (2014) shows this by looking at the expansion of schooling opportunities under the Rosenwald Rural Schools Initiative in the US. This expansion of women's education was associated with a reduction in the number of children born but it also led to a decrease in childlessness rates as more women entered on the extensive margin. Also, Van Bavel et al. (2018) show that during the baby boom of the 1950s and 1960s women with post-primary schooling had lower probabilities to remain childless.

[4] Therefore, the Latin American case differs considerably from the European case that had low levels of illegitimacy during the fertility transition (Clark, 2007).

On the contrary, in pre-industrial England, De La Croix et al. (2019) show that the English upper classes were more often childless than the rest, which resulted in comparatively modest rates of reproduction among the upper classes. In a time before effective contraception within marriage, it was difficult for couples who were sexually active to avoid pregnancy so the authors suggest that sexual abstinence varied across classes, while it is also possible that higher rates of venereal diseases such as gonorrhoea, chlamydia, and syphilis, among the upper classes led to higher rates of sterility.

3.2 Individual-level effects: women's educational attainment

It is now a consensus in the literature that increases in education are significantly related to decreases in fertility and women's desired family size. However, a causal examination of this relationship is often limited by the simultaneity in the decision-making between childbearing and schooling. To overcome this issue, several papers look at the implementation of universal education policies or the introduction of compulsory schooling. Most of this literature finds that increases in women´s education reduce fertility (Behrman, 2015; Osili & Long, 2008; Alzúa & Velázquez, 2017). For the case of Colombia, Cortés, Gallego, and Maldonado (2016) show that cash transfer programs in the 2000s that conditioned payments to educational attainment reduced teenage pregnancy rates, especially when the benefits were conditional on school success. For the case of Nigeria, Osili and Long (2008) estimate a reduction in fertility of women younger than 25 after the introduction of universal primary education. The causal effect of education on fertility has been challenged by Cummins (2022) while Martin and Juarez (1995) argue that more attention should be paid to the mechanisms that explain the association.

The exact mechanisms through which education affects fertility outcomes are perhaps less clear. On the one hand, an increase in women's education can create new labour market opportunities, raise the economic aspirations of women, and increase consumption aspirations, therefore, expanding the opportunity cost of childbearing (Easterlin & Crimmins, 1985; Castro Martin, 1995; Becker, 1960). On the other hand, women's education can translate into lower infant and child mortality rates. This can affect the number of births and reduce fertility (Kravdal, 2002; Baudin et al., 2015). Additionally, more educated women wait longer to have sex and have a more positive attitude towards contraception (Grant & Hallman, 2008; Castro Martin, 1995).

Indirectly, education can spread information about family planning or new norms regarding family size and structure which can translate into more acceptance and use of contraceptive methods to limit fertility (Caldwell, 1980; Axinn & Barber, 2001).

3.3 Community-level effects: education and urbanisation

Finally, education attainment is also an aggregate phenomenon that can affect fertility levels in a specific community (Frye & Lopus, 2018). Education has the potential to create significant spillovers from the educated to the non-educated group by propagating new norms and behaviours (Frye & Lopus, 2018; Axinn & Barber, 2001). For example, Colleran, Jasienska, Nenko, Galbarczyk, and Mace (2014) show that in the case of Poland, less-educated women adopted the low-fertility behaviour of the more educated women, which led to a convergence in fertility rates despite differences in educational levels. The transmission of the new norms and behaviours could be direct, by communication and interaction with peers or indirect through observation and imitation. Information about the use and availability of contraception could be passed from the more educated women to the uneducated while less-educated women can adopt preferences for a smaller number of children if they live in a community with a higher proportion of smaller families. Additionally, general increases in female education can transform social norms breaking old ideas and traditional modes of reproduction (Kravdal, 2002; Tienda, Diaz, & Smith, 1985). Therefore, community-level characteristics could be important in fertility outcomes, especially in a context of rapid educational change. As Tienda et al. (1985) argues in the case of Peru, once the majority of women in a cohort reached at least primary education, the educational composition of a community had a significant effect on the reproductive behaviour of women.

4 Data

The empirical analysis is based on individual-level data from the 10% samples of the censuses of 1973, 1985, 1993 and 2005 from IPUMS International (Minnesota Population Center, 2019) and the complete census of 2018 from the National Department of Statistics (DANE). Most of the Colombian literature has provided fertility measures with surveys that are representative only at the aggregated level or have not considered a long-run perspective as

I do.[5] Furthermore, the vital registration data in Colombia is weak with high levels of under-registration. On the contrary, Colombian censuses are of good quality, and in terms of census coverage, their record is superior to that of most Latin American countries (Vejarano & McCaa, 2002). Colombia has a longstanding tradition of implementing censuses, and since its Independence in 1820, 18 censuses have taken place in the country, most of them with an interval of 10 years. Therefore, these censuses provide the most complete source of the Colombian population and allow me to explore fertility using detailed socioeconomic variables, such as enrolment in schooling, marital status, fertility (measured as children ever born, and children surviving), housing construction materials, ownership, etc. Table 1 presents the main summary statistics of the censuses.

Table 1: Descriptive statistics of censuses

	1973	1985	1993	2005	2018
Mean age (sd)	21.9 (18.1)	26.6 (18.7)	25.9 (19)	29.05 (20.9)	32 (20.2)
Mean family size (sd)	6.67 (3.3)	6.02 (3.2)	5.33 (2.6)	4.64 (2.3)	3.07 (1.6)
Mean numb. children ever born (sd)	5.15 (3.6)	4.28 (3.3)	3.74 (2.9)	3.6 (2.7)	3.04 (4.8)
Urban (%)	62	70	73	61	77
Share with electricity (%)	61	80	87	92	96
Share with aqueduct (%)	68	71	81	77	86
Share with primary schooling (%)	71	84	85	90	94
Share with secondary schooling (%)	24	40	47	50	66
Source	IPUMS	IPUMS	IPUMS	IPUMS	full census
Population in sample	1,988,831	2,643,125	3,143,567	3,329,187	41,126,636

Note: I do not include in my analysis data for the military forces, institutions such as hospitals and indigenous communities. Source: IPUMS-international and DANE.

Regarding the limitations of these sources, censuses can be affected by under-enumeration, misreporting of ages, and significant differences in group characteristics. For instance, age heaping appears to be particularly prevalent among individuals with low levels of education, and under-registration is likely to impact children aged between 0 and 1 year.[6] Additionally, the census does not provide data on the mother's age at birth, which is a crucial variable for estimating age-specific fertility rates.[7] In Section 7.A, I elaborate on how I address this

[5] One exception is Miller (2010) who uses the census of 1973 and 1993. Similarly, Potter et al. (1976) use samples of the 1973 census to study the fertility decline at the national level but focuses on the 1973 period and does not provide retrospective fertility estimations as I do.

[6] See A'Hearn, Baten, and Crayen (2009) for information on age heaping and its correlation with literacy and numeracy.

[7] See Reid, Jaadla, Garrett, and Schürer (2020) and Timæus (2021) for further limitations regarding the calculation of age-specific fertility rates using census data.

concern. Therefore, while the point estimates of fertility may lack precision, especially for the 1973 and 1985 censuses, the trends should still offer valuable insights.

5 The long-run relationship between education and fertility in Colombia

As fertility and education experience similar changes around the same time, the relationship between fertility and education has been broadly studied in Colombia. Using a 4% census sample of the 1973 census, Potter et al. (1976) shows that the gap in fertility levels between educated and non-educated women remained unchanged during the fertility transition. By 1990, Heaton and Forste (1998) find that the gap between uneducated and educated women was closing as declines in fertility were larger for the least educated women. However, in a recent paper, Batyra (2020) challenges this finding and shows that in 2005 the differences in rates of first birth between the lowest and highest educated women were still evident in Colombia. Unfortunately, these studies use different fertility measures which makes it difficult to draw a clear pattern of the long-run relationship between education and fertility.

This section presents new stylised facts about the long-run relationship between female education and fertility updating previous estimations of fertility differentials.

5.1 National

5.1.1 Total Fertility Rate

I estimate Total Fertility Rates (TFR) between 1958 and 2017 by the educational category of the mother and the estimations are done following the Own Child Method described in Section 7.A.[8] The TFR reports the average number of live births among 1,000 women exposed throughout their childbearing years to a given set of age-specific fertility rates. In other words, it is a hypothetical measure for a synthetic cohort of women. Given that the TFR takes into account the distribution of births within the childbearing years and uses the same standard population in every calculation, it can be interpreted as the completed family size to evaluate changes in fertility across time (Palmore & Gardner, 1983).[9]

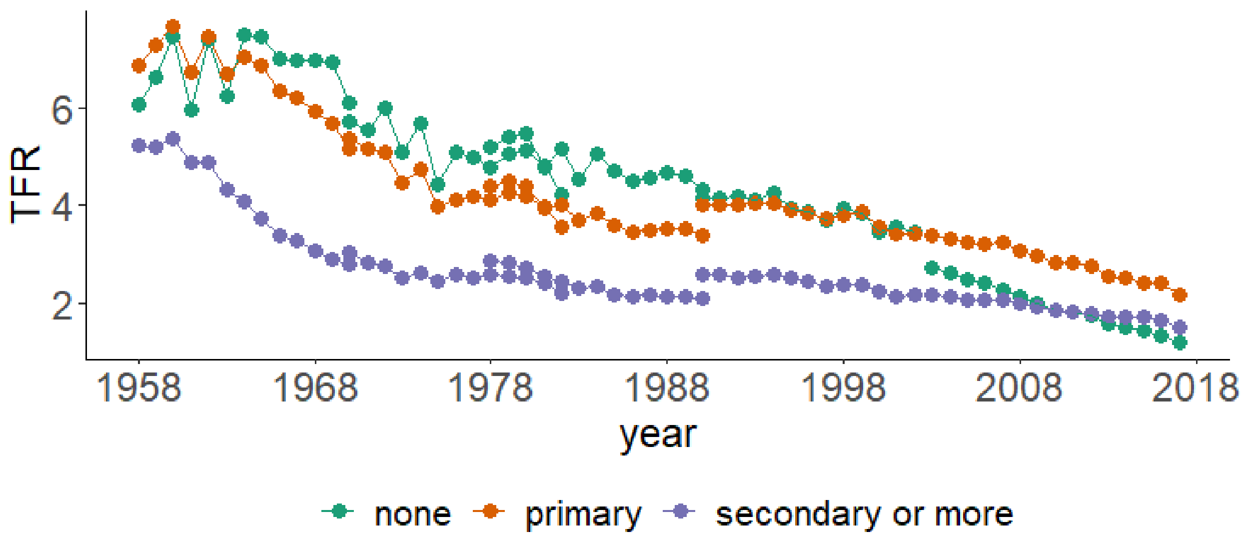
[8] The point estimates by educational levels are reported in Section 7.B

[9] The completed family size is the average number of children born per woman by the end of their childbearing years.

The results in Fig. 3 show that fertility declined continuously until 2017 in all educational groups, but it shows that fertility levels were already descending in 1958 for women with secondary, while it started falling in 1962 for women with primary and no education.[10] From 1962 to 1970, fertility dropped in all schooling categories but it declined faster in secondary schooling, amplifying the gap between educated and non-educated women, which is consistent with the findings of Potter et al. (1976). Between 1970 and 1980 the fall in the total fertility rate slowed down for the highest educational category, while it accelerated for women with no education. By 1980, women with secondary education had, on average, 2 children, women with primary education had 3 and women with no education had 4 children. From 1980 to 2003 fertility kept declining at a slower rate in the three educational categories and the gap in fertility levels between highly-educated and non-educated women remained almost unchanged. After 2003 fertility changed little for highly educated women, while continued to decline for women with primary or no education and by 2017, the gap between educated and non-educated women was the smallest of the whole period studied. Women with secondary education had, on average, around 1.5 children while women with primary education had 2.

[10] The estimations for women with no education fluctuate more, probably due to age-heaping. Also, during most of the period, there is little difference in the fertility of women with no or primary education. Only after 1994, there seems to be a mismatch in the trends. This could be explained by the small number of women with non-education that appear in the 2018 census. Only 5% of women reported having no education in this census.

Figure 3: Total Fertility Rates by educational levels of mothers



Note: The graph shows the Total Fertility Rate calculated implementing the Own Child Method based on all women between 15 to 64 years old and children between 0 to 14 years old. Sources: Authors' calculations based on 1973, 1985, 1993 and 2005 census samples from IPUMS-International and 2018 full-count census data.

5.1.2 Intensive margin

Although the TFR can be interpreted as the completed family size of a synthetic cohort of women, with the census data it is also possible to observe directly completed family size by focusing on the number of children born to women older than 50 years old (as it is unlikely that women older than 50 years old have another birth, the number of children ever born reported is a good proxy for completed family size). I estimate the number of children ever born to women between 50 and 60 years old by educational level.[11] I calculate the average number of children ever born by cohort including all women (Fig. 4a) and women with at least one birth (Fig. 4b). Overall both graphs show a similar pattern, and this is also comparable to the results of the TFR. The results of completed fertility in Fig. 4 reveal a clear educational gradient in fertility even before fertility started declining for all women as well as for mothers. Fertility declined across all educational groups for women born after

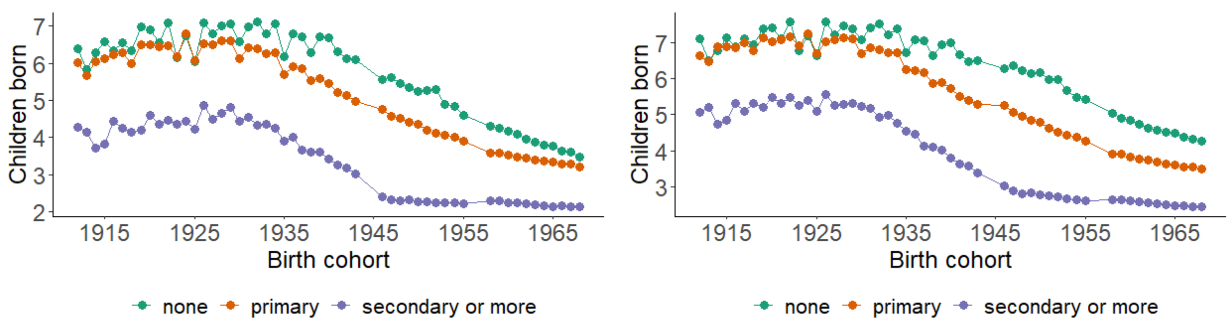
[11] This age group allows me to observe women with completed fertility in the 4 censuses. To avoid overlapping in the information of the censuses the information from the cohort of women born between 1912-1923 comes from the 1973 census, the cohort born between 1924-1935 comes from the 1985 census, the cohort born between 1936-1943 comes from the 1993 census, the cohort born between 1944-1955 comes from the 2005 census and the cohort born between 1958-1968 comes from the 2018 census.

1930. However, the gap only started to close for women born after 1958 as fertility declined slower for women with secondary education.

The findings of completed fertility indicate that fertility decreased across all educational groups more or less simultaneously, but, in contrast to the TFR, the gap did not close as women with secondary education experienced a faster fall in fertility in comparison to uneducated women.

Figure 4: Intensive margin: children ever born

(a) Children born (b) Child born cond. on having a birth



Note: The graphs show the total number of children ever born to women between 50 and 60 years old using the reported variable in the censuses. The cohort of women born between 1912-1923 comes from the 1973 census, the cohort born between 1924-1935 comes from the 1985 census, the cohort born between 1936-1943 comes from the 1993 census, the cohort born between 1944-1955 comes from the 2005 census and the cohort born between 1958-1968 comes from the 2018 census. Panel A presents the results for all women and Panel B the results for all women (conditionally on being mothers). Sources: Authors' calculations based on 1973, 1985, 1993 and 2005 Census samples from IPUMS-International and 2018 full census from DANE.

5.1.3 Extensive margin

I estimate the percentage of women that remained childless for the same cohort of women (born between 1912-1968) and I estimate this for ever-married women (which includes women in a partnership, divorced and widows) and non-married (which includes only women that declared to be single). I separate these groups as in Colombia, and in other Latin American countries, motherhood has been independent of marital status. In fact, from 1973 to 2005 the percentage of children born inside marriage declined across the country from around 50% in 1973 to less than 10%.[12]

Looking at ever-married women, the results show that in comparison to fertility rates and completed fertility, the educational gradient vanishes while childlessness declines rapidly in

[12] Appendix Fig. 6 shows the percentage of women that remained unmarried over time.

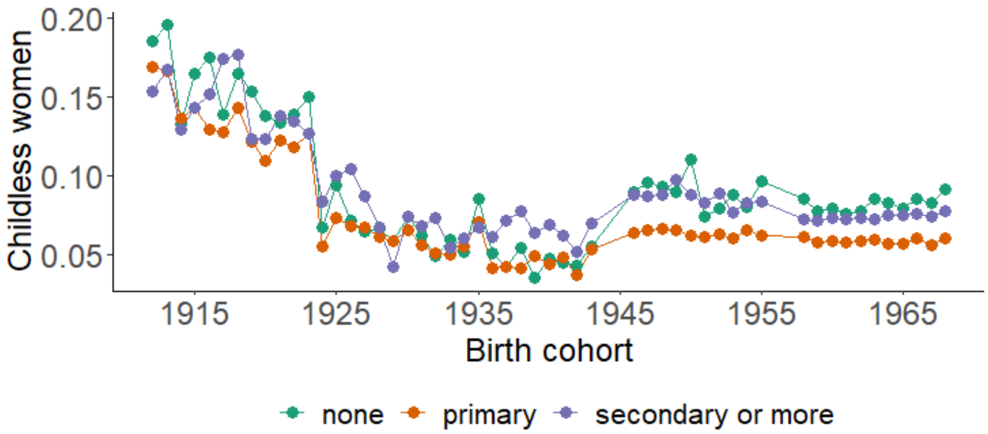
all educational groups. The fall in childlessness is similar to the estimations of Baudin et al. (2015) for the US case where childlessness falls from around 20% to around 5% from 1912 to 1940. Then for the cohort born after 1944, the childless rate increases slowly in all educational groups reaching around 10% (see Fig. 5).

The simultaneity of the decline of childlessness within marriage across all education groups indicates that, as shown by Aaronson et al. (2014) for the US case and DeCicca and Krashinsky (2023) for Canada, the share of women who did not have children declined as schooling opportunities expanded. These results suggest that voluntary childlessness was the main driver of childlessness for women. The absence of an educational gradient suggests that sexual abstinence and sterility due to venereal diseases did not vary across educational levels as much as they did in pre-industrial England (De La Croix et al., 2019). The findings indicate that widespread changes in health and economic conditions could partially explain the drop in childlessness within marriage (Castro & Tapia, 2021), but more research on the explanation of this pattern is needed.

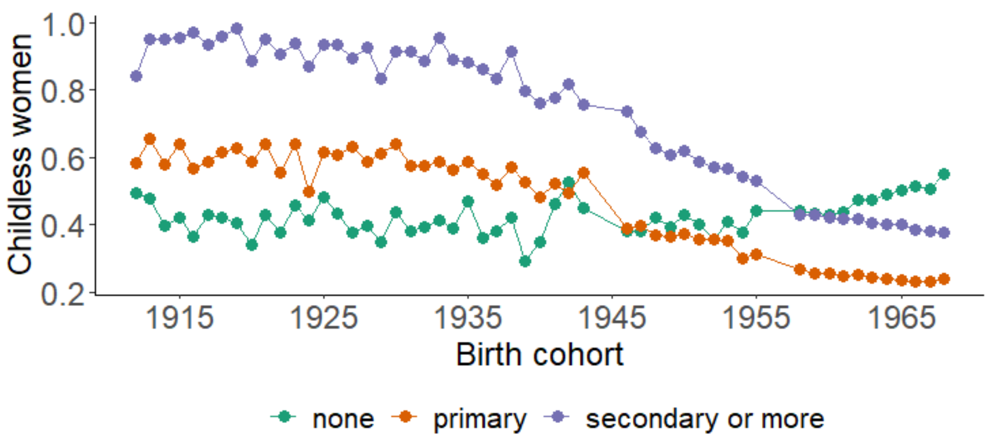
The results for single women reveal a different picture. The fertility decline was accompanied by a fall in childlessness in ever-married women and not a fall in childlessness in single women. In fact, childlessness in educated single women remained more or less constant until the 1940s cohort, when childlessness started to fall. What is more surprising in comparison to the previous results, is that the probability of remaining childless for single women is closely related to the education of women and the results show a clear educational gradient. Non-educated single women were significantly more likely to have a child than single women with secondary education up to the 1955 cohort. For almost the whole period studied, around 90% of single women with secondary education remained childless while more than half of the non-educated women were mothers. These patterns changed for the cohorts born after 1940, and childlessness decreased for both women with primary and secondary education. On the contrary, the percentage of single women with no education who remained childless increased to around 50%.

Figure 5: Extensive margin: proportion of childless women

(a) Ever married women



(b) Never married women



Note: The graphs show the percentage of women between 50 to 60 years that remained childless. The cohort of women born between 1912-1923 comes from the 1973 census, the cohort born between 1924-1935 comes from the 1985 census, the cohort born between 1936-1943 comes from the 1993 census, the cohort born between 1944-1955 comes from the 2005 census and the cohort born between 1958-1969 comes from the 2018 census. Panel a the results for ever-married and Panel b is for unmarried women. Ever-married women include women who report being: married, cohabiting, divorced or widows. Unmarried women are women who report being single. Sources: Authors' calculations based on 1973, 1985, 1993 and 2005 Census samples from IPUMS-International and 2018 full-count census data.

All in all, women born after the 1930s had fewer children, and a small but constant proportion of married women remained childless. Fertility declined steadily across all educational groups and in most measures the educational gradient is evident. However, the TFR suggests convergences across educational levels, while the reported number of children indicates a slower convergence. Bongaarts and Lightbourne (1996) also looked at the number of children

Table 2: Wanted children vs. children ever born

N. of children	0 yrs of schooling	1-6 yrs of schooling	7+ yrs of schooling
1976	7.4	4.9	2.8
1986	4.8	3.9	2.3
N. of wanted children			
1976	3.9	2.7	2.2
1986	2	2.2	1.8

Notes: The information for 1976 comes from the WFS, while the information for 1986 comes from the DHS. Source: From Bongaarts and Lightbourne (p.235-236:1996).

born and the number of wanted children in Colombia between 1976 and 1986. As shown in Table 2, fertility differentials by levels of education were substantive but diminished over time. As for fertility preferences, they find relative convergence in the number of children wanted between 1976 and 1986. Casterline and Mendoza (2009) show that since 1975 the percentage of unwanted births in Colombia has remained more or less stable and around 40% of births are unwanted.[13] This might indicate that variations in fertility across groups are explained by variations in unwanted fertility rather than in fertility preferences, however, it is beyond the scope of this paper to resolve this.

It is unclear what can drive convergence in fertility preferences but education has the potential to create significant spillovers from the educated to the non-educated group propagating new norms and behaviours (Frye & Lopus, 2018; Kravdal, 2002; Axinn & Barber, 2001). In that scenario, fertility levels will converge despite divergences in educational outcomes (Colleran et al., 2014). Education can also spread information about family planning or new norms regarding family size and structure which can translate into more acceptance and use of contraceptive methods to limit fertility which can explain the variation in the number of unwanted children (Caldwell, 1980; Axinn & Barber, 2001).

5.2 Individual

To fully disentangle the relationship between women's education and fertility, I exploit the censuses' individual-level character and incorporate individual and community-level variables to examine the relationship between fertility outcomes and women's education. I look at both the intensive and the extensive margin of fertility for women with completed fertility

[13]The authors defined unwanted births as births not wanted at the time of conception.

in the census of 1973 and the samples for 1985, 1993, 2005 and 2018. Additionally, I study the prevalence of starting, spacing and stopping in the census of 1973, when fertility was changing more rapidly. The model is shown in Eq. (1).

$$Y_{i,a,m} = \beta_0 + \beta_1 * \text{education level}_i + \beta_2 * \text{Z[\% women secondary education]}_{a,m} + \\ \beta_3 * \text{Z[urbanisation rate]}_m + \mathbf{X}_i \lambda + \epsilon_{i,a,m} \quad (1)$$

Where $Y_{i,a,m}$ corresponds to a fertility measure or behaviour for a woman i, born in cohort a and living in a municipality m. The coefficient β_1 measures the relationship between the individual education of a woman on fertility, β_2 is the estimated effect of the percentage of women with secondary education for each cohort of women at the municipal level and β_3 measures the relationship with the level of urbanisation. To ease interpretation, both community variables are standardised using a *Z-score* method. $\mathbf{X}_i$ is a vector of individual controls such as age, urban location, access to public services, socioeconomic status and marital status. Other unobserved factors are captured with the random error term $\epsilon_{i,a,m}$. The standard errors are robust and clustered at the municipal level.

5.3 Fertility margins

Table 3 shows the estimated relationship between schooling and community variables and the fertility of women with completed fertility born between 1912 and 1968. The fertility outcome in the first five columns is the number of children ever born to women between 50 and 60 years old conditional on having a birth (intensive margin). In columns 6 to 10 the fertility outcome is an indicator variable equal to zero if the woman has at least one child and one if the woman is childless (extensive margin) and the coefficients are presented as odd ratios, to make the interpretation of the effects easier.

For women born between 1912 and 1923 primary education reduced the total number of children in comparison to women with no education and increases the probability of remaining childless by 60%. Secondary education reduced the total number of children by almost two children and further increased the probability of remaining childless by 250%. Similar effects are found in the other cohorts of women. In all cases the educational gradient is clear: both primary and secondary education reduce the total number of children and increase the probability of remaining childless. The effects are comparable across the cohorts, primary education reduces fertility by around one child, secondary education reduces the total number of children by almost 2 children and the increases in the probability of remaining childless are around 60% for women with primary schooling and 200% for women with secondary schooling in comparison to uneducated women. In the five cohorts, the effects are economically bigger for secondary education than for primary education. This relationship can emerge because more educated women face a higher opportunity cost of childbearing and can achieve greater relative autonomy in comparison to less-educated women (Jejeebhoy, 1995). Also, women with secondary schooling can have higher consumption aspirations, have a more positive attitude towards contraception and face lower infant and child mortality rates (Grant & Hallman, 2008; Castro Martin, 1995; Easterlin & Crimmins, 1985; Castro Martin, 1995; Becker, 1960).

Peer effects, such as the percentage of women with secondary education in the woman's cohort in her municipality have a negative and significant effect on the number of children in all cohorts. The size of the effect is similar across cohorts and an increase of one standard deviation in the percentage of women with secondary education implies a reduction of fertility of around 0.2. Similarly, the effects of the urbanisation rate of her municipality are moderate and an increase of one standard deviation in the urbanisation rate decreases fertility by 0.10. For the extensive margin, the proportion of women with secondary education and changes in the urbanisation rate have no significant effect on fertility. Overall these results suggest that in the case of Colombia, education affected fertility outcomes mainly directly while community variables had a smaller effect.[14] However, this is changing for the cohorts born after 1950, as the percentage of women with secondary education seems to play a more significant role both in the intensive as well as the extensive margins. These results are in line with research for other developing countries that find diffusion effects in progress. For example, for India, McNay, Arokiasamy, and Cassen (2003) find significant relationships between the use of contraception and the peer's education and this could account for the spread of contraceptive use among uneducated women.

[14]Table 6 reproduces the estimations using municipality-fixed effects instead of community variables. The results show that individual-level effects are robust to the inclusion of these fixed effects and the coefficients change marginally.

Table 3: Estimated relation between schooling and community variables and fertility

	Intensive: Num. of children					Extensive: Remaining childless				
	1912-1923	1924-1935	1936-1943	1944-1955	1958-1968	1912-1923	1924-1935	1936-1943	1944-1955	1958-1968
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Individual variables										
no schooling (reference)										
primary	-0.6098***	-0.8621***	-1.011***	-1.162***	-0.3069***	1.6604***	1.7199***	1.5640***	1.1879***	4.3666***
	(0.0589)	(0.0512)	(0.0387)	(0.0669)	(0.2060)	(0.0417)	(0.0456)	(0.0905)	(0.0347)	(0.0944)
secondary	-1.838***	-2.102***	-2.067***	-1.985***	-1.153***	3.5501***	3.5253***	3.1393***	2.3683***	2.5689***
	(0.0991)	(0.0891)	(0.1055)	(0.0914)	(0.0905)	(0.0568)	(0.0756)	(0.0935)	(0.0625)	(0.0796)
Community variables										
Z[% of women secondary in age-cohort]	-0.2475***	-0.1921***	-0.2229***	-0.2513***	-0.3403***	0.9925	0.9403	0.9912	1.060*	0.8785**
	(0.0597)	(0.0223)	(0.0223)	(0.0271)	(0.0233)	(0.0366)	(0.0422)	(0.0316)	(0.0308)	(0.0447)
Z[urbanisation rate]	0.0061	0.0148	-0.1019*	0.0862**	0.1680***	0.9383	1.1021	1.0395	1.0469	1.065
	(0.1140)	(0.0782)	(0.0534)	(0.0432)	(0.0241)	(0.0630)	(0.0721)	(0.0573)	(0.0547)	(0.0434)
S.E Clustered	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality
Observations	29,600	71,478	67,312	128,407	1,965,477	33,302	77,933	71,803	145,135	2,210,695
Adjusted R^2	0.06938	0.08447	0.17573	0.24987	0.05020	0.24644	0.32466	0.29805	0.19931	0.09792
Method	OLS	OLS	OLS	OLS	OLS	Logit	Logit	Logit	Logit	Logit

Notes: Columns 1 to 5 estimate the effect of education on the intensive margin (number of children ever born conditional on ever having a birth) and Columns 6 to 10 estimate the effect of education on the extensive margin and to ease the interpretation of the coefficients, these are reported as odd-ratios. The community variables percentage of women with secondary education by age cohort and the urbanisation rate are standardised using a *Z-score* method. The samples consider only women with completed fertility. The cohort of women born between 1912-1923 comes from the 1973 census, the cohort born between 1924-1935 comes from the 1985 census, the cohort born between 1936-1943 comes from the 1993 census, the cohort born between 1944-1955 comes from the 2005 census and the cohort born between 1958-1968 comes from the 2018 census. All models include individual controls such as age, urban location, access to public services, socioeconomic status and marital status. Standard errors in parentheses are clustered at the municipality level, and ∗∗∗: 0.01, ∗∗: 0.05, ∗: 0.1 indicate statistical significance. For Logit models I report the squared correlation instead of R^2.

5.3.1 Other fertility outcomes

I then turn my attention to other fertility outcomes, such as the age of starting, spacing between births and stopping. Starting is defined as the age at which a woman starts her maternal life, and commonly an earlier starting age would translate into higher fertility. In this research, I proxy starting with the probability of having a child when a woman is between 19 to 22 years old. This age range allows me to study childbearing at an early age while at the same time focusing on women who should have already completed secondary schooling to alleviate the concern of simultaneity in the decision-making between childbearing and schooling. Spacing is defined as the average of all intervals between childbirths and I estimate this for women who had more than one child and are aged 23 to 36. As child mortality and leaving home can affect the measurement of spacing and these issues are more problematic when linking older mothers to older children, I do the analysis of spacing for women between 23 and 25 separate from women between 26 to 36, to minimise this concern.[15] Although longer spaces could reduce the total number of live births, when stopping is achievable earlier through contraception, a shorter spacing could imply that a woman focuses her fertility efforts in a narrower period. Stopping corresponds to the age at which a woman stops having children (usually once she attained her desired number of children) and it is proxied in this research with the probability of having a child at 40 to 45.

The results are shown in Table 4. Column 1 shows the relationship between education and

[15]Unfortunately, the presence of twins can also create bias in the measurement of spacing and I cannot account for this with the census data.

starting. In terms of prevalence, in 1973 around 37% of women started their fertility life at ages 19 to 22. The results reveal that there is a clear and significant educational gradient: obtaining primary schooling reduces the probability of having a birth at this age by 26% in comparison to women with no education but the effect is bigger when looking at secondary schooling (a reduction of 71%). On the contrary, the percentage of women with secondary education and the level of urbanisation of the municipality of residence are not associated with the probability of having a child at a young age. These results confirm that having access to secondary education had a key effect on fertility while there is no evidence of community-level effects. Additionally, these results are consistent with the idea that individual-level exposure to schooling directly affects the behaviours of students. The literature has found that students with improved literacy, numeracy, and cognitive skills wait longer to have sex (Grant & Hallman, 2008; Marteleto, Lam, & Ranchhod, 2008). Also, education is related to an increase in aspirations for a career which as Jensen (2012) shows results in fewer children.

The results for spacing in Columns 2 and 3 show that the educational gradient also appears in this strategy and more educated women reduce their spacing in comparison to less educated women. This result suggests that women with secondary education are concentrating their fertility efforts on a shorter period by reducing the space between births. This is the case for young women (23-25 years old) as well as for the older group (26-36 years old). Women with secondary education start later, have a shorter space between births and as Column 4 shows stop earlier in comparison to women with no education. As for the community effects, the percentage of women with secondary education has no significant effect on the size of the space, while the urbanisation rate of the municipality moderately reduces the average size of spacing.

The results in Column 4 indicate that on average, 82% of women stopped before the age of 40 and the probability of having a birth at ages 40 to 45 was mainly affected by having secondary education. Similar to the results of completed fertility, the majority of this cohort of women, born between 1928 and 1933, had achieved primary education while around 15% finished secondary school. Therefore, the more disadvantaged women who did not have access to any education were more likely to have birth at these ages, and their probability of childbearing was not affected by the educational level of their peers. This result also suggests that for this cohort of women, education could be reflecting individual-level social status or income, which are important confounders and limit the interpretation of this result.[16] Nonetheless, the results rule out potential community effects and demonstrate that by 1973 the educational gradient existed at the individual level and not across municipalities. The results are consistent with the results of Table 3 and this finding implies that economic development that happens at the municipal level, like urbanisation and changes in education, cannot fully account for the fertility decline.

Table 4: Estimated relation of schooling and community variables on limiting behaviours in 1973

	Starting: Any birth age 19-22	Spacing: Interval between births ages 23-25	Spacing: Interval between births ages 26-36	Stopping: One more birth age 40-45
	(1)	(2)	(3)	(4)
Individual variables				
no schooling (reference)				
primary	0.7410***	-0.1879***	-0.1792***	1.0285
	(0.018)	(0.0090)	(0.005)	(0.018)
secondary	0.2888***	-0.2805***	-0.3439***	0.5685***
	(0.030)	0.0199	(0.021)	(0.038)
Community variables				
Z[% of women secondary in age-cohort]	0.9617	0.0115	0.0026	0.9862
	(0.0375)	0.0140	(0.0137)	(0.003)
Z[urbanisation rate]	0.9770	-0.0292**	-0.0247*	0.878***
	(0.0375)	0.0136	(0.0135)	(0.0008)
S.E Clustered	Municipality	Municipality	Municipality	Municipality
Observations	755,111	182,746	782,039	456,047
Pseudo R^2	0.45	0.05	0.13	0.10
Method	Logit	OLS	OLS	Logit

Notes: Column 1 estimates the probability of having a child for women between 19 to 22 years old using a logit model and to ease the interpretation of the coefficients, these are reported as odd-ratios. Columns 2 and 3 estimate the mean size of the interval between 2 children for women that are between 23 and 36 years old and the estimations are done using an OLS model. Column 4 estimates the probability of having one more birth for women with at least one child that are between 40 to 45 years old and the estimations are done using a logit model. The community variables percentage of women with secondary education by age cohort and the urbanisation rate are standardised using a *Z-score* method. As for previous Logit models, to ease the interpretation of the coefficients, these are reported as odd ratios. All models include individual controls such as age, urban location, access to public services, socioeconomic status and marital status. Spacing also includes the number of children as a control. Standard errors in parentheses are clustered at the municipality level, and $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$ indicate statistical significance.

The results of this section support the existence of a link between women's education and fertility and indicate that the gap between educated and uneducated women in fertility existed during the fertility decline and that uneducated women were unlikely to adopt simultaneously the fertility behaviour of more educated women, although this does not rule out that uneducated women could adopt this behaviour with a lag. The results also allow us to conclude that access to secondary education was a key factor behind the differences in fertility. Additionally, the results suggest that women with the same educational status will display similar fertility behaviour across all cohorts.

The results of a small effect of the community variables make sense in a society with little interaction across different classes, in which the process of learning from peers is limited by

[16] Although all the specifications include a set of controls for socioeconomic status with the information available in the census to minimise this issue.

the places in which peers interact. This, especially the result on the percentage of women with schooling in the municipality, makes sense in a setting like Colombia where schooling has been segregated and where there is little interaction across social classes. However, a final caveat is that the municipality could also not be the right level to measure community effects as municipalities vary in population size and socioeconomic development.

6 Conclusion

This research provided new stylised facts of the long-run relationship between fertility and women's education in Colombia. Using census data I estimated the relationship between education and fertility at several levels of aggregation and along the two margins of fertility. The findings caution that the relationship between fertility and women's education is not necessarily monotonic and depends on the aggregation of the data.

At the national level, the fertility gap between the lowest and highest educated women existed during the fertility transition and depending on the measure the gap did not close. However, fertility declined across all educational groups and there is no evidence of fertility reversal. These findings suggest that the fertility decline, at the aggregated level, cannot be explained through changes in education.

At the individual level, the relationship between schooling and fertility holds strongly. For all cohorts, both primary and secondary education increased the probability of remaining childless, reduced the total number of children and reduced the probability of having a birth at younger or older ages. It is important to highlight that in all cases, the effect of secondary schooling is significantly bigger, which could indicate that other variables such as social status and income can explain this effect. Future research should explore the channels through which secondary education reduces fertility.

Peer effects, such as the percentage of peers with secondary education, are mostly ruled out for women born before the 1950s, as these had a small effect on the total number of children, the probability of remaining childless and the use of strategies to limit fertility (e.g. starting, stopping).

Taken together the findings confirm that in Colombia fertility declined rapidly and across all educational groups suggesting a cultural change that diffused quickly across the country. Although convergence in fertility rates has not been achieved yet, fertility declined smoothly also for non-educated women born before the 1950s. It is relevant to further investigate what explains the decline in this group of women, given that educational peer effects are ruled out.

Finally, the results of the extensive margin in single women deserve attention. For this group of women, the educational gradient is clear and stable during the period studied. Single women with secondary education remained childless in a much higher proportion (up to 90%) than non-educated women (close to 50%), and the trend changes little over time. Although the causes of this pattern are not explored in the paper, it is clear that single women without education and with children represent one of the most vulnerable population groups, as uneducated single mothers generally have less earning power and their children are likely to have worse socioeconomic outcomes. Understanding why the educational gradient exists for single women and not for married women is crucial to disentangling the mechanisms through which education affects fertility.

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7 Appendices

7.A Own Child Method

Given the poor quality of vital registration for this period in Colombia, I construct Age-Specific Fertility Rates (ASFR) and Total Fertility Rates (TFR) at the departmental level from censuses using the Own Child Method (OCM). The OCM was developed in the 1960s to calculate fertility rates when birth registration data is incomplete or unavailable, or when the mother's age at birth of the child is not registered, as is the case in the census (Grabill & Cho, 1965; Cho, Retherford, & Choe, 1986). This method has been widely used to estimate fertility in historical censuses and for developing countries. For example, Reid et al. (2020) estimate fertility rates for England and Wales in 1911; Dubuc (2009) estimate fertility by ethnic and religious groups in the UK; Avery, St. Clair, Levin, and Hill (2013) present a cross-county comparison, and Dribe and Scalone (2014) use this method for Sweden between 1880-1970.

The method is based on two key elements of the census: the recorded age of people in the household, and, when available, the relationship of each member of the household to the household head. I use the variable 'MOMLOC' constructed by IPUMS in which they pair a potential child with a potential mother following different rules depending on the relationship of both to the head of the household, their age and the fertility reported by the potential mother. All persons in the sample are eligible to receive a mother's link if they have a specified relation to the head. Additionally, all women over age 15 are eligible to be mothers if they do not explicitly report having no children (see Sobek and Kennedy (2009) for an explanation of the linking methodology).

With the variable 'MOMLOC' I calculate the mother's age at birth as the difference between her age and her child's age. Following Reid et al. (2020), I calculate single years ASFR to compute the TFR for 1958 to 2017, as shown in Eq. (2) and Eq. (3). These rates are calculated using children between 0 to 14 years old, and mothers between 15 and 64 years old in the census year. The selected age of children avoids the common issue of not matching children who are not living with their parents.[17]

$$ASFR_a, y = \frac{\text{Adjusted number of children born to women age } a \text{ in year } y}{\text{Adjusted number of women age } a \text{ in year } y} \tag{2}$$

[17] Also as discussed below the possibility of orphanhood increases with the age of the children and the mother.

$$TFR_y = \sum_{age=15}^{64} ASFR_{a,y} \quad (3)$$

I define the ASFRs of each year as the ratio between all children born in the year y (children age 0 in the census were born between 1972 and 1973 and children age 14 were born between 1958 and 1959) to women aged 15 to 64 at each year y. I calculate the Total Fertility Rate as the sum of the ASFR at each year.

As the census would not report the number of women that have died in previous years, I adjust the number of women at each year by the probability of surviving of the mother using single-year life tables. Similarly, as the census only reports the number of children that are alive in the year of the census, I adjust the number of children at each age with the life tables. For national estimations I use the national life-table of the same decade of the census.[18] I cannot however control for potential differences in mortality regimes by the educational status of the mother, which is likely to underestimate the mortality of both mothers and children for women with low educational status. Given that I am estimating the ASFR based only on those pairs of mother-child that I was able to link, I adjusted the number of children for the proportion of children at each age that I did not link: in other words, I adjust for the proportion of matched children.[19] Recently Timæus (2021) demonstrated that this adjustment could lead to a biased estimation of the fertility patterns overestimating fertility at younger ages and underestimating fertility at older ages. However, Timæus (2021) admits that the bias in estimates of total fertility rate is smaller as the errors for women of different ages more or less cancel each other out. Additionally, he highlights that this concern affects particularly estimations that are done using the data on children aged 15 or more. I provide estimations of Total Fertility Rates looking at children 14 years old or younger, which minimises this concern.

[18] The life tables come from the National Agency of Statistics (DANE). Most of them were an abridged table and to obtain single-year survivorship probabilities I use the `MORTPAK` package from the United Nations. For details about the package and other forms of expanding an abridged life table see Kostaki and Panousis (2001) and Heligman and Pollard (1980). I use life tables from 1970, 1980, 1990 and 2000.

[19] On average I linked 87% of children age 0 and 81% of children between 5 to 14 years old.

7.B Total Fertility Rates estimations

Table 5 presents the point estimates of the TFR by educational levels. The TFR was estimated following the OCM and using the ´MOMLOC´variable provided by IPUMS. The estimations for the 2 years previous to the censuses are considerably smaller in comparison to what the overall trend suggests, and this could be the result of misreporting of the age of children who are about to turn one or two years old. Another possible explanation is that there are unrecorded births and under-enumeration of zero-years-old (Reid et al., 2020). Therefore, I remove these two observations. Also, when estimations come from different censuses, I keep both measures, as in the years 1970, and 1978 to 1982. The estimations do not perfectly overlap because the censuses can suffer from differential under-enumeration by age and census year (Reid et al., 2020).

Table 5: Total Fertility Rates by educational level, 1958-2002

Census Year	Year	no education	primary	secondary or more
	1958	6.6	6.3	4.5
	1959	7.1	6.6	4.4
	1960	7.8	6.7	4.6
	1961	6.6	6.0	4.3
	1962	7.7	6.3	4.1
	1963	6.8	5.6	4.0
1973	1964	7.6	5.5	3.3
	1965	7.5	5.2	3.2
	1966	7.0	4.7	2.9
	1967	6.9	4.6	2.9
	1968	6.8	4.2	2.6
	1969	6.6	4.0	2.5
	1970	5.9	3.7	2.4
	1970	5.9	4.3	2.7
1985	1971	5.7	4.0	2.5

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Table 5: Total Fertility Rates by educational level, 1958-2002 (Continued)

	1972	5.9	3.9	2.4
	1973	5.1	3.5	2.3
	1974	5.5	3.6	2.3
	1975	4.5	3.2	2.3
	1976	4.8	3.3	2.4
	1977	4.8	3.3	2.3
	1978	4.7	3.3	2.3
	1979	4.9	3.5	2.2
	1980	4.9	3.4	2.2
	1981	4.6	3.2	2.1
	1982	4.1	2.9	2.0
	1978	5.1	3.6	2.7
	1979	5.3	3.6	2.6
	1980	5.3	3.5	2.5
	1981	4.7	3.2	2.4
	1982	4.9	3.2	2.3
	1983	4.4	2.9	2.1
1993	1984	4.8	3.0	2.2
	1985	4.5	2.8	2.0
	1986	4.3	2.7	2.0
	1987	4.3	2.8	2.0
	1988	4.4	2.8	2.0
	1989	4.4	2.8	1.9
	1990	4.2	2.7	1.9
	1990	4.3	3.6	2.4

2005

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Table 5: Total Fertility Rates by educational level, 1958-2002 (Continued)

	1991	4.3	3.6	2.4
	1992	4.3	3.5	2.4
	1993	4.3	3.6	2.4
	1994	4.4	3.6	2.4
	1995	4.2	3.5	2.3
	1996	4.1	3.4	2.3
	1997	4.0	3.3	2.2
	1998	4.1	3.4	2.2
	1999	4.1	3.5	2.2
	2000	3.7	3.2	2.0
	2001	3.7	3.1	2.0
	2002	3.7	3.0	2.0
	2003	2.7	3.4	2.2
	2004	2.6	3.3	2.1
	2005	2.5	3.3	2.1
	2006	2.4	3.2	2.1
	2007	2.3	3.2	2.1
	2008	2.1	3.1	2.0
	2009	2.0	3.0	1.9
2018	2010	1.8	2.8	1.8
	2011	1.8	2.8	1.8
	2012	1.7	2.7	1.8
	2013	1.6	2.6	1.7
	2014	1.5	2.5	1.7
	2015	1.4	2.4	1.7

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Table 5: Total Fertility Rates by educational level, 1958-2002 (Continued)

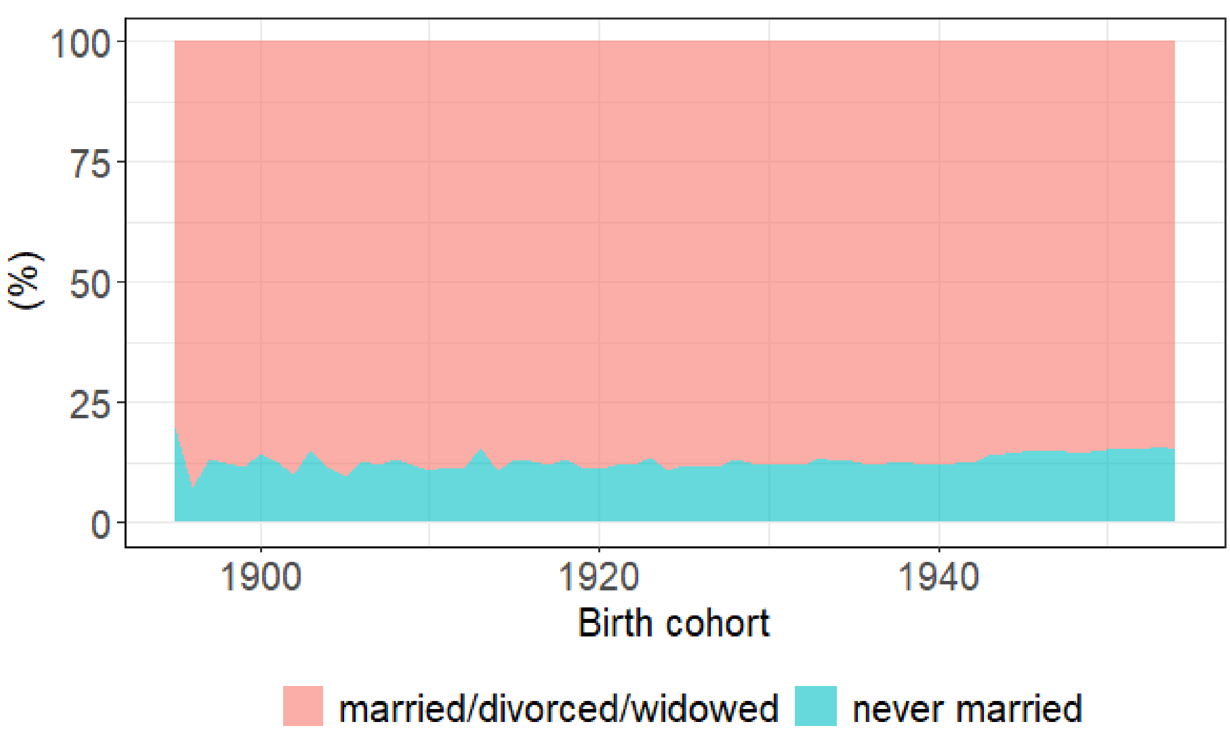
2016	1.3	2.4	1.6
2017	1.2	2.1	1.5

Notes: Total Fertility Rate calculated implementing the Own Child Method based on all women between 15 to 64 years old and children between 0 to 14 years old. Sources: Authors' calculations based on 1973, 1985, 1993 and 2005 Census samples from IPUMS-International and 2018 full-count census from DANE. See Section 7.A for a detailed explanation of the methodology.

7.C Marital status by education

The Fig. 6 shows the percentage of married and unmarried women by year of birth. Around 10% of women remained unmarried and this pattern changed little over time.

Figure 6: Women's marital status by education



Note: The graph shows the percentage of married and unmarried women older than 50 years old. Sources: Authors' calculations based on 1973, 1985, 1993 and 2005 Census samples from IPUMS-International.

7.D Robustness: Municipal fixed effects

As a robustness check for the individual level effects, I replace the community variables for municipal fixed effects, as municipal fixed effects are a better control for potential omitted variables. Community variables can be related to other economic variables that were not included in the original regression while municipal fixed effects control for both observed and unobserved municipality characteristics. The results confirm that the effects of individual education on fertility are not driven by potential omitted variables and are robust to the inclusion of municipal fixed effects.

Table 6: Effects of schooling with municipal fixed effects - fertility

	Intensive: Num. of children				Extensive: Remaining childless			
	1912-1923	1924-1935	1936-1943	1944-1955	1912-1923	1924-1935	1936-1943	1944-1955
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Individual variables								
no schooling (reference)								
primary	-0.6447***	-0.8479***	-0.9732***	-1.113***	1.5709***	1.6558***	1.5440***	1.1923***
	(0.0493)	(0.0525)	(0.0353)	(0.0631)	(0.0413)	(0.0397)	(0.0466)	(0.0349)
secondary	-1.829***	-2.074***	-2.044***	-1.963***	3.4418***	3.4868***	3.1867***	2.4390***
	(0.0944)	(0.0820)	(0.1029)	(0.0933)	(0.0552)	(0.0703)	(0.0792)	(0.0599)
S.E Clustered	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality	Municipality
Observations	46,308	81,011	71,086	128,455	50,743	87,273	74,235	145,128
R^2	0.11481	0.11414	0.20640	0.27474	0.25050	0.33667	0.32355	0.21654
Method	OLS	OLS	OLS	OLS	Logit	Logit	Logit	Logit

Notes: Columns 1 to 4 estimate the effect of education on the intensive margin (number of children ever born conditional on ever having a birth) and Columns 5 to 8 estimate the effect of education on the extensive margin and to ease the interpretation of the coefficients, these are reported as odd-ratios. The samples consider only women with completed fertility. The cohort of women born between 1912-1923 comes from the 1973 census, the cohort born between 1924-1935 comes from the 1985 census, the cohort born between 1936-1943 comes from the 1993 census and the cohort born between 1944-1955 comes from the 2005 census. All models include individual controls such as age, urban location, access to public services, socioeconomic status and marital status. All models include municipal fixed effects. Standard errors in parentheses are clustered at the municipality level, and $***$: 0.01, $**$: 0.05, $*$: 0.1 indicate statistical significance. For Logit models I report the squared correlation instead of R^2.

Table 7: Effects of schooling with municipal fixed effects - limiting

	Starting: Any birth age 19-22	Spacing: Interval between births ages 23-38	Stopping: One more birth age 40-45
	(1)	(2)	(3)
no schooling (reference)			
primary	0.7183***	-0.1495***	1.0141
	(0.016)	(0.009)	(0.019)
secondary	0.2806***	-0.1218***	0.5745***
	(0.031)	(0.019)	(0.04)
Municipal f.e.	Yes	Yes	Yes
S.E Clustered	Municipality	Municipality	Municipality
Observations	755,111	1,162,194	456,066
Pseudo R^2	0.38	0.06	0.10
Method	Logit	OLS	Logit

Notes: Column 1 estimates the probability of having a child for women between 19 to 22 years old using a logit model and to ease the interpretation of the coefficients, these are reported as odd-ratios. Column 2 estimates the size of the interval between 2 children for women that are between 23 and 38 years old and that had at least 2 children and the estimations are done using an OLS model. Column 3 estimates the probability of having one more birth for women with at least one child who are between 40 to 45 years old and the estimations are done using a logit model and the results are also reported as odd-ratios. All models include individual controls such as age, urban location, access to public services, socio-economic status and marital status. Standard errors in parentheses are clustered at the municipality level, and $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$ indicate statistical significance.