RESOURCE CONSTRAINTS AND EDUCATIONAL ATTAINMENT IN DEVELOPING COUNTRIES: COLOMBIA DURING THE TWENTIETH CENTURY [*]

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Abstract

This paper investigates the extent to which secondary and higher education supply constraints affected aggregate educational attainment in Colombia for cohorts born from 1909 to 1981. Until the 1950s, secondary and tertiary Colombian education was highly restrictive, aimed solely at training socially elite students. After the 1950s the number of secondary schools and colleges increased considerably, and consequently, enrollment and attainment at both levels improved. Using variation in cohort size within regions over time to proxy for changes in education demand I estimate that for cohorts born between 1909 and 1944 a 10% increase in cohort size reduced the cohort high school completion rate by 6% and the college completion rate by 9%. For cohorts born after 1945, I find a significantly smaller elasticity, such that a 10% increase in cohort size reduced the high school completion rate by 3% and the college completion rate by 4%.

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Introduction

Over the last two decades, the economic returns to the supply skills in developing countries have increased substantially (Goldberg and Pavnik 2006). Driven by globalization and skill-biased technological change, this rising return to skill suggests that demand for skilled workers has outgrown the capacity of the educational system in developing countries to produce such workers (Katz and Murphy 1992; Goldin and Katz 2008). Available estimates suggest that a probable 40% across-the-board tertiary enrollment expansion in developing countries by the year 2010 will nonetheless bar from the higher education system about 100 million qualified students (Kapur and Crowley 2008).

In this paper, I investigate the extent to which supply constraints reduced educational attainment in Colombia during the twentieth century. For most of the twentieth century, access to the Colombian education system was remarkably limited. During the first half of the century, a private, for-fee scheme dominated secondary school provision in Colombia, which guaranteed exclusive access to only a select socio-economically elite class of students. For instance, during the 1930s and 1940s, the nationwide average secondary pupil/teacher ratio was about ten to one, while at the primary level it was closer to forty-five to one (Ramirez and Téllez 2007). Access to college was even more restricted prior to the 1950s. Universities were clustered in a small number of Colombian cities and only four of Colombia's twenty-three regional departments were home to any tertiary education institutions prior to 1940.

The structure of the education system was reflected in the dismal levels of educational attainment prior to the 1940s. Less than 5% of adults born before 1935 had a secondary diploma and less than 1% had a college degree. Colombian inequality and the average return to education increased substantially between the 1930s and early 1960s as a consequence of the restrictive education policies prior to WWII (Londoño 1995).

Largely due to industrial development and urbanization, access to secondary education increased significantly after the 1950s. Between 1945 and 1960, total government spending in education tripled, secondary teacher training schools expanded, and the government built or nationalized many secondary schools. As a consequence, secondary school enrollment grew faster than population between 1945 and 1960 and the fraction of the population with at least a high school diploma reached almost 50% for cohorts born in the late 1970s and early 1980s. In the 1960s tertiary enrollment increased as well and college completion rates for the population increased from about 2% for cohorts born around 1935 to over 10% for cohorts born in the late 1970s. The educational expansion that began in the 1950s and 1960s induced a sharp decline in Colombian inequality and in the average return to education after 1960 (Londoño 1995).

To identify the role of supply constraints on aggregate educational attainment I use a 'cohort crowding' approach (see Card and Lemieux 2001; Bound and Turner 2007). The intuition behind the cohort-crowding approach I use in this paper is that increases in cohort size increase the demand for education and can therefore reduce the cohort rate of educational attainment if the supply of education resources does not adjust proportionally. I use Colombian census data collected in 1973, 1985, 1993 and 2005 to estimate natural year-to-year variation in population size to proxy for exogenous changes in education demand for cohorts born between 1909 and 1981. I analyze the effect of cohort size on educational attainment using time series variation in cohort size and educational attainment and also variation within departments – administrative units roughly equivalent to U.S. states – over time. I measure educational attainment in terms of high school and college completion rates.

I find three key results. Aggregate time series and department-level analyses both indicate a highly inelastic education supply response to population changes for cohorts born between 1909 and 1944. For these cohorts I estimate that a 10% increase in cohort size at the department level reduces the cohort high school completion rate by 6% and the college completion rate by 9%. The lack of education supply responsiveness was the result of an exclusive education system that restricted access through a private for-fee system at the secondary level.

For cohorts born after 1945, I find that increases in cohort size reduced average school enrollment within departments over time. I estimate an elasticity of school enrollment with respect to cohort size of approximately -0.12. The age pattern of the school enrollment elasticity suggests that cohort size negatively affects school enrollment rates to a greater extent at later ages such as the typical high school (15-18) and college ages (19-22).

Finally, aggregate time series and department-level analyses suggest that a 10% increase in cohort size reduced the cohort high school completion rate by 3% and college completion rate by 4% for cohorts born between 1945 and 1981. I also find that part of the 'cohort crowding' effect for cohorts born in the 1950s and after corresponded to compositional changes in the socioeconomic characteristics of larger versus smaller cohorts and therefore did not entirely reflect supply-side constraints.

Relative to cohorts born before 1945, the close to 50% reduction in the elasticity of educational attainment with respect to cohort size for cohorts born after 1945 highlights the importance of the supply of resources for educational attainment. In the Colombian context, the supply side response that occurred after the 1950s was a combination of school construction, teacher training and better use of facilities such as increased pupil/teacher ratios at the secondary and tertiary levels.

2. Colombian Education in Historical Context

Education policies and the evolution of educational attainment during the twentieth century in Colombia can be divided in two periods: before and after WWII (Ramirez & Téllez 2007, Herrera 1999, Helg 1987). For most of the twentieth century and particularly in the first half, the Colombian education system was tailored to the elite urban class: the children of high-level public servants, industrialists, financiers, doctors and lawyers (Helg 1987).

After WWII industry and in particular the textile, beverages and chemicals sectors began to flourish in cities as a consequence of war-induced shifts in the supply and demand of Colombian imports and exports (Echavarría and Villamizar 2007). The industrialization process led to increased urbanization and internal migration towards urban centers. At the same time, Colombia experienced a population ‘boom’ starting with cohorts born in the early 1950s.

The economic and demographic shifts that occurred during the 1950s increased the demand for secondary schooling. Between 1945 and 1960, total government spending in education tripled, secondary teacher training schools expanded, the government built many secondary schools and nationalized previously clerical secondary schools. As a consequence, secondary school enrollment grew faster than population between 1945 and 1960.

2.1. 1900 to 1940s

At the beginning of the century, the Colombian economy was predominantly agrarian and more than 70% of the population was illiterate. After the “thousand-day war” – a battle between liberals and conservatives which ended in 1902 – conservatives emerged victoriously and ruled until the late 1930s (Helg 1987).

Two notable features of the conservative hegemony between 1900 and 1940 were the non-compulsory status of education and the decentralized structure of education finance. Even as late as the 1950s, departmental—rather than central government-- revenue was the source of 86% of primary education government expenditures (Helg 1987). The decentralized funding structure contributed to the perpetuation of strong regional educational provision disparities because departments that were more affluent during the nineteenth century (i.e. Antioquia) were able to devote more than twice the level of per pupil resources to education relative to poorer departments (i.e. Bolivar). The central government did not disperse any compensatory funding (Helg, 1987).

The second educational feature of the conservative hegemony era was the nearly absolute monopoly of secondary school provision granted to the private sector, particularly to the Catholic Church. During the 1910s and 1920s secondary schooling was an elite privilege. A private for-fee secondary schooling was the way to price-out the masses, relegating them to manual labor in agriculture or mining. In the early 1920s there were approximately 300 secondary schools in Colombia, of which 50% were confessional (Ramirez & Téllez 2007, Helg 1987). Another 40% of secondary schools at the time were for-profit secular schools, typically located in areas with weaker church presence.[1] The following illustrative comment made by a confessional school's principal encapsulates the prevailing mentality toward providing education to the lower classes, as cited in Ramirez & Téllez (2007:478):[2] "Experience has taught us that most families can pay

[1] The remaining schools are private liberal schools, which stand in opposition to the church, and foreign secular schools.

[2] Translation is mine.

the fee and the ones that cannot probably should not deviate their children out of [manual] work professions." Prior to 1950, less than 10% of total government education expenditures went to secondary. Of the 10%, 60% was financed by the departments and 40% by the central government (Helg 1987).

Student-teacher ratios reflect the degree to which secondary supply was constrained. The earliest available data suggests that between early 1930s and late 1940s, the average student-teacher ratio in secondary schools was about ten to one. In contrast, the average student-teacher ratio in primary schools during the same time period was closer to 45 to one (Ramirez & Téllez 2007). The same source indicates that between 1903 and 1950 there were more than ten elementary schools for each secondary school and that as a fraction of primary enrollment, secondary enrollment was less than 10%. As Figure I, Panel B shows, there was very little growth in the number of secondary schools prior to 1945. As a consequence, secondary enrollment prior to 1945 was stagnant (Figure II, Panel A).

A third feature of the educational system under conservative rule prior to the 1940s was the socio-economic exclusivity of tertiary education. In 1905 eight universities - five public and three religious – operated in Colombia. Two more private universities opened before 1925 (Figure I, Panel C).[3] Universities were geographically clustered in a small number of Colombian cities such that only four of Colombia's twenty-three departments had any tertiary education institutions prior to 1940. As a consequence of the exclusivity of tertiary education, there was virtually no growth in tertiary enrollment prior to 1955 (Panel B, Figure II)

[3] The public universities are Nacional, Antioquia, Cartagena, Cauca and Nariño. The religious universities are Rosario, Javeriana and Santo Tomas. The two other universities in 1925 are Externado and Libre, both private secular universities.

With the private user-fee structure of secondary schooling as gatekeeper and the regional disparities in higher education supply, government expenditures in higher education subsidized the education of elite urban classes, preserving the already highly-stratified society. In the early 1950s, for instance, central financing covered two thirds of total government tertiary expenditures and departments covered the remaining one third. As a fraction of central government education spending, tertiary outlays were the highest among all education levels (Helg 1987).

2.2. 1940s to today

By the late 1940s two structural transformations directly affected education policy and educational attainment. The first was an economic transformation induced by WWII. During WWII, Colombian coffee exports plummeted because Europe was at war. The war also reduced imports, mainly of manufactured goods. War-induced shifts in the demand for exports and the supply of imports served to stimulate industrial growth – mainly textiles, beverages and chemicals - and to displace resources away from agriculture. As a result, from 1938 to 1954 the share of the labor force in industrial production tripled, increasing from 12% to 36% (Helg 1987). The change in productive structure after WWII increased the demand for more skilled workers in industrial sectors.

The second post-WWI structural transformation was demographic. During the 1950s death rates dropped as a consequence of improvements in food supply and sanitation, particularly in urban areas. Birth rates remained at pre-WWII levels (Ramírez and Téllez 2007). As a result, population grew at an annual rate of 4% between 1951 and 1964 relative to average annual growth rates of 2.5% between 1918 and 1951 (Helg 1987). In his testimony to congress in 1966, the Colombian national education minister noted that the actual population for 1964 exceeded projections by almost one million people or about 6% of the 1964 level (Arango 1966).

Between the 1940s and 1960s urban population grew ten times faster than did total population (Helg 1987). Besides the demographic transition, rural-urban migration played an important role in urban growth. Rural migration during between the 1940s and 1960s was driven by a 'pull' force - increased employment opportunities in the urban industrial sector that attracted rural workers – as well as a 'push' force - increased rural violence during the 1950s, the period known as *la violencia*, which forced rural families from their homes. As I show later, migration declined secularly for cohorts born in the early 1960s and after.

Between 1945 and 1960, total government spending in education tripled from 1% to 3% GDP, and remained at over 3% until the late 1980s (Ramirez & Téllez 2007). Access to secondary education grew rapidly between the 1940s and 1960s in response to the industrial sector's growing demand for skilled workers. During this time the number of secondary schools doubled (Figure I, Panel B) and the average pupil-teacher ratio increased from ten to one to eighteen to one (Ramirez & Tellez 2007). The central government also authorized the use double school shifts (morning and evening) as a way to use secondary schools' infrastructure more efficiently (Gómez Valderrama 1964).

As a consequence of the different policies, secondary school enrollment grew by more than 200% between 1945 and 1960 from about 55,000 enrolled students to more than 160,000. (Figure II, Panel A). The secondary schooling expansion continued during the 1970s, 1980s and 1990s during which growth in the number of secondary schools and enrollment accelerated from about 4,000 schools and 1.3 million students in the 1970s to more than 10,000 and 3 million students in the 1990s (Figure I, Panel B and Figure II, Panel A). As a fraction of the 12-17 year-old population, secondary enrollment went from 10% in the 1960s to over 60% in the 1990s (Ramírez and Téllez 2007).

One consequence of the increased access to secondary schools after WWII was the subsequent increase in the demand for tertiary education, particularly after the 1960s. During the second half of the twentieth century the number of colleges grew considerably but less so than the growth of secondary schools. The number of tertiary –particularly private-- institutions grew rapidly after the 1960s, and between 1975 and 2005 tertiary enrollment grew by a factor of nine, from 180,000 students to 1.2 million (Figure II, Panel B).

The second implication of the increased access to education after the 1950s was a reduction in inequality (Londoño 1995). Colombian inequality and the average return to education increased substantially between the 1930s and early 1960s as a consequence of the restrictive education policies prior to WWII (Figure A2). By the same token, the educational expansion that began in the 1950s led to a sharp decline in inequality and the return to education after the early 1960s.

3. Time series correlation between educational attainment and cohort size

Pre-WWII, access to secondary and tertiary education in Colombia was limited to a small urban elite and population grew faster than both enrollment and attainment at both levels. Post-WWII, access and enrollment in secondary and tertiary institutions increased in response to population growth and increased demand for skills from the industrial sector. In this section I investigate the aggregate evolution of the relationship between an individual's secondary and tertiary educational attainment and the size of her birth cohort.

3.1 Estimated educational attainment by birth cohort

To construct measures of educational attainment by birth cohort I use data from the Colombian population censuses of 1973, 1985, 1993 and 2005 for natives of age 24 to 64 years old at the time of the census. I model the educational attainment of individual *i*, age *j*, born in year *c* as follows:

$$E_{ijc} = \alpha_c + f(j) + \varepsilon_{ijc}, \qquad (1)$$

where E_{ijc} is the educational attainment of individual *i*, α_c is a birth cohort effect, $f(j)$ is a fixed age profile to account for the fact that educational attainment is observed at different ages, and ε_{ijc} is a combination of sampling and specification error. The $f(j)$ age profile is a quartic polynomial in age, normalized to equal zero at age forty. I estimate equation (1) for two different educational outcomes: completed high school and completed college.

Panel C of Figure II shows the age-adjusted cohort aggregate time series of educational attainment for cohorts born between 1909 and 1981. The data findings mirror the narrative constructed through historical research. There is virtually no progress in high school or college completion rates for cohorts born between 1909 and the early 1930s, which remain at around 4% and 1%, respectively during the period.

As a result increased access to secondary education after 1950 the fraction of the adult population to attain at least a high school diploma grew to 10% for cohorts born in the 1940s and reached almost 50% of the adult population for cohorts born in the late 1970s and early 1980s (Figure II, Panel C). Card and Lemieux (2001) estimate for the US that close tor 90% of the US adult population born in the early 1970s had graduated from high school.

Relative to cohorts in the early 1930s, college completion rates grew tenfold to reach 10% of the adult population for cohorts born in the 1970s and 1980s. For comparison, over 30%

of the US adult population born in the early 1970s had graduated from college (Card and Lemieux 2001).

3.2. Construction of birth cohort size time series

To construct a time series of birth cohort size I use data from the Colombian population censuses of 1973, 1985, 1993 and 2005 for natives of age 24 to 64 years old at the time of the census. Following the methodology in Card and Lemieux (2001) I first construct population counts by department of birth, year of birth and census year. I then estimate the following model:

$$\log(CohortSize)_{dcy} = \pi_c + \overline{f(j)}_{dcy} + e_{dcy}\,, \qquad (2)$$

where $\log(CohortSize)_{dcy}$ is the natural logarithm of the population count of individuals born in department *d,* in year *c* and observed in census year *y*; π_c is a birth cohort effect; $\overline{f(j)}_{dcy}$ is a quartic polynomial in the average age of the department of birth, cohort and census year cell and e_{dcy} is a combination of sampling and specification error. The time series of birth cohort size is captured by the $\hat{\pi}_c$ effects.

3.3. Cohort size and educational attainment

Pre-WWII, the supply of secondary slots grew at a slower pace than did the population, indicating a declining secondary completion rate. Figure III illustrates the negative correlation between the high school completion rate and cohort size. Figure III plots the de-trended natural logarithm of the age-adjusted cohort high school completion rate (measured on the left y-axis) and of the age-adjusted cohort size (measured on the right y-axis). From the beginning of the twentieth century until the 1930 birth cohort, high school completion rates essentially mirrored demographically-induced fluctuations in cohort size.

The high school completion rate increased substantially between the 1935 and 1955 birth cohorts. The increased high school completion rate was the result of the relatively stable size of these birth cohorts in conjunction with the dramatic expansion in the number of secondary schools and secondary enrollment that began in the late 1940s and continued until the 1970s.

Starting with cohorts born in the early 1950s, Colombia experienced a demographic transition characterized by continued high birth rates and decreased mortality rates that extended until the cohorts born around 1965. During this high-birth low-death demographic stage the high school completion rate declined relative to its peak for cohorts born in the late 1940s and early 1950s. Figure IV shows a similar negative time-series correlation between de-trended cohort size and cohort college completion rates.

Table I shows regression analogs of Figures III and IV. The pattern of time-series correlation coefficients suggests a stronger negative association between educational attainment and cohort size for cohorts born pre- as compared to post-1945. This pattern is not surprising considering that there was virtually no growth in secondary or tertiary enrollment prior to 1950 (Figure II).

Table I also indicates a stronger negative correlation between the size of a cohort and its college completion rate than that between the size of a cohort and its high school completion rate. Two reasons explain the larger cohort crowding relationship in college vis-à-vis high-school. First, individuals who are left out of high school are unlikely to enroll in college at a later time. Second, throughout the entire twentieth century, access to college in Colombia was more restricted than was access to high school. Prior to 1950, many Colombian departments did not have colleges. Many students who finished high school in departments without a college entered the labor force. The few with means to enroll in college outside of their home department moved, creating additional pressure on colleges that were already serving local geographic student populations.

4. The relationship between cohort size and educational attainment

If the capacity of the educational system does not expand as rapidly as the student-age population or if it only partially adjusts to changes in population size, students in larger cohorts are "crowded-out" of the educational system. In this section I present a stylized framework of the causal link between cohort size and educational attainment.

I refer to an analytical framework that is largely based on the work of Bound and Turner (2007) and Hansmann (1981). I extend their work by providing a simple parametric example that explicitly illustrates the key comparative static of how exogenous education demand shifts induced by population changes affect enrollment and ultimately educational attainment.

On the supply side of education production, schools and universities (henceforth "schools" in the model) combine their own resources with the ability and effort of students to produce educational attainment. Schools have two sources of revenue: tuition and government transfers. Schools maximize their utility by choosing the number of students to enroll and the amount to spend per student (i.e. quality) subject to: i) student demand, which is an increasing function of quality and a decreasing function of tuition; and ii) a budget constraint. The assumption that schools maximize utility rather than profit is motivated by the large fraction of public and religious schools in Colombia.[4]

Let q and n denote quality and enrollment. Tuition is given by P and denoted by the inverse demand function:

[4] Macleod and Urquiola (2009) provide an alternative framework with a for-profit motive in education provision.

$$P = P\left(q, \frac{n}{pop}\right), \qquad (3)$$

where $\frac{n}{pop}$ represent the cohort enrollment rate. Student demand increases with quality, so that $P_q > 0$, and demand decreases with tuition, $P_{n/pop} < 0$.

Government transfers are given by D. Total production costs are $C = C(q,n)$, with $C_q > 0, C_n > 0$. For public and non-profit schools, the budget constraint corresponds to a zero net revenue (NR) constraint, given by:

$$NR \equiv nP\left(q, \frac{n}{pop}\right) + D - C(q,n) = 0, \qquad (4)$$

Schools care about quality and enrollment.[5] For each school $i's$, the utility function is:

$$U^i = U^i(q,n), \qquad (5)$$

with $U_q^i > 0, U_n^i > 0, U_{qq}^i < 0, U_{nn}^i < 0$. A school-specific utility function captures the idea that some schools might place greater weight on quality while others might emphasize enrollment. Therefore, each school $i's$ problem is to choose quality and enrollment so as to maximize (5) subject to (3) and (4).

4.1 A parametric example

I make the following parametric simplifications to illustrate the key comparative statistic in the model. Let the inverse education demand function be linear in its arguments and, thus, take the following form:

$$P\left(q, \frac{n}{pop}\right) = q - \frac{n}{pop}. \qquad (6)$$

[5] Schools that care more about quality might, for example, be more selective and charge higher fees.

I also assume that education is produced under a constant returns to scale technology and that the per-student cost of producing education of quality q is q. Therefore, total costs $C(q,n)$ are: $C(q,n) = nq$.

Finally, assume that tuition P is exogenously determined. Under these assumptions, the zero net revenue constraint $NR = 0$ given by equation (4) becomes:

$$q = P + \frac{D}{n}. \qquad (7)$$

The slope of the zero non-revenue constraint is therefore:

$$\frac{dq}{dn}\Big|_{NR=0} = -\frac{D}{n^2}. \qquad (8)$$

To illustrate the effect of exogenous education demand shifts induced by changes in population size, I analyze two extreme cases: i) schools that maximize enrollment and ii) schools that maximize quality.

Case 1: Enrollment maximization

An enrollment-maximizing school will enroll as many students as possible as long as it satisfies the zero net revenue constraint. Therefore, it will set enrollment at the point were demand, given by (6) equals the zero net revenue constraint, given in (7). The enrollment-maximizing level of enrollment n^e is:

$$n^e = \sqrt{D * pop}, \qquad (9)$$

And the quality of education that the enrollment-maximizing school provides is:

$$q^e = P + \sqrt{\frac{D}{pop}}. \qquad (10)$$

Case 2: Quality maximization

A quality-maximizing school will choose a level of enrollment no larger that the enrollment-maximizing choice. Intuitively, a quality-maximizing school can always raise the level of quality provided by restricting supply and generating excess demand since the production technology is increasing in student quality and per-pupil resources. Therefore the optimal enrollment level for a quality-maximizing school is given by:

$$\min\{n^q, n^e\}, \qquad (11)$$

where n^q is implicitly defined by the tangency of the marginal rate of substitution between enrollment and quality and the no-profit constraint, and n^e is the enrollment-maximizing level given by (9). For the quality-maximizing provider, enrollment will be independent of student demand and therefore, the quality-maximizing level of enrollment will be lower than the level of enrollment determined by demand: $n^q \leq n^e$.

4.2 Comparative statics

The key comparative static in this model is how does an exogenous demand shift caused by an increase in cohort size changes student enrollment. As before, I analyze the comparative static for two extreme cases. For the case of enrollment maximization the comparative static is given by:

$$\frac{dn^e}{dpop} = \frac{1}{2} * \sqrt{\frac{D}{pop}}, \qquad (12)$$

For the quality-maximization case:

$$\frac{dn^q}{dpop} = 0, \qquad (13)$$

since the level of enrollment is independent of student demand for the quality-maximizing school.

This highly stylized parametric framework predicts that an exogenous shift in demand caused by an increase in cohort size will induce a less than proportional increase in enrollment. At one extreme, equation (12) suggests that in the enrollment maximization case, without proportional increases in government transfers D, exogenous increases in cohort size lead to a less than proportional increase in enrollment due to lower resources per student D/Pop. At the quality maximization extreme -- representative of the religious secondary schools in the earlier part of the twentieth century -- changes in demand will not affect enrollment and will only exacerbate excess demand. In all other intermediate cases the adjustment will range from zero to less than proportional, depending on how the school weighs the tradeoff between enrollment and quality.

5. Cohort Size, Enrollment and Educational Attainment within Departments over Time

In the aggregate time-series data, educational attainment is negatively correlated with cohort size. However, there are at least two reasons to favor a cohort size and educational attainment analysis at the department level over time. The first reason is that Colombian departments have traditionally played a key role in education finance. Between 1923 and 1950, departmental and municipal educational outlays represented more than 60% of total government expenditures in education (Ramírez and Tellez, 2007). Over the same period, departments alone financed more than 80% of total primary education expenditures, more than 60% of secondary and about 35% of tertiary (Helg, 1987). While the departmental share of government expenditures in education declined during the 1960s in response to increased central government education support, it still represented about 40% of the total over the period (Ministerio de Educación Nacional, 1969).

The second reason to focus on changes in cohort size and educational attainment within departments over time is that aggregate changes in cohort size might affect national labor market conditions and the returns to high school/college education. For example, larger cohorts might have lower returns to education if younger workers are imperfect substitutes for older workers (Welch 1979). To the extent that labor markets are nationally integrated, looking at variation in cohort size within departments over time, net of national trends, eliminates this potential source of bias.

In this section I discuss how I use variation within departments over time to study the relationship between cohort size, enrollment and attainment. Throughout, I restrict my analysis to departments only, leaving out national territories.[6]

5.1. Cohort size and school enrollment by age

5.1.1. Estimation of relationship between enrollment and cohort size

To estimate the relationship between enrollment in school and cohort size I use individual level school enrollment data for nationals age 5 to 22 at the time of the census from Colombian censuses 1973, 1985, 1993 and 2005 to construct the average enrollment level by department, cohort of birth and census year. Separately for each age group, I then estimate an equation of the following form:

$$\log(Enrollment)_{dc} = \beta \cdot \log(CohortSize)_{dc} + \gamma_d + \delta_c + \gamma_d \cdot cohort + \vartheta_{dc}, \qquad (14)$$

[6] National territories, which represent less than 2% of total population, only gained departmental status with the constitutional reform of 1991. The national territories are: Arauca, Casanare, Putumayo, San Andrés, Amazonas, Guainía, Guaviare, Vaupes and Vichada.

where $\log(Enrollment)_{dc}$ is the natural logarithm of average school enrollment for individuals born in department d and cohort c, $\log(CohortSize)_{dc}$ is the natural logarithm of cohort size by department and cohort of birth, γ_d and δ_c are department of birth and cohort of birth fixed effects, $\gamma_d \cdot cohort$ are department-specific time trends and ϑ_{dc} is a combination of other unobserved factors affecting enrollment at the department-cohort level and sampling error. The parameter β measures the elasticity of enrollment with respect to cohort size. The model is separately estimated for age groups defined by the age dyads 5-6, 7-8…., 21-22.

5.1.2. Enrollment and cohort size results

Figure V presents results of this estimation procedure. The circles in Figure V correspond to the estimate of $\hat{\beta}$ for each age group in equation (14). The vertical lines represent the 95% confidence intervals computed using heteroskedasticity robust standard errors.

Figure V suggests that for cohorts born after 1950 there is a negative and statistically significant relationship between cohort size and school enrollment. At the same time, while estimates for the different age groups are statistically indistinguishable from each other, Figure V reveals a clear pattern in the magnitude of the coefficients that is consistent with the time series evidence. The cohort crowding effects on enrollment occur at typical transition ages in the education cycle and are strongest after age 14.

For example, for individuals 7-8 years old -- the typical age range for students starting elementary school-- a 10% increase in cohort size reduces enrollment by 1.5%. The cohort size elasticity point estimates for 11 to 12 year olds -- the typical age range for students transitioning to middle school and -- and for 15 to 16 year olds -- the typical age range for students transitioning to high school— are comparable in magnitude to the estimate for the 7-8 age group, implying a 1.5% reduction in enrollment for a 10% increase in cohort size.

As Figure V indicates, the cohort size elasticity of enrollment increases (in absolute value) almost monotonically after age 14. The age pattern of the cohort size elasticity suggests stronger 'cohort crowding' effects on enrollment during secondary school and particularly college, although the point estimates are indistinguishable from each other.

5.2. Changes in cohort size and high school completion

I now discuss the effect of demand shocks induced by population variation on educational attainment, beginning with the high school completion outcome. The type of variation in cohort size that identifies the demand shock effect on high school completion is illustrated in Figure VI. In Figure VI I plot for each of six selected departments the de-trended times series evolution of the cohort high school completion rate and cohort size (Figures for all departments are available upon request). Year to year variation in cohort size identifies the demand shock effect for cohorts born before 1945. For cohorts born after 1945, the variation in cohort size induced by the demographic transition into lower mortality rates and high birth rates for cohorts born between 1945 and 1965 and the fertility reduction thereafter identify the demand shock effects.

5.2.1 Estimation of changes in cohort size and high school completion

To test whether department-specific changes in cohort size relate to department-level changes in the cohort high school completion rate I estimate models of the following form:

$$\log(HS)_{dc} = \theta \cdot \log(CohortSize)_{dc} + \gamma_d + \delta_c + \overline{f(j)}_{dc} + \xi_{dc}, \qquad (15)$$

where $\log(HS)_{dc}$ is the natural logarithm of the high school completion rate for individuals born in department d in year c; $\log(CohortSize)_{dc}$ is natural logarithm of age-adjusted population count by department and cohort of birth (age-adjustment is a quartic polynomial in age normalized to equal zero at age forty to account for the fact that different cohorts are measured at different ages in the different censuses); γ_d and δ_c are department of birth and cohort of birth fixed effects, $\overline{f(j)}_{dc}$ is a quartic polynomial of the mean normalized age in each department and cohort of birth cell and ξ_{dc} is a combination of other unobserved factors affecting high school attainment at the department-cohort level and sampling error. The parameter θ measures the elasticity of high school completion with respect to cohort size. I estimate model (15) using data aggregated at the department and birth cohort cell level from a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. In the preferred specifications I include department-specific trends.

Not all individuals born in a given department live in that department during their teen and early adulthood years. The relevant measure of cohort size for the effect on high school or college completion is the size of a person's cohort at the time and in the department they enroll in high school or college. Therefore, the measure of cohort size I use contains some measurement error.

To calculate the amount of measurement error in my constructed cohort size variable, I follow Bound and Turner (2007) and use data from Colombian censuses 1973, 1985, 1993 and 2005 for 15-17 year old nationals and regress the natural logarithm of current department of residence's cohort size on the natural logarithm of department of birth's cohort size, controlling for department and census year effects. The coefficient on the department of birth cohort size variable is 0.92, suggesting that the extent of measurement error is about 8%. Tables II and III also show estimates corrected for measurement error, with standard errors calculated using the delta method.

5.2.2 Changes in cohort size and high school completion results

Table II shows estimates of the elasticity of the cohort high school completion rate with respect to cohort size. Estimates in Panel A, columns (1) and (2) indicate that for cohorts born between 1909 and 1944 a 10% increase in cohort size reduces the cohort high school completion rate by about 6%. Including department-specific trends, as in column (2), changes little the cohort size point estimates.

Panel B and Panel C of Table II show separate results for men and women. For cohorts born before 1945, results suggest slightly stronger 'cohort crowding' effects for women than for men although the 95% confidence intervals for all the estimates overlap considerably.

Columns (3) and (4) of Table II show cohort size estimates for cohorts born after 1945. Relative to early cohorts, the cohort size elasticity of high school completion is noticeably lower for cohorts born after 1945. The point estimates indicate that for these cohorts, a 10% increase in cohort size reduces high school completion by 1.4% to 3.2%. Including department-specific trends generally increases (in absolute value) the elasticity estimate.

In contrast with estimates for early cohorts, estimates of the elasticity of cohort size are larger (in absolute value) for men than for women born after 1945 (Panel B and Panel C of Table II). Educational attainment begins to grow faster for Colombian women than for men starting with the 1930s birth cohorts, and after 1960 birth cohort, women are increasingly more educated than men (Appendix A, Figure A1).

The pattern of high school completion elasticities with respect to cohort size in Table II highlights the human capital consequences of the restricted nature of secondary schooling during the first part of the twentieth century in Colombia. The rapid expansion in secondary schools and enrollment after 1950 led to a secondary schooling system that was better able to incorporate rising demands for more education induced by urbanization and nascent industrialization that take off during the second half of the twentieth century.

5.3. Changes in cohort size and college completion results

Figure VII illustrates the time series variation in cohort size and the cohort college completion rate, net of a quadratic trend, for selected departments. The secular decline in population growth relative to its long-term trend for cohorts born between 1925 and 1945 is a period of increasing college completion rates. Similarly, the negative effect of the high-birth low-death demographic transition for cohorts born between the late 1940s and early 1960s corresponds to a period of declining college completion rates. As Figure VII shows, the low-birth low-death demographic transition that takes place beginning with cohorts born in the early 1960s corresponds to a period of increasing cohort college completion rates.

Estimates in Table III (regression analogs of Figure VII) correspond to specification (15) with the natural logarithm of the department and birth cohort-specific college completion rate as the dependent variable. Consistent with the time series and historical evidence, the capacity of the tertiary sector did not respond to changes in college demand during the early part of the twentieth century. As a consequence, for cohorts born before 1945, a 10% increase in population led to an 8% to 9% reduction in the cohort college completion rate.

For cohorts born after 1945 there is considerably lower and statistically different effect of cohort size on cohort college completion rates of about -.3 to -.4 in the preferred specifications that include department-specific trends (columns 3 and 4 of Table III). College availability expanded drastically after the early 1960s (Figure I.B) and this expansion resulted in much higher college enrollment and completion rates. Despite the significant expansion in college supply, a 10% increase in cohort size leads to a 3% to 4% reduction in college completion rates for cohorts born after 1945, with slightly larger (although statistically indistinguishable) cohort crowding effects for men (Panel B and C, Table III).

The Colombian college cohort crowding estimates for cohorts born after 1945 are similar in magnitude to the U.S. estimates reported by Card and Lemieux (2001) and Bound and Turner (2007). They estimate that a 10% increase in cohort size reduces cohort college completion by between 2% and 4%.

Similar estimates of the elasticity of BA completion to cohort size in Colombia and the U.S. could reflect in part a comparable public-private institutional mix in the provision of higher education in the two countries. In recent years, about 50% of all higher education institutions are private and about 70% of the college population attends private institutions in Colombia and in the U.S. A similar public-private college market mix suggests potentially similar college funding sources at the aggregate level, which in turn determine the overall supply-side responsiveness to demand shocks such as changes in cohort size.

5.4 Migration

In this section I investigate the quantitative importance of migration in measures of cohort size. Using data from 15-40 year olds in Colombian censuses 1985, 1993 and 2005 I construct cohort-level estimates of migration probabilities in the previous five years as follows:[7]

$$Migrate_{icy} = \pi_c + f(j)_{icy} + \upsilon_{icy}, \qquad (16)$$

where $Migrate_{icy}$ equals one if individual i of birth cohort c and observed in census year y migrated during the previous five years and zero otherwise, π_c are birth cohort effects, $f(j)_{icy}$ is a quartic polynomial in individual age normalized to zero at age thirty, and υ_{icy} is a combination

[7] Question on migration during previous five years is not available in the 1973 Census.

of sampling and specification error. I construct two different migration indicators: within and across departments.

Figure VIII plots the birth cohort effects $\hat{\pi}_c$, separately for the two different migration outcomes. Consistent with the historical evidence of the pull toward industry and push out of violence, migration was highest for cohorts born in the late 1940s and early 1950s, and declined thereafter. For instance, 9% of individuals born in 1945 had migrated from a different department during the previous five years and about 7% had migrated from a different town within the same department. Among individuals born in 1985, 2% had migrated from a different department and 4% had migrated within the same department (Figure VIII.A).

Figure VIII.B shows de-trended migration time-series. Relative to the long term trend, Figure VIII.B indicates increasing migration for cohorts born in the late 1940s and early 1950s. Relative to its long term trend, the decline in migration for cohorts born between 1955 and 1965 contrasts with the increase in population (relative to its long term trend) for these cohorts (Figures III and IV). Similarly, the period of fastest migration growth takes place between the 1965 and 1975 birth cohorts, which corresponds to the transition from low mortality and high fertility to low mortality and low fertility rates (Florez 2000 and Figures III and IV).

For cohorts born after 1955, aggregate migration and population trends are negatively correlated. The negative correlation between migration and population therefore suggests that in the later part of the twentieth century migration likely mitigated rather than accentuated education demand shifts induced by population growth.

6. Changes in cohort composition over time

Due to the dramatic re-composition of the student-age population for cohorts born after WWII, in this section I investigate differences in the socioeconomic characteristics of large and small cohorts along dimensions that affect educational attainment. I explore the relationship between socioeconomic characteristics and cohort size for cohorts born after 1957 in Table IV. I construct a sample from Colombian censuses 1973, 1985, 1993 and 2005 of 15 and 16 year-old nationals who report living with at least one parent.

The socioeconomic characteristics I focus on are whether household has electricity, whether household has sewage system, number of children in household, whether father (if present) is a college graduate and whether mother (if present) is a college graduate. I compute the mean for each of these characteristics by department of birth and cohort. Using a specification like (15), I regress each one of the household and parental characteristics on the natural logarithm of birth cohort size, controlling for department and cohort of birth fixed effects. Each coefficient reported in Table IV thus comes from a separate regression. Table IV also reports estimates weighted by population size, which is of little practical importance.

With the exception of number of children in the household and whether the household mother is a college graduate, all other coefficients are statistically insignificant. The cohort size estimate on number of children in the household indicates that a 10% increase in cohort size at the mean leads to a 1% increase in the number of children (0.052/4.55). Similarly, the cohort size estimate on whether the mother is a college graduate indicates that a 10% increase in cohort size reduces the department-level probability of having a college-graduate mother by about 11% at the mean (0.0015/0.013). To the extent that household size and parental education affect children's educational attainment, part of the 'crowding out' effect I document for cohorts born after 1945 is explained by demand-side, compositional changes and not entirely by supply-side constraints.

7. Conclusion

During the first half of the twentieth century, the supply of education in Colombia was constrained and as a result, relative to smaller cohorts, larger ones had substantially lower rates of high school and college completion. Using variation in cohort size within departments over time I estimate that for cohorts born between 1909 and 1944 a 10% increase in cohort size reduces cohort high school completion rates by 6% and college completion rates by 9%.

After WWII there is considerable growth in the number of secondary and tertiary education institutions and in enrollment, resulting in higher average attainment. While larger cohorts born after 1945 were also less educated, on average, than smaller ones, the education system was better able to accommodate increasing demand. As a result of the educational expansion that occurred after 1950, many youths who would have otherwise been forced to exit the education system after completing primary school, enrolled in secondary and even tertiary education.

For cohorts born between 1945 and 1981 I estimate that a 10% increase in cohort size reduces cohort high school completion rates by 3% and college completion rates by 4%. Part of the 'cohort crowding' effect for cohorts born after 1945 reflects compositional changes in the socioeconomic characteristics of larger versus smaller cohorts. Therefore, this "cohort crowding" effect does not entirely reflect supply-side constraints.

I attribute the post-WWII reduction in the extent to which supply constraints reduce educational attainment to demand and supply forces. The process of industrialization and urbanization that begins in the 1950s increased the demand for secondary and later tertiary education. At the same time, as a consequence of the rapid growth in public secondary schooling, enrollment for cohorts born after 1950 grew faster than the population. The early massification of secondary schooling and increased access to higher education explain the rapid economic progress and declining inequality in the US for much of the twentieth century (Goldin and Katz 2008). Similarly, the structure of Colombian education before 1950 preserved an already highly-stratified society and stalled educational attainment and economic growth. By contrast, the Colombian educational expansion that took place after the 1950s explains the inequality reduction after 1960 (Londoño, 1995).

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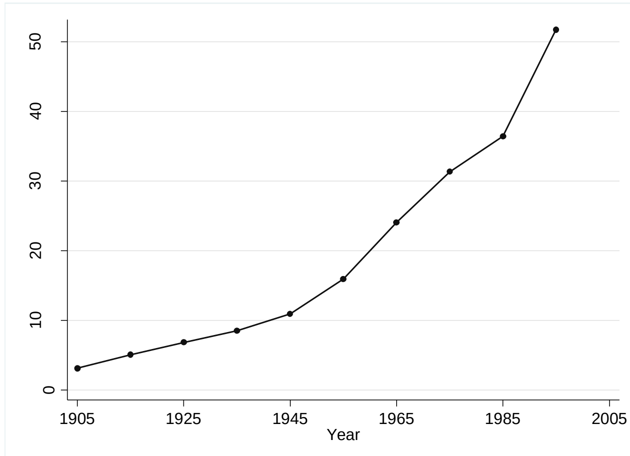
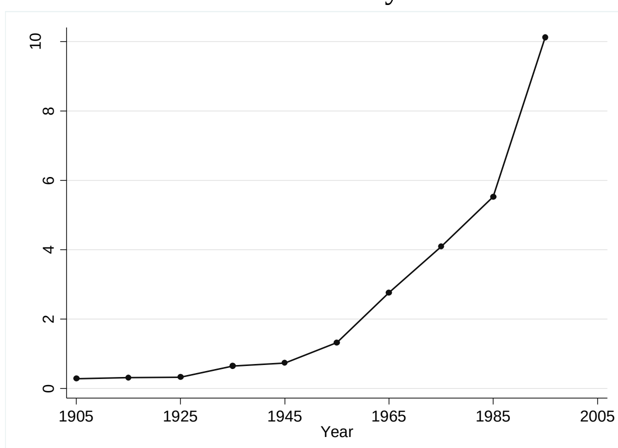
Figure I: Education Institutions in Colombia 1905-2005

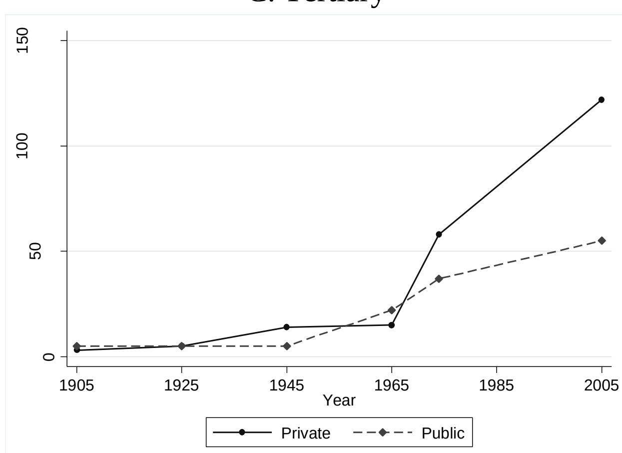
A. Primary



B. Secondary



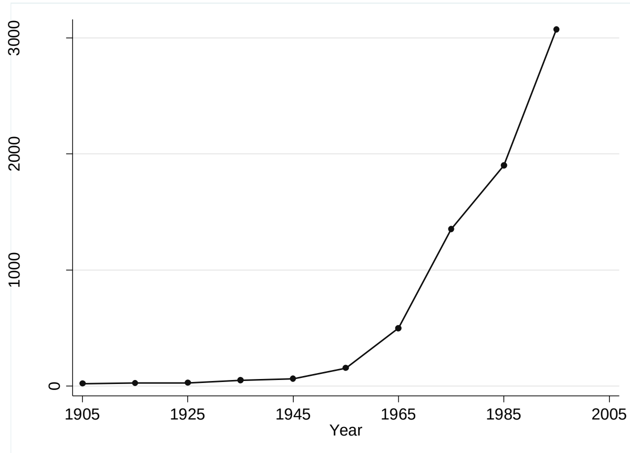
C. Tertiary



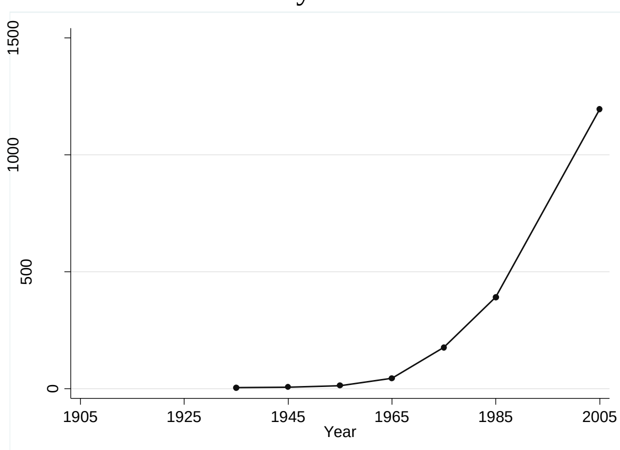
Source: Ramirez and Téllez (2007) for primary and secondary schools, numbers are decadal averages. For tertiary institutions, data is Universidad Nacional (2009) for 1905 and 1925, Lucio & Serrano (1992) for 1945, 1965 and 1975 and Ministerio de Educacion (2009) for 2005.

Figure II: Secondary and Tertiary Enrollment and Attainment

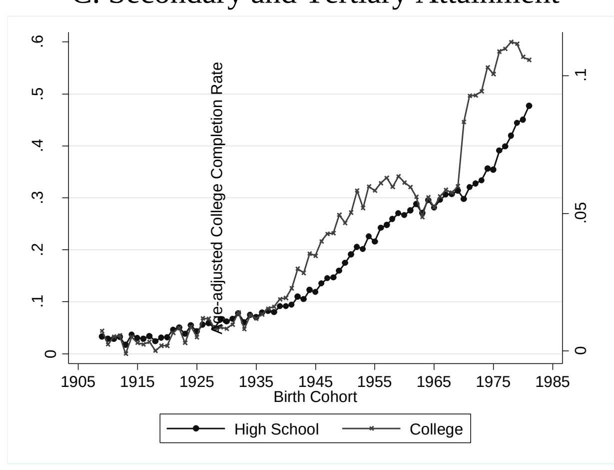
A. Secondary Enrollment



B. Tertiary Enrollment

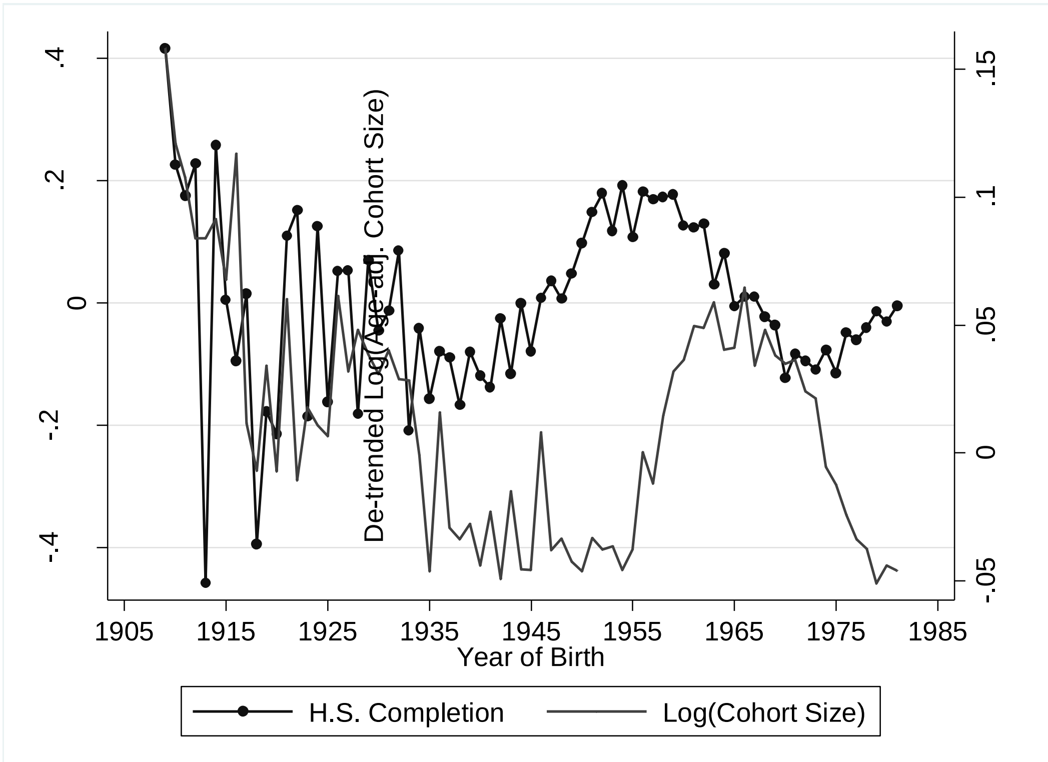


C. Secondary and Tertiary Attainment



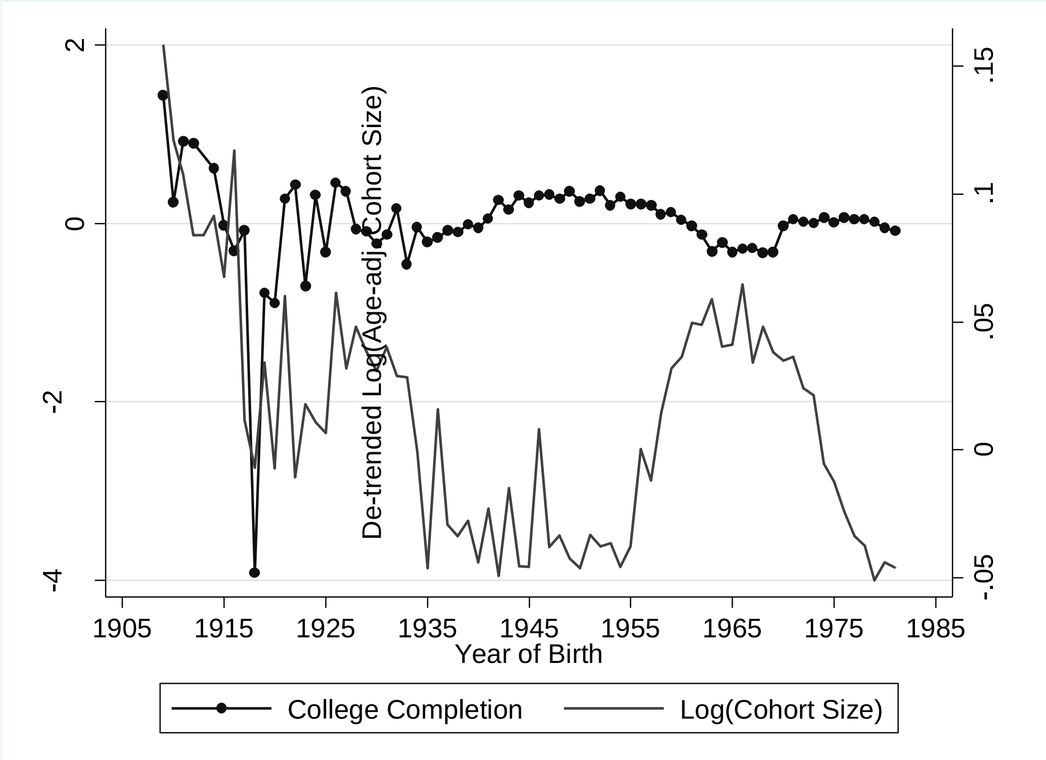
Notes: Secondary enrollment data is from Ramirez and Tellez (2007) and represents decadal averages. Tertiary enrollment data is from Lucio and Serrano (1992) until 1985 and from SNIES Ministerio de Educacion (2009) http://snies.mineducacion.gov.co/men/ for 2005. In Panel C, age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty. Age-adjusted cohort aggregates in Panel C are estimated using a sample of 24-64 year-old nationals in Colombia censuses 1973, 1985, 1993, 2005.

Figure III
De-trended High School Completion Rates and Cohort Size by Birth Cohort



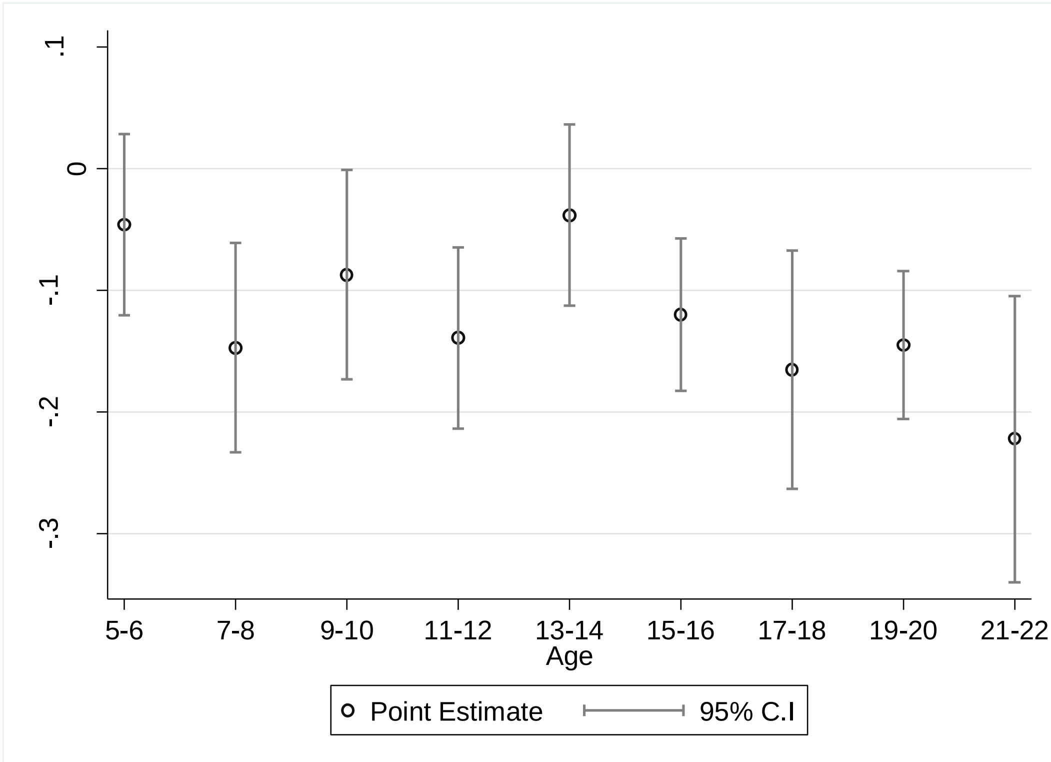
Notes: Graph plots the residual of the natural logarithm of age-adjusted high school completion rate by birth cohort net of a quadratic time trend and the residual of the natural logarithm of age-adjusted birth cohort size net of a quadratic time trend. Age-adjusted cohort aggregates are estimated using a sample of 24-64 year-old nationals in Colombia censuses 1973, 1985, 1993, 2005. Age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty. Cohort size series is a moving average with three lags and four leads.

Figure IV
De-trended College Completion Rates and Cohort Size by Birth Cohort



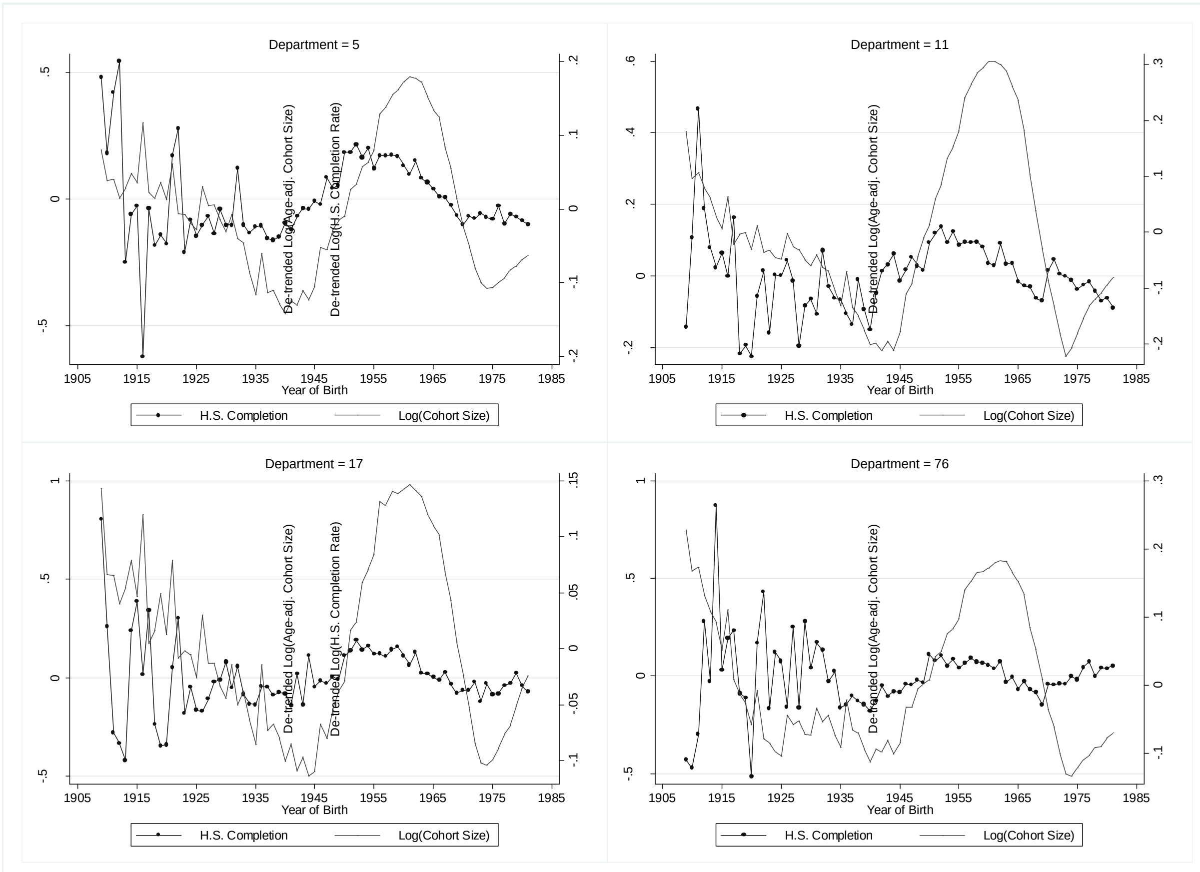
Notes: Graph plots the residual of the natural logarithm of the age-adjusted college completion rate by birth cohort net of a quadratic time trend and the residual of the natural logarithm of age-adjusted birth cohort size net of a quadratic time trend. Age-adjusted cohort aggregates are estimated using a sample of 24-64 year-old nationals in Colombia censuses 1973, 1985, 1993, 2005. Age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty. Cohort size series is a moving average with three lags and four leads.

Figure V
School Enrollment Elasticity with Respect to Cohort Size by Age Group



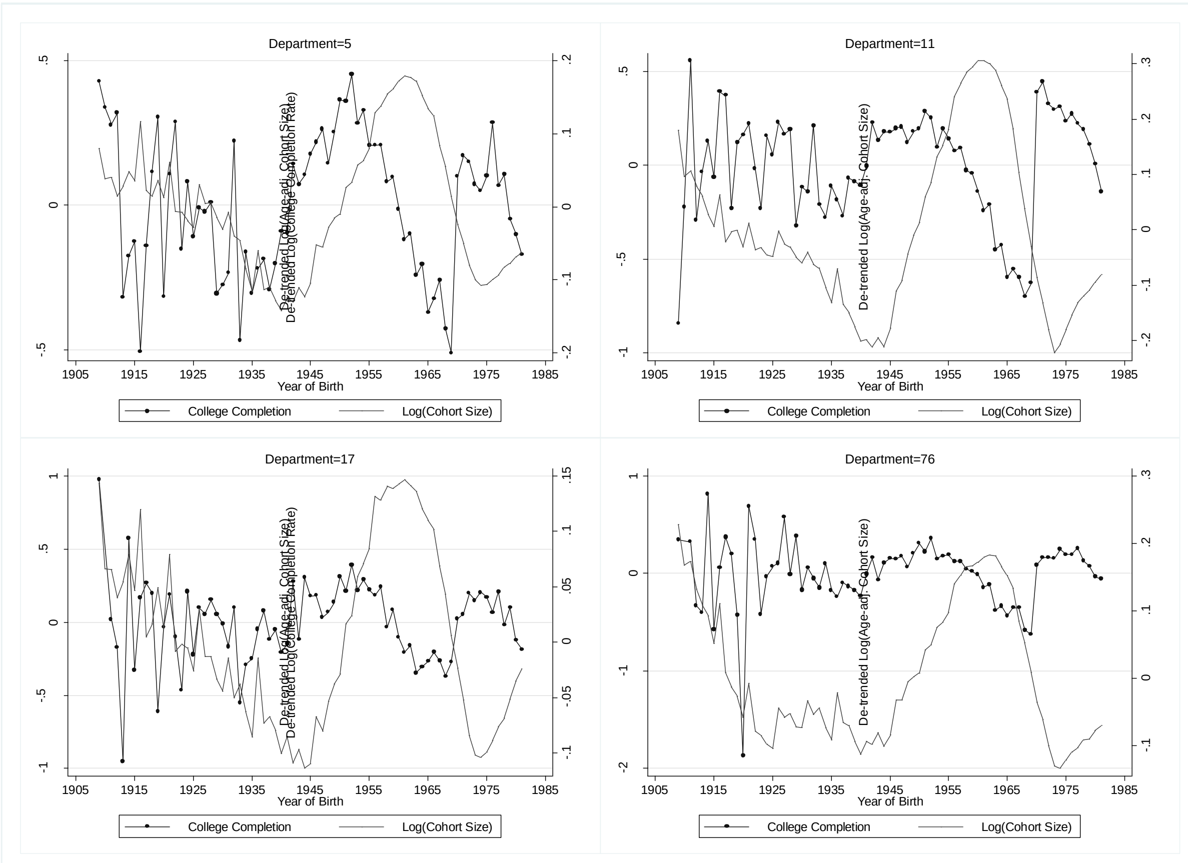
Notes: Circles correspond to coefficients on Log (Cohort Size) from separate regressions for each age group of the department and birth cohort-specific average school enrollment rate (dichotomous enrolled/not at the individual level) that also control for department and cohort of birth fixed effects and department-specific time trends. The vertical lines correspond to 95% confidence intervals computed using heteroskedasticity robust standard errors. Department and birth cohort-specific average enrollment rates and cohort size measures are estimated from a sample of 5-22 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005.

Figure VI
De-trended High School Completion Rates and Cohort Size by Birth Cohort
Selected Departments



Notes: Graph plots the residual of the natural logarithm of the age-adjusted high school completion rate by birth cohort net of a quadratic time trend and the residual of the natural logarithm of age-adjusted birth cohort size net of a quadratic time trend, separately for selected departments. Age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty. The natural logarithm of age-adjusted birth cohort size is a moving average with three lags and four leads. Department and birth cohort-specific high school completion rates and age-adjusted cohort size measures are estimated using a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. Department=5 corresponds to Antioquia, 11 to Bogota, 17 to Caldas and 76 to Valle.

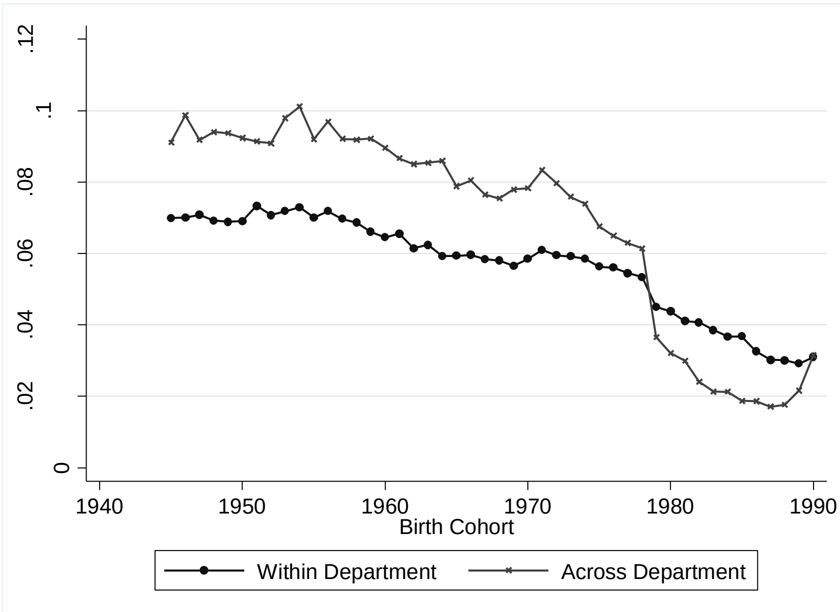
Figure VII
De-trended College Completion Rates and Cohort Size by Birth Cohort
Selected Departments



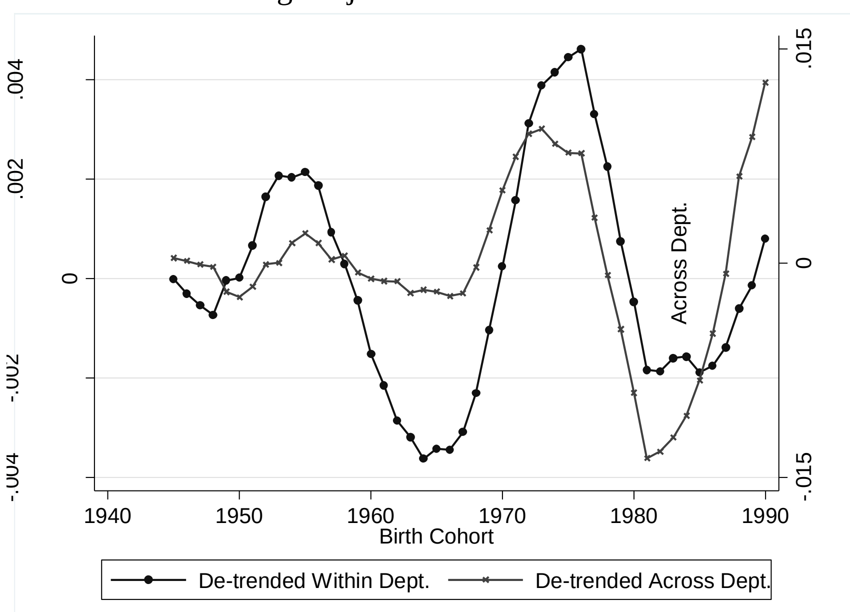
Notes: Graph plots the residual of the natural logarithm of the age-adjusted college completion rate by birth cohort net of a quadratic time trend and the residual of the natural logarithm of age-adjusted birth cohort size net of a quadratic time trend separately for selected departments. Age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty. The natural logarithm of age-adjusted birth cohort size is a moving average with three lags and four leads. Department and birth cohort-specific college completion rates and age-adjusted cohort size measures are estimated using a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. Department=5 corresponds to Antioquia, 11 to Bogota, 17 to Caldas and 76 to Valle.

Figure VIII
Migration Within and Across Departments by Birth Cohort

A. Age-adjusted



B. Age-adjusted net of time trends



Notes: Panel A plots the age-adjusted (quartic polynomial in age normalized to zero at thirty) probability of migration by birth cohort. Panel B plots the residual of the age-adjusted probability of migration by birth cohort, net of a quadratic time trend. The residual is a 5-year moving average. Age-adjusted migration probabilities by birth cohort are estimated from a sample of 15-40 year-old nationals in Colombian censuses 1985, 1993, 2005.

Table I
Time series correlation between educational attainment and birth cohort size

	Log (College Completion Rate)		Log (High School Completion Rate)	
	(1)	(2)	(3)	(4)
A. All Birth Cohorts 1909-1981				
Log (Cohort Size)	-1.600	-1.479	-0.445	-0.391
	[0.066]	[0.635]	[0.086]	[0.083]
B. Birth Cohorts 1909-1944				
Log (Cohort Size)	-1.625	-1.542	-0.436	-0.435
	[0.766]	[0.754]	[0.086]	[0.091]
C. Birth Cohorts 1945-1981				
Log (Cohort Size)	-0.509	-0.432	-0.219	-0.347
	[0.200]	[0.221]	[0.188]	[0.109]
Linear Time Trend	Yes	Yes	Yes	Yes
Quadratic Time Trend	No	Yes	No	Yes

Notes: Data is cohort aggregate data. Log (College Completion Rate) is the natural logarithm of the age-adjusted college completion rate by birth cohort. Log (High School Completion Rate) is the natural logarithm of the age-adjusted high school completion rate by birth cohort. Log (Cohort Size) is the natural logarithm of the age-adjusted population count by cohort of birth. Age-adjusted cohort aggregates are estimated using a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. Age-adjustment is a quartic polynomial in age, normalized to equal zero at age forty.

Table II
The effect of cohort size on high school completion rates within departments over time

	1909-1944		1945-1981	
	(1)	(2)	(3)	(4)
A. All				
Log Cohort Size	-0.568	-0.582	-0.129	-0.29
	[0.112]	[0.128]	[0.026]	[0.039]
Corrected Log Cohort Size	-0.617	-0.632	-0.14	-0.316
	[0.122]	[0.140]	[0.028]	[0.042]
Observations	831	831	888	888
B. Men				
Log Cohort Size	-0.583	-0.684	-0.122	-0.34
	[0.095]	[0.113]	[0.030]	[0.058]
Corrected Log Cohort Size	-0.633	-0.743	-0.133	-0.37
	[0.103]	[0.123]	[0.033]	[0.063]
Observations	810	810	888	888
C. Women				
Log Cohort Size	-1.029	-0.761	-0.112	-0.214
	[0.157]	[0.189]	[0.029]	[0.045]
Corrected Log Cohort Size	-1.119	-0.827	-0.122	-0.232
	[0.171]	[0.205]	[0.032]	[0.048]
Observations	779	779	888	888
Age Controls	Yes	Yes	Yes	Yes
Department Fixed Effects	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes
Department-specific Trends	No	Yes	No	Yes

Notes: Dependent variable is the natural logarithm of department and birth cohort-specific high school completion rate. Log (Cohort Size) is the natural logarithm of department and birth cohort-specific age-adjusted population count. Department and birth cohort-specific high school completion rates and age-adjusted cohort size measures are estimated using a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. Age controls are a quartic polynomial of mean age by department and birth cohort cell. The Log (Cohort size) measurement error correction is 0.92. Heteroskedasticity robust standard errors are in brackets. Standard errors for corrected cohort size estimates are computed using the delta method.

Table III
The effect of cohort size on college completion rates within departments over time

	1909-1944		1945-1981	
	(1)	(2)	(3)	(4)
A. All				
Log Cohort Size	-0.805	-0.863	-0.139	-0.362
	[0.146]	[0.193]	[0.044]	[0.088]
Corrected Log Cohort Size	-0.875	-0.938	-0.151	-0.394
	[0.158]	[0.210]	[0.048]	[0.095]
Observations	756	756	888	888
B. Men				
Log Cohort Size	-0.786	-0.678	-0.09	-0.388
	[0.139]	[0.181]	[0.052]	[0.106]
Corrected Log Cohort Size	-0.854	-0.737	-0.098	-0.421
	[0.151]	[0.196]	[0.057]	[0.115]
Observations	751	751	888	888
C. Women				
Log Cohort Size	-1.103	-0.601	-0.094	-0.287
	[0.241]	[0.321]	[0.070]	[0.116]
Corrected Log Cohort Size	-1.199	-0.654	-0.103	-0.312
	[0.262]	[0.347]	[0.076]	[0.126]
Observations	504	504	888	888
Age Controls	Yes	Yes	Yes	Yes
Department Fixed Effects	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes
Department-specific Trends	No	Yes	No	Yes

Notes: Dependent variable is the natural logarithm of the department and birth cohort-specific college completion rate. Log (Cohort Size) is the natural logarithm of department and birth cohort-specific age-adjusted population count. Department and birth cohort-specific college completion rates and age-adjusted cohort size measures are estimated using a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005. Age controls are a quartic polynomial of mean age by department and birth cohort cell. The log (Cohort size) measurement error correction is 0.92. Heteroskedasticity robust standard errors are in brackets. Standard errors for corrected cohort size estimates are computed using the delta method.

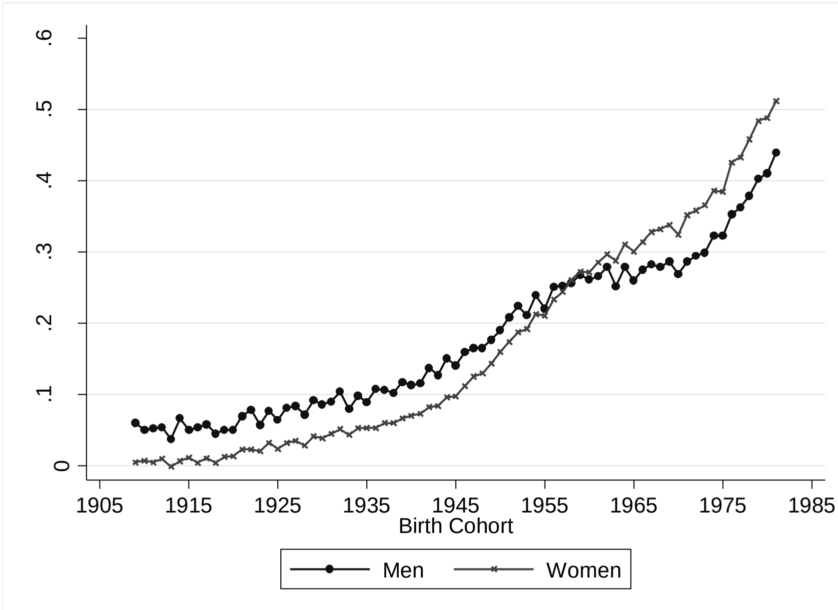
Table IV
Household Characteristics and Cohort Size

	Coefficient on Log(Cohort Size)	
	(1)	(2)
Dependent Variable is:		
Household has Electricity (Mean=0.74)	-0.03	-0.03
	[0.047]	[0.046]
Household has Sewage (Mean=0.57)	0.046	0.035
	[0.027]	[0.025]
Number of Children (Mean=4.55)	0.52	0.52
	[0.079]	[0.079]
Father College Graduate (Mean=0.02)	-0.008	-0.009
	[0.006]	[0.006]
Mother College Graduate (Mean=0.013)	-0.013	-0.015
	[0.006]	[0.007]
Cohort Fixed Effects	Yes	Yes
Department Fixed Effects	Yes	Yes
Population Weights	No	Yes
Observations	192	192

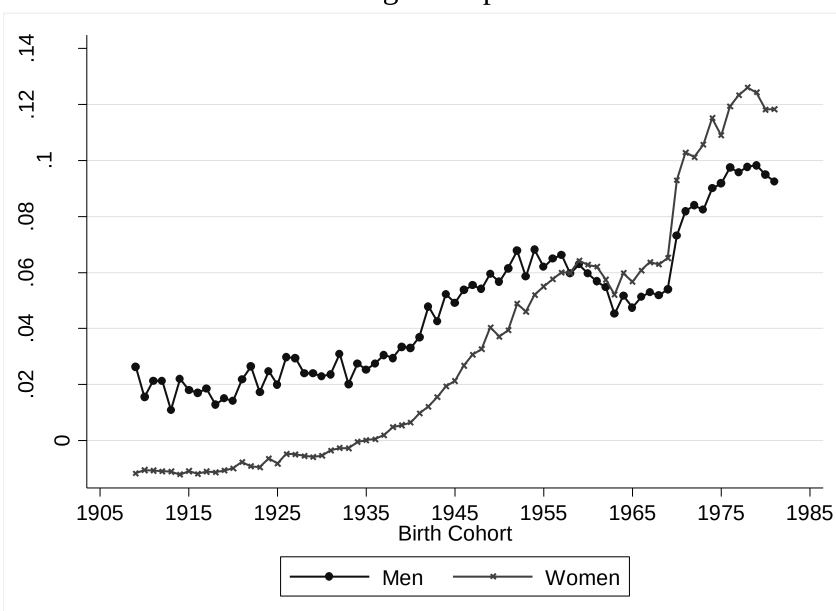
Notes: Data for 15 and 16 year-old nationals who live with at least one parent in Colombian censuses 1973, 1985, 1993 and 2005. Each coefficient comes from a separate regression in which each household characteristic aggregated at the department of birth and cohort is regressed on the natural logarithm of the department and cohort of birth-specific cohort size, controlling for department and cohort of birth fixed effects. Heteroskedasticity-robust standard errors brackets.

Appendix A
Figure A1
Educational Attainment by Gender

A. High School Completion

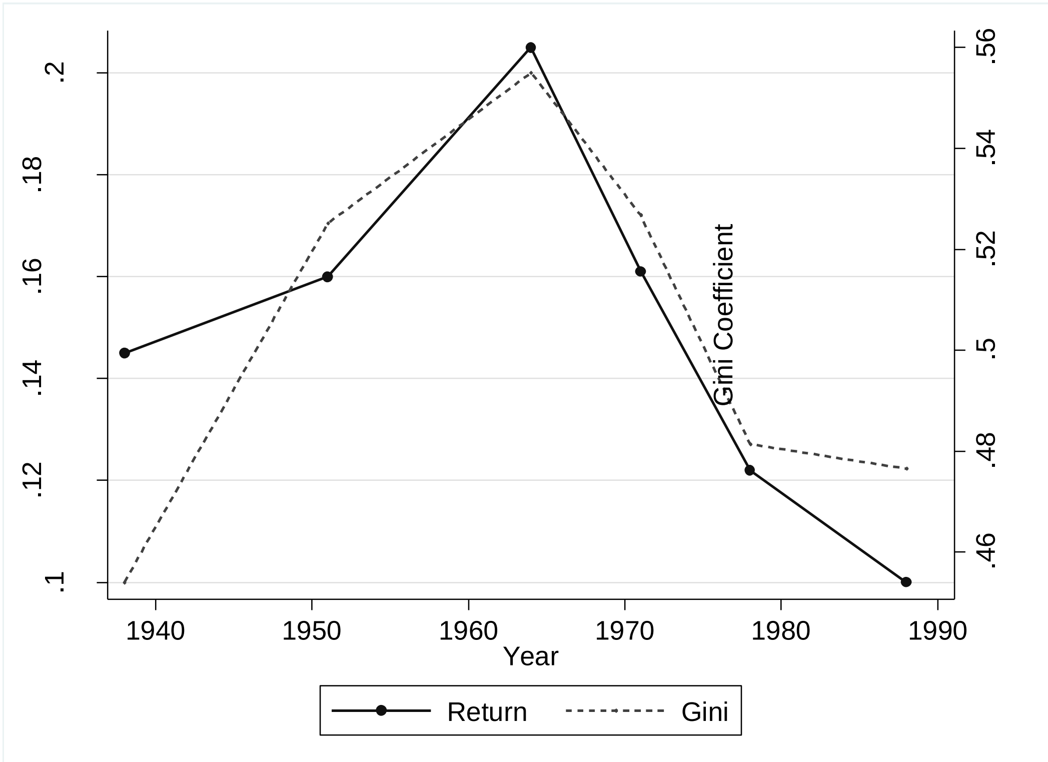


B. College Completion



Notes: High school and college completion rates are age-adjusted using a quartic polynomial in age, normalized to equal zero at age forty. Age-adjusted cohort aggregates by gender are estimated using equation (1) in the text from a sample of 24-64 year-old nationals in Colombian censuses 1973, 1985, 1993, 2005.

Figure A2
Evolution of Inequality Measures in Colombia



Notes: source is Londoño (1995) Figure 1.1 for Gini coefficient and Figure 3.6 for returns to schooling. Londoño calculates average returns to schooling as the difference between average wages for non-agricultural workers and average wages for unskilled workers, divided by average education of urban workers.