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Socioeconomic Determinants and Spatial Convergence of Biological Well-being: The Case of Physical Stature in Colombia, 1920-1990[1]

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Abstract

This paper explores the relationship between the physical stature of Colombians born during the 20th century and several socioeconomic variables. Using a dataset of more than 225,000 individuals built from judicial background certificates, we find an important increase in the stature of the population: the average height of women increased 4.1 centimeters and that of men increased 5.7 centimeters. Econometric results suggest important differences in the individual's stature according to gender, level of education, occupation, and place and date of birth. Similarly, the disease environment and access to public services significantly affect people's height. We find that departmental average height disparities decreased and the gap across regions closed throughout the century.

JEL classifications: I10, I14, I15, N36

Keywords: Anthropometrics, Height, Biological well-being, socio-economic determinants, convergence, Colombia.

[1] We want to thank Daniel Zarama for his support as research assistant. The authors are President of Universidad del Norte, Senior Researcher, Banco de la República, and Economists from Economic Policy Studies Department, Banco de la República, respectively.

Determinantes Socioeconómicos y Convergencia Espacial del Bienestar Biológico: El caso de la estatura en Colombia: 1920-1990[2].

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Resumen

Este artículo investiga la relación entre la estatura de los colombianos nacidos en el siglo XX y algunas variables socioeconómicas. Usando una base de datos de más de 225,000 individuos construida a partir de certificados de antecedentes judiciales, encontramos un aumento importante en la estatura de la población: la estatura promedio de las mujeres aumentó 4,1 centímetros y la de hombres aumentó 5,7 centímetros. Los resultados econométricos sugieren diferencias importantes en la estatura según género, nivel educativo, ocupación, salud, acceso a los servicios públicos y lugar y fecha de nacimiento. Encontramos que las disparidades en la estatura promedio entre departamentos se redujeron y la brecha entre las regiones se cerró a lo largo del siglo.

Clasificación JEL:: I10, I14, I15, N36

Palabras Clave: Antropometría, Estatura, Bienestar, Calidad de vida, Convergencia, Colombia.

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I. Introduction

Living standards in Colombia improved significantly during the 20th century. Progress was made in income per capita, education, and health (Jaramillo, Meisel and Ramírez, 2017). Important advances were also obtained in the biological welfare of the population. Anthropometric measures indicate that women and men grew on average 9 centimeters between 1905 and 1985 (Meisel and Vega, 2007).

The analysis of the long-term evolution of human stature has been widely used in economic history literature in order to measure changes in biological welfare in different countries (e.g. Komlos and Baten, 2003; Steckel, 2008; Komlos, 2003; Bassino, 2015, Heyberger, 2014; Beltran and Tapias, 2015; María Dolores and Martinez-Carrion, 2011; Meisel and Vega, 2007 and Peracchi, 2008). As María Dolores and Martinez-Carrion (2011) point out, anthropometric history has improved our knowledge about living standards and biological welfare. Also Chanda (2008), highlights that the evolution of adult heights reflects environmental changes, namely nutrition, work intensity, and exposure to disease.

Recently, anthropometric research has taken an interest in analyzing the long-term relationship between human adult heights and socio-economic factors (Ayuda and Puche Gil, 2014; Huang, van Poppel and Lumey (2015); Gyenis and Joubert 2004; among others). Understanding the determinants of adult stature is important in order to comprehend the achievements made in health and living standards, especially for emerging countries, as is the case of Colombia. This country is an interesting case of study, given that the first half of the twentieth century was a period of rapid economic growth, which led to substantial gains in the living standards, especially in education and life expectancy, achieving rapid convergence to international standards.

This paper aims to deal with potential differences in adult height associated with certain socio-demographic characteristics of Colombians born between 1920 and 1990. Specifically, we contribute to the literature by estimating econometrically the socioeconomic determinants of height in an emerging country. We focus on education, age, gender, occupation, size of the municipality of the individual's birthplace, the diseases environment, and access to public services. Additionally, we explore inequality and spatial convergence of stature between regions by estimating beta (β) and sigma (σ) convergence.

To analyze the long-term trend in height, we use a database rich in socio-economic information about a large number of individuals over a long period of time, which had not been used for academic purposes. The source is the judicial background certificate, which was issued by the former Administrative Security Department of Colombia (DAS) during the twentieth century. The judicial background certificate was necessary to leave the country, work in the public sector, purchase weapons, sign a contract with the State, and optionally (but required in most cases) to work in the private sector. Among other characteristics, the certificate reports the person's height.[3] When the DAS was dissolved in 2011, the judicial background records were transferred to the *Archivo General de la Nación* (General National Archive). These archive contains more than ten million judicial background certificates

[3] For an example of a judicial background certificate see Appendix 1.

issued during the twentieth century in the main Colombian towns and cities. This database is an important contribution to anthropometric literature due to its degree of demographic representativeness, the lack of self-reported height measures, and its non-truncated character.

The econometric results show that in Colombia the height of individuals is significantly related to socio-economic variables. In particular, we find important differences in stature according to gender, level of education, occupation, disease environment, access to public services, and place and date of birth. Moreover, the results indicate that the inequality in stature across departments has decreased considerably throughout the century, suggesting that departmental disparities in biological well-being and net nutrition have been reduced.

The rest of the paper is organized as follows: in the next section we discuss the related literature. Section 3 describes the data source and presents descriptive statistics. Section 4 presents the econometric estimations and discusses the results. Finally, we present the conclusions in the last section.

II. Related Literature

In recent years, the economic literature has been interested in analyzing the effects of socioeconomic variables on biological wellbeing indicators such as height. Research for different countries has found causal effects of different socio-economic variables on adult height. For example, Ayuda and Puche-Gil (2014) study the determinants of stature in Spain's male population between 1859 and 1960. In particular, the authors use height information of 82,039 conscripts in the Valencian region, finding a close relationship between education, occupation, income, and height. Martinez-Carrion and Moreno-Lazaro (2007) examine whether there was an urban height penalty in Spain's Southeastern coast and in the Castile–Leon's region during the period 1840 to 1913, which corresponds to the period of early industrialization in Spain. Their results show that average urban heights in these regions were well above rural ones for most of the period analyzed; therefore, there was no urban height penalty. For another Spanish region, Andalusia, Martinez-Carrion and Camara (2015) analyze the social differentials in height among young males during the period between 1879 and 1899. They find that the strong inequalities in net nutritional status affected stature in that region.

Huang, van Poppel, and Lumey (2015) explored the differences in height by socio economic status among 371,105 Dutch military conscripts born between 1944 and 1947. The results indicate large differences in individuals' statures by education level and their father's occupation. Similarly, Schoch, Staub, and Pfister (2012) analyze the height of Swiss conscripts for the years 1875–1950 and its relationship with social inequality. The authors find that social-class affiliation was the most important determinant of differences in the biological standard of living. For the case of Hungary, Gyenis, and Joubert (2004) investigate the relationship between socio-economic factors and height, weight, and body mass index of Hungarian university students and conscripts for the period 1933-1998. These authors find important differences in height according to parental occupation, educational level, family composition, and place of birth and residence.

For Japan, Bassino (2006) studied the effects of per capita income, health, and regional inequality on the physical stature of the Japanese at the prefecture-level for the period 1892–

1941. The results suggest that there is a relationship between income, health, and height of the population across the 47 Japanese prefectures. Bassino, Dovis and Kolmos (2018) examine the relationship between socioeconomic variables, such as year and province of birth, occupation, and education, and the stature of Philippine's population, using a data base of 23,000 Filipino soldiers enlisted by the US military between 1901 and 1913. Contrary to previous studies, this paper finds that few socioeconomic characteristics of the region of birth had a significant influence on individual stature.

As for Latin America[4], López-Alonso (2007) analyses the trend in adult heights from different sectors of Mexican society during the period 1850-1950. The results show that the standard of living of laboring classes did not benefit from the industrialization that took place during the Diaz regime (1876-1910). On the contrary, the stature of the upper classes increased, indicating that these classes benefitted from industrialization. Similarly, Lopez-Alonso and Velez-Grajales (2015) examined the evolution of Mexican adult heights and their relation to the economic cycles, inequality, wars and institutions, for the period 1850-1986. The authors find that these variables affect socioeconomic groups and regions differently, leading to unequal living standard patterns in the Mexican population.

In the case of Argentina, Salvatore, R. (2004) examines height trends in the Northwest during the first half of the twentieth century. The author finds that during this period the Northwest region presented significant improvements in its health and nutrition as well as in stature. However, within the region, education, skills, and socio-economic status caused important

[4] See Baten (2010), for a detailed review of the existing literature on the long-run evolution of height in Latin America.

differences in individual heights, and these differences increased over time. For Chile, Nuñez and Perez (2015) analyze the trends in stature by age across socioeconomic groups of boys aged 5 to 18 born between 1880 and 1997. The authors find that the average decennial increase in Chilean boys' height was of 0.9 cm for boys of upper socioeconomic status and of 1.2-1.3 cm for boys in lower economic status. The results are associated with the expansion of social policies since the 1940s, which led to improvements in the living standard conditions of the Chilean population. Recently Llorca-Jaña *et al* (2018), based on military records, provides the first estimates of stature for the Chilean adult population. With information for the colonial period c17310s-1800s, the authors find that Chilean men were taller than men from Mexico, Italy, Portugal, Spain and Venezuela, but shorter than men form Argentina, the United States and the United Kingdom.

Lastly, in the case of Colombia, anthropometric studies have benefited from the development of a well-organized citizen identification system since the early twentieth century: the national identification card, which contains information on adult height. Additionally, the country has very good information from passports and judicial certificates, as a person´s height was included in these documents. Thus, the country stands out for abundant and good-quality anthropometric information since the beginning of the 20th century.

The first study on the evolution of the stature of Colombians dates from 1992. Ordoñez and Polania (1992) used data from the national identification card to construct a random sample of 14,103 individuals (women and men). The authors found that between 1920 and 1970, the average height of women increased 8.7 centimeters (cms) and that of men increased 7.0 cms. Meisel and Vega (2007) analyze the stature of Colombians using as a source both the national identification cards and passport records. The number of database for the national identification cards included 9,321,776 individuals between 1905 and 1985. With this information from the national identification card, the authors found that Colombians' average height increased around 8.9 centimeters in the period 1905-2003. No trend was found using the passports records for the period 1870-1919. However, those who obtained a passport at that time belonged to the Colombian elite, and individuals from that group were relatively tall for the time, even compared to Europeans. In addition, Meisel and Vega (2007a) extended the previous analysis by studying in detail the evolution of stature by departments and cities using the same databases.

In a more recent study, Acosta and Meisel (2013) analyze the evolution of the average height of Colombian ethnic groups for people born between 1965 and 2010 using information from a sample of the National Nutrition and Health Survey conducted in 2010. Their results show that Afro-Colombians were 6 centimeters taller than the indigenous population, and 2 centimeters taller than the rest of the Colombians.

Finally, it is important to mention that the research on anthropometry that has been carried out in Colombia has not analyzed the socio-economic determinants of stature in depth. The present paper contributes to his end.

III. Data description

Our main data source are the judicial background certificates issued by the former Administrative Security Department of Colombia (DAS). The certificates are now in the

General National Archive. This archive contains more than ten million judicial certificates issued during the twentieth century throughout the Colombian territory. The certificates are stored in 25,223 boxes, and all of the certificates in a box come from the same department[5]. Each box contains six packages. The digitalized packages were chosen by stratified random sampling, where the strata were the departments[6]. For each randomly selected box within each department either the odd or even packages (also randomly selected) were digitalized[7] [8]. Stratified random sampling allows for a very high degree of social representativeness. Height measures in the certificates are not self-reported, and are non-truncated.

The final sample[9] consists of 225,805 women (42.5%) and men (57.5%) with a national identification card[10] born between 1921 and 1990 throughout the country (Table 1). The region with the highest number of certificates was the Andean region, followed by the Caribbean and Pacific regions. Most of the people who obtained the judicial background certificate were students or unskilled workers. This is consistent with the fact that the majority of individuals in the sample had registered primary or secondary education as their highest level of education. Less than 20% had tertiary education.

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[5] The Colombian territory is currently divided in 32 territorial units or departments.

[6] In order to have a balanced sample for the entirety of the century, more boxes from the departments with a very small number of observations were digitized. This was the case for: Amazonas, Arauca, Huila, Meta, Magdalena, San Andrés, and Chocó.

[7] The General Archive did not authorize the digitalization of certificates of judicial background of individuals accused of committing a crime but not subject to a judicial decision. This did not bias the sample because this type of certificates represented only 4.8% of the selected boxes. Each box of unauthorized certificates was replaced by another randomly selected box from the same department.

[8] On average each package contains 122 certificates. A total of 2,127 packages were digitized.

[9] Of the 260,163 certificates that were digitalized, 87% were used in the final sample because not all of the individuals were born in our period of interest, and not all of them had a national identification card.

[10] In 1934 the citizenship card (*cédula de ciudadanía*) was established for men over 21 years of age. For women the citizenship document was first issued in 1956. Records of women's heights begin before 1956, due to the fact that women who were born before that date were also given a citizenship card. After 1985, it was established for citizens over 18 years of age.

Table 1. Sample distribution

Variable	Observations	%	Variable	Observations	%
Sex			**Education**		
Women	95,884	42.5%	Primary	43,913	21.7%
Men	129,921	57.5%	Secondary	106,189	52.4%
Total	225,805		Technical/Technician	13,731	6.8%
			Tertiary	38,934	19.2%
			Total	202,767	
Region			**Work force**		
Amazon	3,567	1.6%	Unskilled	63,729	46.2%
Andean	147,672	65.4%	Skilled	42,637	30.9%
Caribbean	31,007	13.7%	Students	29,566	21.4%
Pacific	37,535	16.6%	Armed forces	1,929	1.4%
Orinoquia	6,024	2.7%	Total	137,861	
Total	225,805				

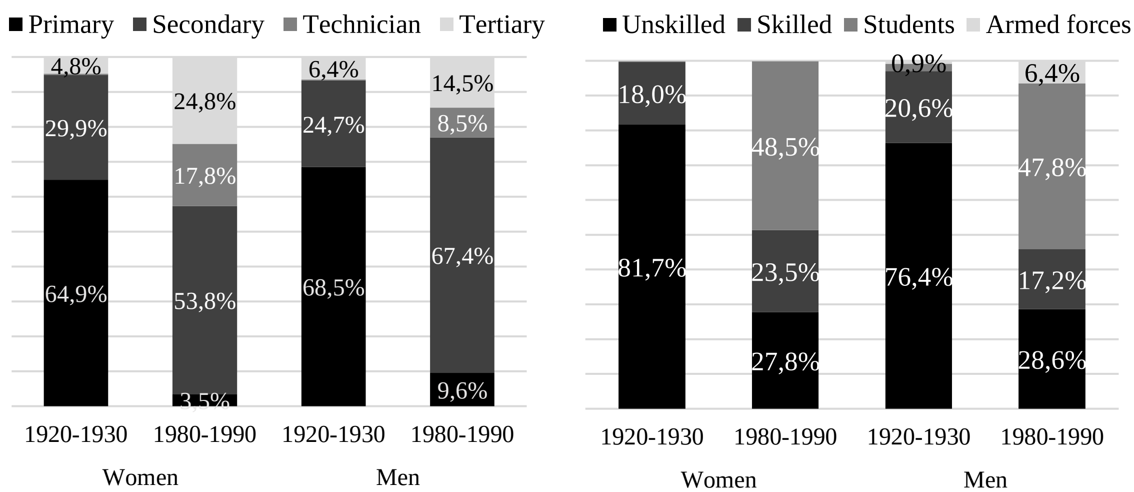
Source: Author's calculations based on digitized certificates of judicial background issued by the former DAS.
Note: The Amazon region comprises the departments of Amazonas, Caquetá, Guaviare, Guiana, Putumayo and Vaupes. The Andean region comprises the departments of Antioquia, Caldas, Risaralda, Quindío, Cundinamarca, Tolima, Huila, Boyacá, Santander, Norte de Santander, and the Capital of the Country Bogotá. The Caribbean region includes the departments of Cordoba, Sucre, Bolivar, Atlántico, Magdalena, Cesar, Guajira, San Andres and Providencia. The Pacific region includes the departments of Chocó, Valle del Cauca, Cauca and Nariño. The Orinoquia region comprises the department of Meta, Casanare, Arauca and Vichada.

Substantial improvements took place during the 20th century in terms of education (Figure 1). For both women and men there was a significant increase in the percentage of individuals with secondary and tertiary education from the first to the last decade accompanied by a decrease in the percentage of individuals with primary education. In the first decade, the educational attainment distribution was not different for women and men. In the last decade of the century, the percentage of women and men with tertiary education was 24.8% and 14.5%, respectively. The difference is statistically significant in favor of women.

Also, there was a substantial change in the workforce composition during the last century (Figure 1). A significant increase in the percentage of skilled workers and students took place.

Differences between women and men were unstable throughout the century: the percentage of unskilled women was considerably higher, and the percentage of students and skilled women workers was lower than the percentage of men in the first decade of the century. In the last decade, there were no significant differences between women and men in the percentage of unskilled workers and students, and the percentage of female skilled workers was significantly higher than the percentage of male skilled workers.

Figure 1. Change in Education and Workforce: Women and Men



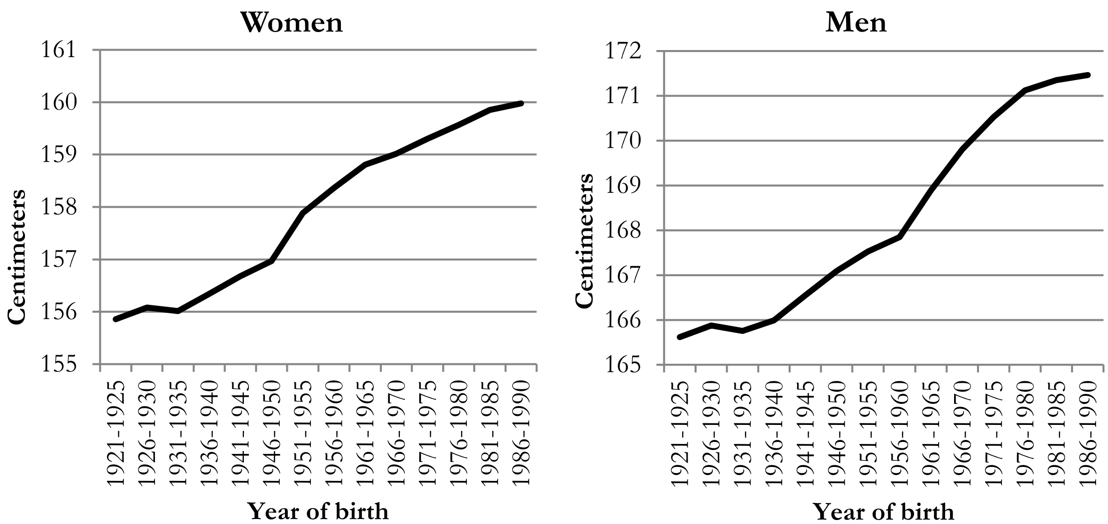
Source: Authors' calculations based on digitized judicial background certificates issued by the former DAS.

The positive trend in the average height of Colombians during the 20th century can be seen in Figure 2. The average height for women increased 4.1 centimeters between the first and the last decades of the century, and men's average height increased 5.8 centimeters. This trend is similar to the results found by Meisel and Vega (2007), which includes data for the entire Colombian population in the 20th century. Meisel and Vega (2007) explain the improvement in height by the advances in nourishment, urbanization,[11] and the fall in food

[11] As urbanization increased, the excessive hours of heavy physical workload decreased.

prices due to high investments in transportation since 1950. The average height of Colombian men from 1981 to 1990 was very similar to English and Dutch men from 1900 to 1905, and French and Spanish men in 1940 and the 1960s, respectively (Hatton and Bray, 2010).

Figure 2. Evolution of Average Height in the 20th century

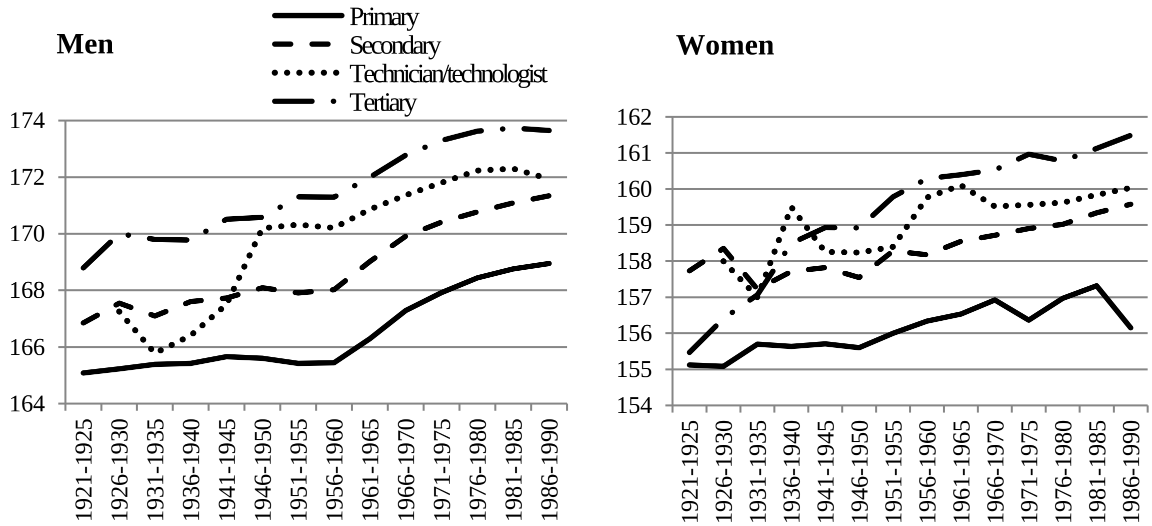


Source: Authors' calculations based on digitized judicial background certificates issued by the former DAS.

Height differentials can be observed for different educational levels. As the level of education increases, average height increases[12] (Figure 3). From 1921 to 1990, the average height of individuals with secondary and tertiary education grew 0.02% and 0.06% annually, respectively, in the case of women; it did so by 0.04%, and 0.05%, respectively, in the case of men. The height differentials between skilled and unskilled workers, on average, was 2.2 centimeters throughout the century for women, and 3 cms for men (Figure 4 and Figure 3). This difference was statistically significant since 1930 for men and women.

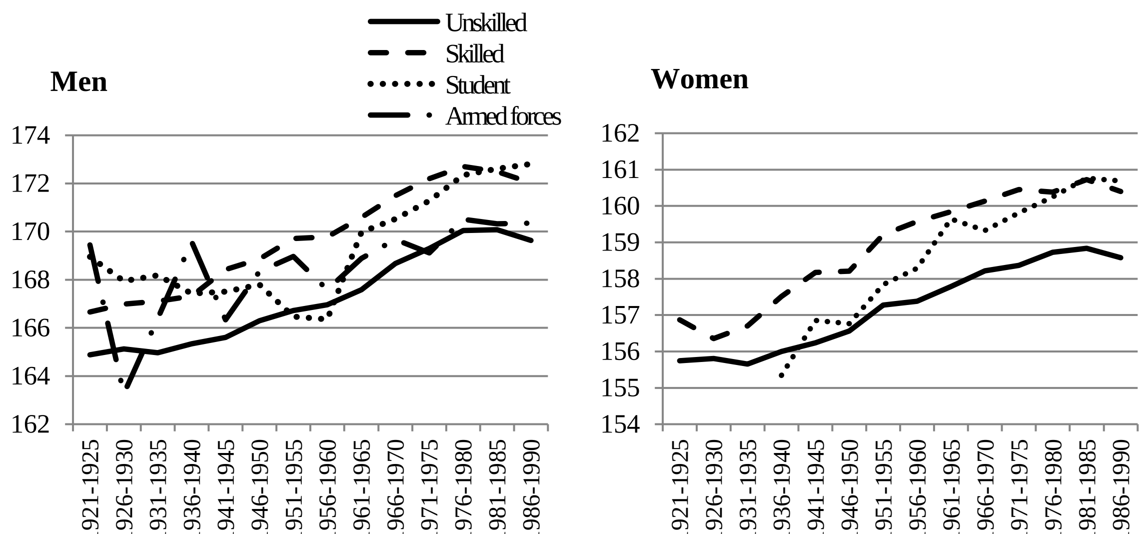
[12] The only exception is technical and technological degrees, but these degrees did not exist or had not been regulated for the whole of the twentieth century.

Figure 3. Evolution of Average Height in the 20th century by Educational Level



Source: Authors' calculations based on digitized judicial background certificates issued by the former DAS.

Figure 4. Evolution of Average Height in the 20th century by Labor Force Type

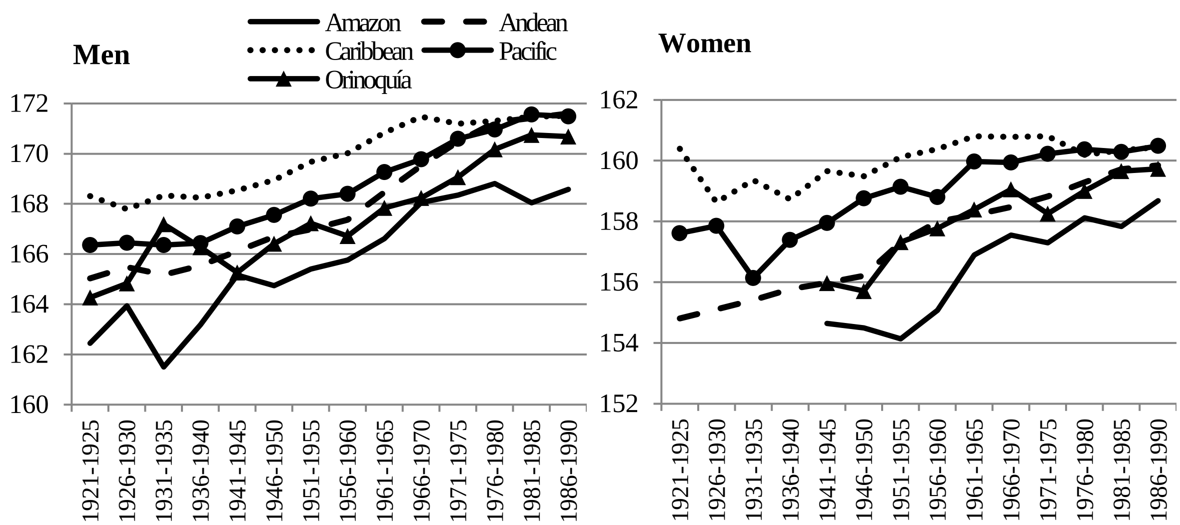


Source: Authors' calculations based on digitized judicial background certificates issued by the former DAS.

The height differences across regions were relatively stable during the course of the century, as can be seen in Figure 5. On average, people born in the Caribbean region were significantly taller than the rest of the population until 1970. This points towards convergence because the

Caribbean region, both for men and women, had the lowest average annual growth rate in height. The Andean region, which started the century with the second smallest average height, was the region with the highest growth rate in the 20th century.

Figure 5. Evolution of average height in the 20th century by Regions



Source: Authors' calculations based on digitized judicial background certificates issued by the former DAS.

IV. Econometric estimations and results

A. Socioeconomic determinants of height

As the anthropometric literature has shown, adult height is affected by economic, social, and disease environments in childhood. In this section, we investigate the relationship between the stature of Colombians born in the 20th century and several socioeconomic variables such as the year of birth, gender, education, occupational activities, and size of the municipality of the individual's birthplace. We also include the rate of deaths from gastrointestinal and respiratory diseases, as well as deaths from maternal puerperal diseases, and the percentage of households in each department covered by aqueducts.

In particular, the year of birth is an important variable because, as mentioned by Ayuda and Puche-Gil (2014), it includes the role that economic, social, and political conditions could play on the quality of life. On the other hand, the level of education reached by the individual would reflect her/his socio-economic level and its effect on biological well-being measured by her/his height in adulthood. The occupation also provides information on the effect of the individual's socioeconomic status on her/his height, as it could be considered as a proxy for income level of the family[13]. Additionally, a person's place of birth can provide information about the social, environmental, economic, and health conditions of the individual during the first years, which is a determinant of physical development.

We also include the mortality rates from gastrointestinal, respiratory, and puerperal diseases as control variables, since height is affected by the disease environment, especially during childhood. Stature is determined by genetic potential, environmental factors, and by net nutrition in childhood. As Deaton (2006) points out, net nutrition is the result of food consumption and the losses to activities and to diseases. Consequently, gastrointestinal diseases (especially diarrhea), fevers, and respiratory infections negatively affect nutrition and, consequently, stature.[14] Lastly, the coverage of aqueducts is important since the decline of mortality and morbidity rates was partly caused by improvements in the provision of public goods, especially regarding sanitary conditions.[15]

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[13] For more details, see Ayuda and Puche-Gil (2014).
[14] According to Silventoinen (2006) the most important non-genetic factors affecting growth and adult body height are nutrition and diseases. In addition, Oxley (2016) mentions several studies that have analyzed the relationship between stature and health, having found a significant negative relationship between height and mortality and height and morbidity.
[15] For an analysis of the contribution of the provision of public services, namely aqueducts and sewage, to the reduction in mortality rates from different types of diseases see Jaramillo, Meisel, and Ramírez (2017).

In order to analyze the socioeconomic determinants of height we estimate the following equation:[16]

$$log(height)_{i,j} = \alpha + \beta_1 Year_{i,j} + \beta_2 Sex_{i,j} + \beta_3 Edu_{i,j} + \beta_4 Ocup_{i,j} + \beta_5 Top20_{i,j} + \beta_6 Gastro_{i,j} + \beta_7 Resp_{i,j} + \beta_8 Matern_{i,j} + \beta_9 Aqued_{i,j} + \delta FE_j + \varepsilon_{i,j} \quad (1)$$

where: i indexes the individual and j indexes the department. $log(height)$ corresponds to the logarithm for height, measured in centimeters (cms), $Year$ is the individual's year of birth; Sex is a dummy variable that takes the value of 1 if the person is male and 0 if the person is female; Edu represents the highest level of education reached (primary, secondary, technical/technological, and university education); $Ocup$ refers to the occupation of the individual (unskilled, skilled labor, student, or armed forces); $Top20$ is a dummy variable that takes the value of 1 if the municipality of birth is ranked among the top 20 according to its population size[17]; $Gastro$ is the mortality rate (per 1,000 inhabitants) from gastrointestinal infections; $Resp$ is the mortality rate (per 1,000 inhabitants) from respiratory diseases; $Matern$ is the mortality rate (per 1,000 inhabitants) from puerperal diseases; and $Aqued$ corresponds to the annual percentage of households in departments covered by aqueducts. Lastly, FE are department fixed effects and ε is the error term.

It is important to mention that we added to equation 1 interaction terms between sex, education, occupation, and size of the municipality with the year of birth to estimate

[16] To estimate equation 1, we use linear regressions estimated by Ordinary Least Squares and robust standard errors and fixed effects.

[17] This variable was built from the five demographic census for Colombia corresponding to the 20th century. The municipalities that were ranked top 20 by population size varied through time.

differential growth rates for height, given the category of interest. Table 2 presents the results of the estimation of equation 1. Each column corresponds to a different specification. In column (1), the provision of aqueduct is not included because we consider it an important determinant of health, so a collinearity problem would arise between health variables and aqueducts. In column (2), we include the provision of aqueducts, but exclude health variables. In addition, in Table 3 we present the estimations of the annual growth rate for stature by variable compared to its corresponding reference category.

Results from Table 2 indicate that the effects of almost all socioeconomic and health variables on height are significant. In particular, men are 5.5% taller than women. The interaction term between sex and year of birth indicates that men grow annually 0.3% more than women. Table 3 shows that the predicted average height of men born in 1921 was, *ceteris paribus*, 8.5 cms higher than women, and this gap widened to 12 cms for individuals born in 1990. On the other hand, younger individuals are taller than the older ones. The coefficient of the variable year of birth indicates that individuals gain 0.014% in height with respect to the individual born a year before, when controlled by disease environment, and 0.025% when controlled by aqueducts coverage.

Regarding education, individuals with more education are taller on average (Table 2). An individual’s level of education reflects the socio-economic status of her/his family and its effects on nutrition and health, because families would have a greater capacity to acquire better quality foods and better nutrients, as well as access to better health services, and better hygiene habits (Chanda 2008). Our results indicate that on average *vis-à-vis* individuals with primary education, individuals with secondary education are 1.1% taller, technicians 2.7%

taller, and university students 2.8% taller. Additionally, Table 3 shows that on average individuals born in 1990 with secondary or technical/technological education are 2 cms taller than individuals with primary education, and individuals with tertiary education are 3.6 cms higher than individuals with primary education.

Individuals who were born in large municipalities are slightly taller (0.22%) than those who live in smaller municipalities (Table 2). Individuals born among the top 20 larger municipalities grow 0.01 percentage points more annually than those born in smaller municipalities, on average (Table 3). Concerning occupation, at the beginning of the century skilled workers and students were shorter than unskilled workers, but the annual growth rate for their stature was higher than for unqualified individuals. Consequently, students and skilled workers were taller on average than unskilled workers at the end of the period (Table 3). On the other hand, the coefficient of individuals in the armed forces, although positive, is the only one that is not statistically significant.

In line with the literature[18], we find a negative and significant relationship between an individual's height and mortality rates from gastrointestinal, respiratory and puerperal diseases that occurred at the time, and department of birth. Interestingly, puerperal diseases have the largest effect on adult height compared to other diseases. An additional death (per thousand individuals) from puerperal diseases in the year and department of birth leads to a 0.011% reduction in adult height. These results are consistent with the literature that finds

[18] For example, Schmidt, Jørgensen, and Michaelsen (2009) examine the relationship between post-neonatal mortality, as a proxy for adverse environmental factors, mainly poor nutrition and infections, and conscript height in the European countries. The authors find a negative relationship between these variables.

that maternal health is vital for child health and development.[19] On the other hand, as expected, a larger provision of aqueducts affects stature positively. For instance, a one percentage-point increase in the coverage of aqueducts increases height by about 1.2 cm (Table 3). This is important given the causal effect of aqueduct coverage on infant mortality and disease prevalence, and, consequently on adult height. [20]

In summary, the results suggest statistically significant differences in adult height according to sex, level of education, place of birth, occupation, and date of birth. Likewise, health and the provision of aqueducts significantly affect stature. The results for Colombia are similar to those found in the literature for other countries such as Spain, The Netherlands, Hungary, Japan, among others, where socio-economic status plays an important role in stature achievements (e.g. Ayuda and Gil, 2014; Gyenis and Joubert, 2004; Bassino, 2006; Huang, van Poppel and Lumey, 2015).

[19] See for example, Bhalotra and Rawlings (2011).
[20] For details, see Jaramillo, Meisel, and Ramírez (2017).

Table 2. Effects of Socioeconomic Variables on Adult Height of Colombians born between 1920 and 1990: Percentage Difference[21]

Variables	(1)	(2)
Year of Birth	0.014%***	0.025%***
	(0.00005)	(0.00004)
Sex (male=1)	5.537%***	5.5%***
	(0.00079)	(0.00078)
Sex*year of birth	0.029%***	0.029%***
	(0.00002)	(0.00002)
Education (reference=primary)		
Secondary	1.069%***	1.104%***
	(0.00101)	(0.001)
Technical/Technological	2.666%***	2.755%***
	(0.00265)	(0.00267)
University	2.755%***	2.773%***
	(0.00137)	(0.00136)
Secondary*year of birth	0.004%	0.003%
	(0.00002)	(0.00002)
Technical/Technological*year of birth	-0.019%***	-0.021%***
	(0.00005)	(0.00005)
University*year of birth	-0.006%***	-0.007%***
	(0.00003)	(0.00003)
Top 20 (reference=rest)		
Top 20 (municipality size)	0.216%**	0.169%
	(0.001)	(0.001)
Top 20*year of birth	0.006%***	0.007%***
	(0.00002)	(0.00002)
Occupation (reference=unskilled labor force)		
Skilled labor	-0.242%**	-0.287%***
	(0.00105)	(0.00107)
Student	-1.231%***	-1.273%***
	(0.00139)	(0.00139)
Armed forces	0.377%	0.39%
	(0.00366)	(0.00374)
Skilled labor*year of birth	0.011%***	0.012%***
	(0.00002)	(0.00002)
Student*year of birth	0.029%***	0.029%***
	(0.00003)	(0.00002)
Armed forces*year of birth	-0.004%	-0.005%
	(0.00007)	(0.00007)

(continues)

[21] Percentage difference is estimated from de OLS coefficients. It is equivalent to $\left(e^{\hat{\beta}} - 1\right) * 100$.

(Table 2 continues)

Variables	(1)	(2)
Health		
Gastrointestinal Diseases Mortality Rate (GMR)	-0.002%**	
	(0.00001)	
Respiratory Diseases Mortality Rate (RMR)	-0.002%**	
	(0.00001)	
Puerperal Diseases Mortality Rate (PMR)	-0.011%***	
	(0.00003)	
Public Service Provision		
Aqueduct provision		0.76%***
		(0.00123)
Departmental fixed effects	YES	YES
Departmental*year of birth	YES	YES
Constant	153.77***	151.30***
	(0.00276)	(0.00185)
Observations	120,732	118,340
R-squared	0.446	0.448

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, Source: Authors' estimations.

Table 3. Estimation of Average Height (cms.) in 1921 and 1990 and its Annual Growth Rate by Socio-economic Indicator

Gender	Reference: **Female**	**Male**	*p-value**
Average height 1921	154.8	163.3	0.000
Annual growth	0.01%	0.04%	0.000
Average height 1990	156.3	168.3	0.000

Education	Reference: **Primary**	**Secondary**	*p-value**	**Technical**	*p-value**	**Tertiary**	*p-value**
Average height 1921	154.8	156.4	0.000	158.9	0.000	159.0	0.000
Annual growth	0.01%	0.02%	0.100	-0.01%	0.000	0.01%	0.030
Average height 1990	156.3	158.4	0.000	158.3	0.000	159.9	0.000

Municipality size	Reference: **Not in top 20 municipality size**	**Top 20 municipality size**	*p-value**
Average height 1921	154.8	155.1	0.040
Annual growth	0.01%	0.02%	0.005
Average height 1990	156.3	157.3	0.040

Labor force type	Reference: **Unskilled**	**Skilled**	*p-value**	**Student**	*p-value**	**Armed forces**	*p-value**
Average height 1921	154.8	154.4	0.022	152.9	0.000	155.4	0.304
Annual growth	0.01%	0.03%	0.000	0.04%	0.000	0.01%	0.504
Average height 1990	156.3	157.1	0.022	157.5	0.000	156.4	0.304

Diseases	Reference:	**1% increase in GMR****	*p-value**
Average height 1921	154.8	154.5	0.034
		1% increase in RMR**	
Average height 1921	154.8	154.5	0.012
		1% increase in PMR**	
Average height 1921	154.8	153.1	0.000

Aqueduct	**Aqueduct**	**1 pp increase of aqueduct provision****	*p-value**
Average height 1921	152.3	153.5	0.000

* *p-value* of the difference with respect to the reference category.
** In the department and year of birth. GRM=gastro-intestinal mortality rate, RMR=respiratory mortality rate, and PMR= puerperal mortality rate. Source: Authors' estimations.

B. Convergence analysis

In this section, we explore the spatial convergence of stature across Colombian departments. This analysis is important due to the disparities in the individuals' height observed across regions (Appendix 2). To this end, we use two measures frequently employed in the literature of economic growth, namely *beta convergence* (β) and *sigma convergence* (σ), which are useful to test convergence in the indicators of biological well-being.[22]

To calculate the β-convergence, we regress the growth rate of height over the period considered (1920-1990), and its initial level.[23] If $\hat{\beta}$ is negative, then there is β-convergence, which means that the departments where the initial stature was higher show a lower height growth rate during the period analyzed. Specifically, we estimate the following equation:

$$height\_growth_{j,T} = \alpha + \beta ln(h_{j,0}) + \varepsilon_j \qquad (2)$$

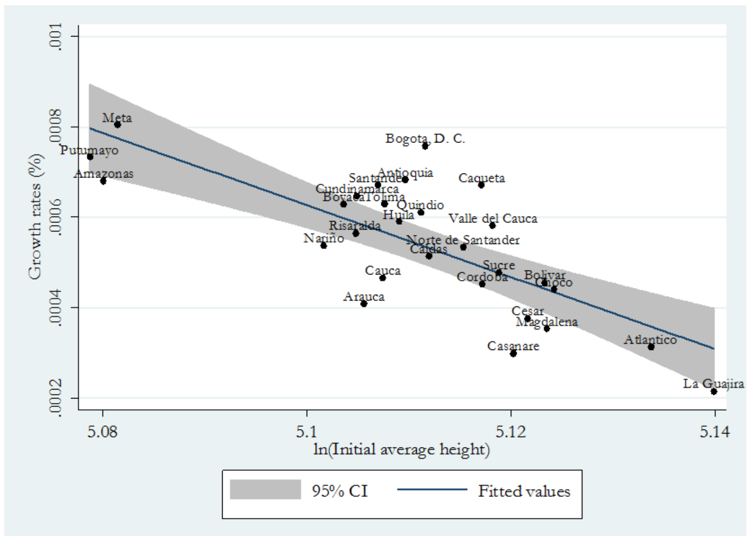
where $ln(h_{j,0})$ is the natural logarithm of the initial height[24] in department j, ε_j is the error term, and $height\_growth_{j,T}$ is the annual rate of height increase over the period 1920-1990.

Graphs 6 and Graph 7 show the relationship between the growth rate for height and its initial level during the period analyzed, for males and females, respectively. As observed, there is

[22] Several analyses of convergence of biological indicators across regions, particularly height, have been carried out for example by Bassino (2006), Chanda *et al* (2008), Kolmos, (2007), Salvatore, R. (2004), and Meisel and Vega (2007).
[23] The methodology of estimating β-convergence is taken from the literature on economic growth (e.g. Barro, 1991, and Barro and Sala i Martin, 1992), which analyzes whether poor countries/regions tend to grow faster than rich countries/regions.
[24] In order to obtain robust results, our measure of initial height is the average of the first decade.

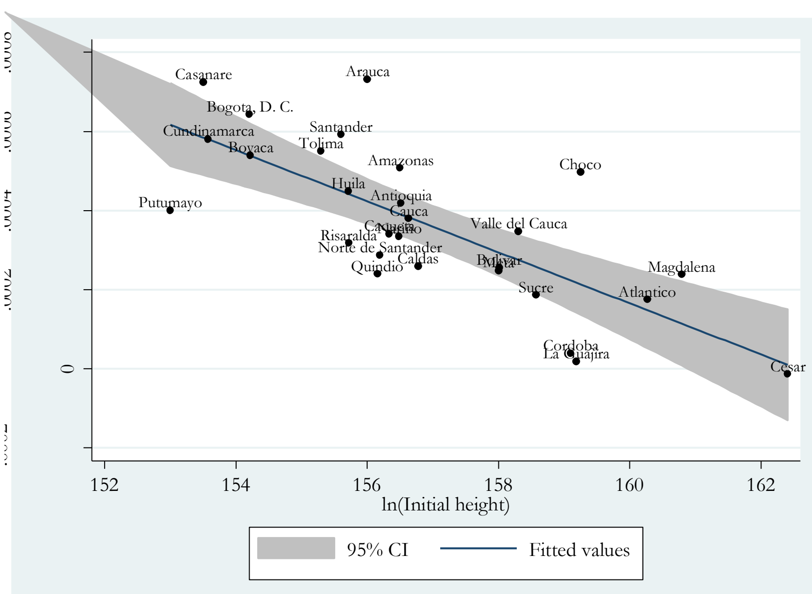
a negative relation between these variables in both cases, which suggests the existence of β-convergence.

Figure 6. *β-convergence* across departments: men born between 1920 and 1990



Source: Authors' estimations

Figure 7. *β-convergence* across departments: women born between 1920 and 1990



Source: Authors' estimations

Table 4 presents the results of the estimation of equation (2). The estimated β coefficient is negative and significant, indicating that a β-convergence of height took place in Colombia across departments for both women and men during the 20th century. In particular, the magnitude of the β-coefficient for males implies that it takes approximately 85 years to eliminate one-half of an initial gap in men's stature, with a speed of convergence around 0.8% per year (Table 4). For women, the speed of convergence is slightly higher, 1.0% per year, which implies that it takes nearly 67 years to eliminate one half of the initial gap in female's height. [25]

These convergence rates for stature are similar to those calculated by Komlos (2007), Bassino (2006), Chanda *et al* (2008), and Meisel and Vega (2007). However, they are lower than those estimated for per capita income. Barro and Sala-i-Martin (1992) find that the β-coefficient (across different data sets) is around 2-3% per year, which implies that it takes 25-35 years to eliminate one-half of an initial gap in per capita incomes.

Table 4. *β-convergence:* men and women born between 1920-1990

	Men Annual height growth rate	**Women** Annual height growth rate
Ln(*initial level of height)*	-0.00797***	-0.0102***
	(0.0013)	(0.0018)
Constant	0.0413***	0.0517***
	(0.0067)	(0.0091)
Observations	28	28
R^2	0.575	0.552

Note: The departments of Guainía, Guaviare, Vichada and Vaupés are grouped due to lack of data availability.
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations.

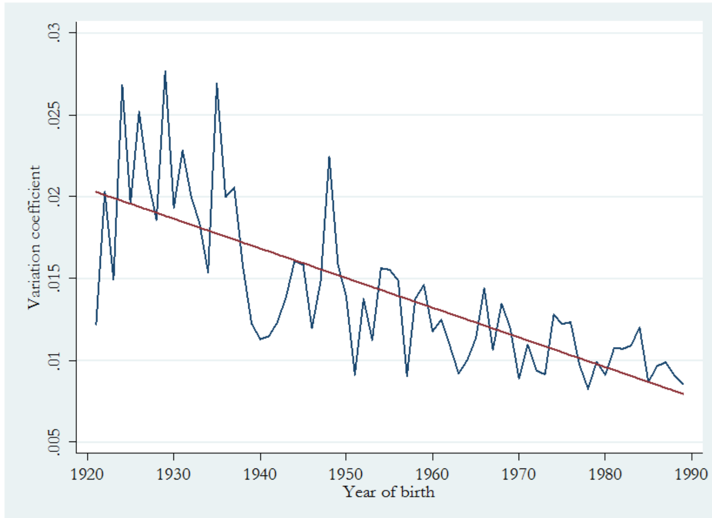
[25] Following Barro and Sala i Martin (1992), we calculate the equation: $ln\ (2)/\beta = t$, in order to estimate the years (t) needed to eliminate one-half of the initial gap.

Furthermore, Figure 8 and Figure 9 depict the results of σ-convergence, estimated as the coefficient of variation (CV) between departments for men and women's height.[26] The CV is expected to fall over time if there is convergence among departments in the average stature of individuals. The graphs show that a process of rapid reduction in the dispersion of female and males' heights took place between the Colombian departments from 1920 to 1990. As observed, the CV indicates relatively high stature inequality during 1920s and 1930s, diminishing afterwards. The fall in dispersion occurred during the second half of the 20th century, and may be partly due to the economic, demographic, and epidemiological transformations that took place in this period, which resulted in significant progress in living standards for the Colombian population.[27] In particular, since the 1950s, we observe significant improvements in public health and sanitary conditions, higher per capita income, and better nutrition.[28]

In the case of men, the coefficient of variation went from 0.02, on average, during the 1920s to approximately 0.01 in 1990. on the other hand, the coefficient of variation of the stature of women born during the twenties was 0.03, on average, and reduced to 0.01 by 1990, which means that the dispersion among the departments in the average stature of women decreased rapidly, evidencing a slightly faster process of convergence of height than in the case of men.

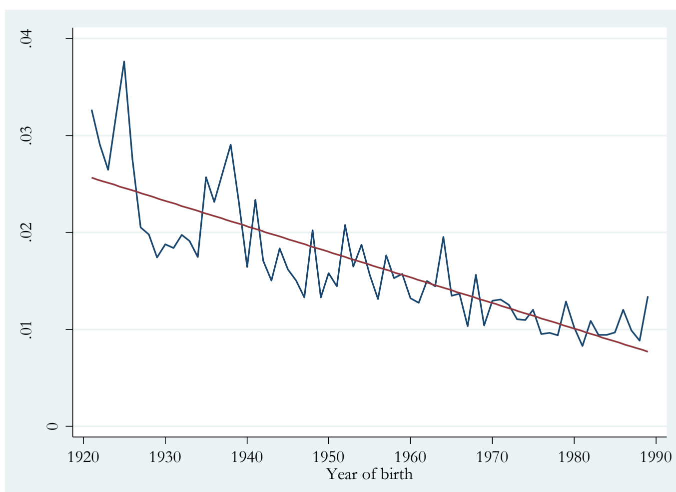
[26] The coefficient of variation (CV) corresponds to the standard deviation of the indicator divided by its mean.
[27] For more details, see Jaramillo, Meisel, and Ramírez (2017).
[28] For example, protein consumption increased from 39.65 gr/person/day in 1946 to 65 gr/person/day in 2000 (see Jimenez, 2014).

Figure 8. ***σ convergence*** **for the Colombian departments: men born between 1920 and 1990**



Source: Authors' estimations.

Figure 9. ***σ convergence*** **for the Colombian departments: women born between 1920 and 1990**



Source: Authors' estimations.

V. Conclusions

In this paper, we analyze the evolution and the process of convergence of the stature of Colombian women and men during the 20th century, as an indicator of the advances in the biological wellbeing of the population. We make a quantitative contribution to the literature by econometrically estimating the socioeconomic determinants of height, including diseases and provision of public services, in an emerging country such as Colombia. We also contribute with a new dataset based on judicial background certificates, with a sample of more than 225,000 observations, that are non-truncated, not self-reported, and highly representative of the population.

We found a substantial increase in the stature of the population born between 1920 and 1990. Therefore, both women and men experienced an improvement in their biological well-being throughout the century. This gain in the biological well-being of the Colombian population coincides with a decrease in height inequality across the departments. The regional dispersion in females' height decreased faster than the dispersion of males' height.

Finally, the results of the econometric estimates suggest a close relationship between socio-economic variables and the height of individuals in Colombia. We find important differences in stature according to sex, level of education, occupation, and place and date of birth. Similarly, health and the provision of aqueducts significantly affected people's height.

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Appendix 1

Figure 10. Photographs of certificates of judicial background


Arango Londoño
(a)
Conceptuación policial
Nacido en Carolina
el día 1913
Departamento de Antioq
Hijo de Luis Arango
y de Rosa Londoño
Estado Solt. Talla 1-68
Profesión obrero
Domicilio Ibagué
Observaciones CC 2870264 - Palermo (H.)
Número de orden 29153
expd. 16082
Fórmula dactiloscópica
S 1 1 3 3 — D 1 1 2' 2
11 5 8 11 P 8 3
PULGAR E
INDICE DERECHOS
Reseñado en el DEPARTAMENTO DEL TOLIMA
Fotografiado por D.
Ibagué, Julio 23/47
Firma del reseñado,

AGUIRRE
T.D. 162296
Concep. Policial:
Prt.
Nacido en Fresno
Depto. Tol.
Fecha nacimiento 3-Abril 1.944
Estado Civil. soltero
Hijo de
y de Alicia
Profesión u oficio: jornalero
Estatura 1.67 Mts.
Color del iris: cast. claro
Color del cutis: trigueño
Domicilio: Fresno, Alto de La Cruz
Instrucción: 4º Primaria
Presentó la C. C. Nº 5.849.625
Expedida en: Armero
Señales particulares:
ARMERO T. D. 05354
PARIENTES O RELACIONADOS

Nombre	Vínculo	Lugar	Dirección
GLORIA AGUIRRE	Hna.	Fresno	Alto de La Cruz
VICTOR AGUIRRE	Tio.	Fresno	" " " "

Fórmula Dactiloscópica
S 3 3 3 3 — D 1 2 2 2
16 2 8 6 5 19 P 14 18 8
PULGAR DERECHO
INDICE DERECHO
Reseñado por: B.C.U.
D. Biográfico R.R.S.
En Armero El 16 ABR 1968
Autografo

311285
T.D.
Concep.-Policial:
Prt.
Nacido en COYAIMA
Depto. TOLIMA
Fecha nacimiento 2 OCTUBRE DE 1.963
Estado Civil CASADA
Hijo de CONSTANTINO
y de DIGNA MARIA
Profesión u oficio EDUCADORA
Estatura 1. 66 mts.
Color del iris CASTAÑO OSCURO
Color del cutis TRIGUEÑO
Domicilio COYAIMA
Instrucción: BTO. PEDAGOGICO
Presentó la C.C. No. 28.647.384
Expedida en: COYAIMA (T)
Señales particulares NINGUNA.
PARIENTES O RELACIONADOS

Nombre	Vínculo	Lugar	Dirección
OLIVERIO PENAGOS	ESPOSO	COYAIMA	LA MISMA.

Fórmula Dactiloscópica:
S 3 3 3 3 D 2 2 2 2
20. 7 9 8 7. 7 4 10. 8 5.
PULGAR DERECHO
INDICE DERECHO
Reseñado por: BR
D. Biográfico INC.
En IBAGUE El III-30-93
Autógrafo

REPUBLICA DE COLOMBIA
DEPARTAMENTO ADMINISTRATIVO DE SEGURIDAD
TARJETA ALFABETICA MUJER
MORENO CAICEDO T.D.
Concep-Policial
Prt.
Nacido en: CHAPARRAL
Dpto: TOLIMA
Fecha de nacimiento: 7 SEPT 1971
Estado Civil SOLTERA
Hijo de: JOSE LEVER
y de IRENE
Profesión u oficio: DOCENTE
Estatura 1.69 mts
Color del iris: CASTAÑO MEDIO
Color del cutis: TRIGUEÑO
Domicilio: Cra 8Nro. 3-14 CHAPARRAL
Instrucción: llbto
Presentó la C.C. No. 28.688.513
Expedida en: CHAPARRAL
Señales particulares: CIC/ CARA LADO DER/
PARIENTES O RELACIONADOS

Nombre	Vínculo	Lugar	Dirección
OSCAR DANEEL PADILLA	ESP/	MISMA	

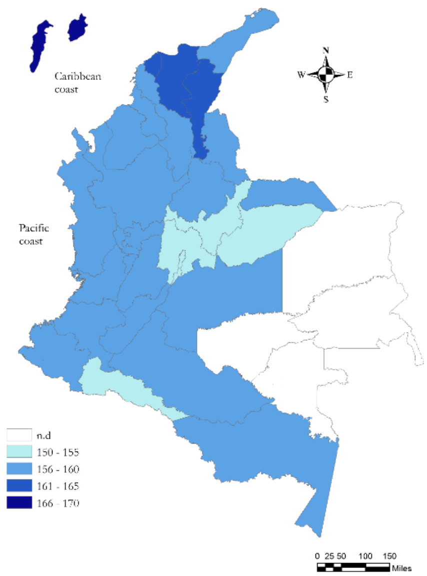
F. Dactiloscopica
Pulgar Derecho
Indice Derecho
Reseñado por:
Biográfico
En IBAGUE 2 ABR 20
Autógrafo
28688513 Chaparral

Source: DAS Archives, *Archivo General de la Nación* (General National Archive), Bogotá,Colombia.

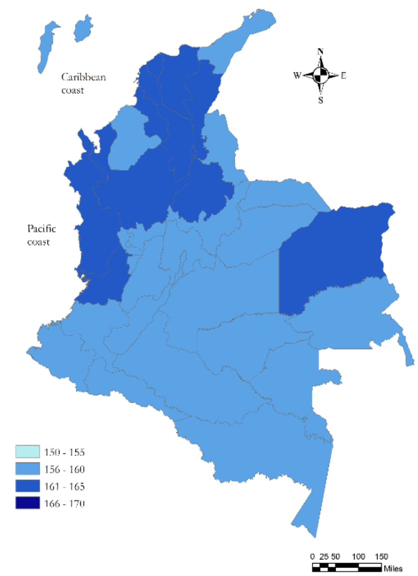
Appendix 2

Map 1. Geographical distribution of average heights: first vs. last decade of the 20th century (centimeters)

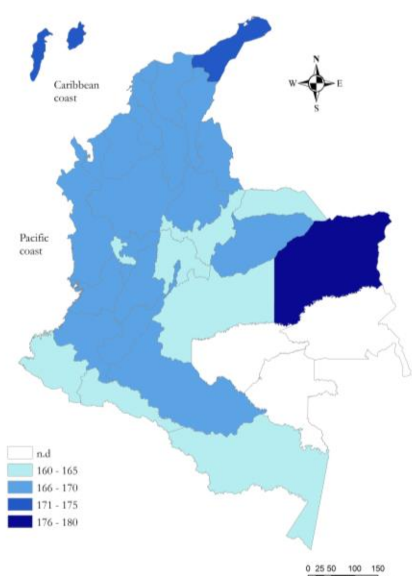
Women born between 1921 and 1930



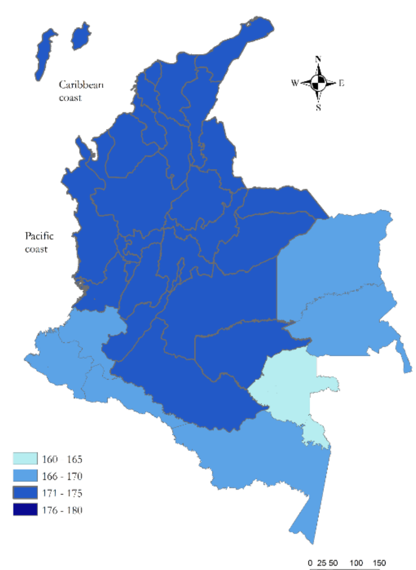
Women born between 1981 and 1990



Men born between 1921 and 1930



Women born between 1981 and 1990



Source: Authors' elaboration based on judicial background certificates issued by the former DAS.


BANCO DE LA REPÚBLICA
COLOMBIA