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Artículo

Gender height dimorphism: An approximation of the living Standards in Colombia, 1920-1990

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A B S T R A C T

This paper analyzes the evolution and the socioeconomic determinants of gender height dimorphism to approach the Colombian living standards during the twentieth century. Using quantile regression, the results indicate that the eco-sensitivity hypothesis holds. In bad economic times, taller men are more penalized, and in good times, they grow more. Also, taller women take greater advantage of economic improvements. The results show an increasing trend in the absolute value of dimorphism throughout the century across quantiles of height. Between 1920 and 1990, absolute height dimorphism increased from 9.9 to 11.8 centimeters in the 10th quantile and from 10.84 to 12.2 centimeters in the 90th quantile. Living standards in Colombia have improved considerably during the twentieth century, as reflected in the evolution of stature. Individuals' socioeconomic status explains the biological welfare and final adult height.

Dimorfismo de género en estatura: una aproximación a los niveles de vida en Colombia, 1920-1990

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R E S U M E N

Este artículo analiza la evolución y los determinantes socioeconómicos del dimorfismo en estatura para aproximarse al nivel de vida de los colombianos durante el siglo XX. Utilizando regresiones cuantílicas, se verifica la hipótesis de eco-sensibilidad. En condiciones socioeconómicas adversas, los hombres más altos son más penalizados, y en tiempos buenas, crecen más. Además, las mujeres más altas aprovechan mejor las buenas condiciones económicas. Se encuentra una tendencia creciente en el dimorfismo y entre los cuantiles de estatura. Entre 1920 y 1990, el dimorfismo absoluto aumentó de 9,9 a 11,8 centímetros en el cuantil 10 y de 10,84 a 12,2 centímetros en el cuantil 90. Finalmente, durante el siglo XX, Colombia ha mejorado las condiciones de vida, reflejado en el aumento de la estatura de hombres y mujeres. El nivel socioeconómico de los individuos explica el bienestar biológico y la estatura adulta final.

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1. Introduction

This paper analyzes Colombia's living standards in the long run by studying the evolution and determinants of gender height dimorphism in the country during the twentieth century. Colombia is an interesting case since few studies discuss differences in adult height between males and females in emerging economies as an indicator of the evolution of a country's living standards in the long run.

Variations of anthropometric measurements as an indicator of the population's living standards and human development from a historical perspective have been well documented in the literature (Bogin *et al.*, 2017; Costa-Font and Gil, 2008; Challú and Silva-Castañeda, 2016; Cámara, 2015, 2018). They have been used by economic historians to measure changes in quality of life in the long run. Adult stature reflects people's living conditions in their past because, in addition to being affected by genetics, it is also influenced by individuals' childhood and adolescent nutrition, environmental, and socioeconomic conditions (Komlos and Baten, 2004; Komlos, 2003; Bassino, 2006; Depauw and Oxley, 2019)[1].

Moreover, changes in gender height dimorphism provide information about differences in the evolution of men's and women's health and living standards and how they respond to environmental and socioeconomic conditions in the long run (Costa-Font and Gil, 2008; Sohn, 2016). The literature has analyzed both absolute and relative height dimorphism. The former corresponds to the difference between men's and women's heights, in centimeters, and the latter, to the absolute dimorphism related to women's height.

As pointed out by Koepke *et al.* (2018), analyzing the height gap contributes to understanding biological sex disparities due to gender, and in particular, characteristics that could determine net nutrition. Also, Cámara (2018) states that sexual dimorphism can provide evidence of environmental stress episodes that impact the population's nutritional status over time.

There are few studies on the differences between men and women regarding their adult height and their determinants. Those that do exist focus mainly on analyzing dimorphism patterns in advanced economies. For these countries, one strand of the literature has found that variations in dimorphism are related to the country's socioeconomic conditions and differentials in socioeconomic status at the individual level. Also, men's stature seems to be more negatively affected under adverse conditions than women's, thus reducing the dimorphism index. Conversely, men grow higher than women in good environmental conditions, and dimorphism may increase (Cámara, 2015, 2018; Costa-Font and Gil, 2008; Bogin *et al.*, 2017; Baten and Murray, 2000; Harris, 2009). Schwekendiek and Baten (2019) found that for China, South Korea, and Taiwan, from the 1960s to the 1980s, people's height increases as their income grew. However, gender inequality in stature rose in China during the transition to a market system in the 1980s, while in South Korea and Taiwan, gender inequality followed an increasing trend during these years[2].

In contrast, another strand of literature shows no evidence for the hypothesis that when environmental conditions are favorable or when there is a higher level of growth and development, dimorphism tends to increase (Sohn, 2016; Gustafsson *et al.*, 2007; Koepke *et al.*, 2018).

Another explanation for changes in stature dimorphism is related to women's roles. Guntupalli and Baten (2009) find that European women in the 10th to 14th centuries were remarkably shorter than men. In comparison, women in the fifteenth and sixteenth centuries were taller since women benefited from their changing social roles during the Renaissance.

For emerging countries, Deaton (2008) indicates that better access to health services and food in recent years explains the increase in dimorphism in India between 1960 and 1980, but no apparent effect is observed between income level and height. However, Guntupalli and Moradi (2009) show that poverty increases gender discrimination in India. Recently, Castellucci *et al.* (2021) found a reduction in height dimorphism in Chile from 1955 to 1995, which is associated with improvements in welfare indicators such as women's health and greater gender equality. Nevertheless, they found that dimorphism is unrelated to the Chilean per capita GDP[3].

Our paper contributes to this literature by analyzing the evolution of biological well-being, measured by height, especially by gender height dimorphism, from a historical perspective of a middle-income country like Colombia, where the literature is scarce. To this end, we use a large dataset of more than 225,000 individuals born between 1920 and 1990. This paper considers the heterogeneity in the height distribution by using quantile regressions, which also control for unobservable effects associated with stature.

This study also provides evidence in favor of the eco-sensitivity hypothesis and explores gender height inequalities during the twentieth century in Colombia. We hypothesize that the differential eco-sensitivity between men and women is present in Colombia in the long run and that there are important differences among quantiles of height.

Cámara (2018) used the term eco-sensitivity (*eco-sensibilidad)* to refer to the existing literature on sex differences in response to environmental changes. The eco-sensitivity hypothesis states that when the socioeconomic conditions are not good, the penalty in biological terms would be higher for men (Cámara, 2015, 2018; Bogin *et al.*, 2017)[4]. Our estimations indicate that the eco-sensitivity hypothesis holds for Colombia in the long run. In bad economic times, taller men suffer more, and in good times, they grow more. In the case of females, taller women take greater advantage of economic improvements. The results also show an increasing trend in the absolute value of dimorphism thought the century across all quantiles of height.

[1] Recent studies include: Galofré-Vilà (2018); Beltran (2015); Floud *et al.* (2014); Floud *et al.* (2011); María-Dolores and Martinez-Carrión (2011); Blum (2014); Komlos and Kelly (2016); Schwekendiek and Baten (2019).

[2] This result is partly explained by the nutritional biases toward men due to cultural factors in these countries.

[3] For Latin American countries, although they do not directly analyze dimorphism, Challú and Silva-Castañeda (2016) do examine the evolution of adult female height in twelve Latin American countries during the second half of the 20th century. They find that people's average height increases by 2.6 cm from the 1950s to the 1990s, with significant variations among countries.

[4] Some studies find that height dimorphism increases as heights do (Cámara, 2015; Schwekendiek and Baten, 2019), while others find that there is no relation between height dimorphism and mean heights (Gustaffson, 2004).

In this paper, we extend previous work by Meisel-Roca *et al.* (2019a) who explored the relationship between the physical stature of Colombians born during the twentieth century and some socioeconomic characteristics. However, Meisel-Roca *et al.* (2019a) did not examine heterogeneity in terms of height quantiles or gender inequalities, or dimorphism in stature[5].

The following section presents the dataset and some stylized facts on gender height dimorphism. Section 3 explains the methodology, section 4 discusses the results, and section 5 concludes.

2. Data

We use information from the Colombian judicial background certificates issued by the former Departamento Administrativo de Seguridad (DAS), previously gathered by Meisel-Roca *et al.* (2019a). This certificate was necessary to leave the country, work in the public sector, sign a contract with the government, and was required in most cases to work in the private sector[6]. Meisel-Roca *et al.* (2019a) mentioned that the Colombian General National Archive stored, in more than 25,000 boxes, nearly ten million judicial records issued during the twentieth century in main Colombian towns and cities. All the certificates in a box are from the same department. As these authors explained, the boxes were chosen by stratified random sampling to digitalize the information, and the strata were the departments. This methodology allows a high degree of representativeness[7].

The certificates include the individual height and socioeconomic characteristics such as gender, education, occupation, and the date and municipality where the individual was born. The sample contains information for 223,822 individuals, 42.8% women, and 57.2% men, born between 1921 and 1990 throughout the country[8]. This database has the advantage that height was not self-reported and is not truncated. The stature reported in the certificates corresponds to the height registered on the national identity card.

We also employ annual information at the departmental level that affects people's quality of life, such as the mortality rate for some diseases (Jaramillo-Echeverri *et al.*, 2019). Table 1 presents the definition, mean, and standard deviation of the variables we included in the empirical analysis.

We calculate absolute and relative height dimorphism. The first is the difference between men's and women's height, and the second is the absolute dimorphisms related to women's height as defined in Koepke *et al.* (2018):

$$\frac{H_i^M - H_i^F}{H_i^F} * 100$$

with H_i^M, H_i^F male and female's height and i represents the individual. The advantage of this measure is that relative height dimorphism is independent of a population's mean height as it describes the percentage by which males are taller than the females (Wells, 2012).

Figure 1 shows the evolution of both indicators by year of birth. We observed two main patterns: a reduction in dimorphism between 1920 and the end of the 1950s (from 9.9 cm to 9 cm in absolute dimorphism, and from 6.4% to 5.8% in relative dimorphism), and an increasing trend after 1960 (from 9 cm to 11.8 cm in absolute dimorphism, and from 5.7% to 7.4% in the relative dimorphism). Colombia's relative gender dimorphism is similar to that of other countries[9]. For example, Cámara (2018) found that relative height dimorphism differs from 7% to 8% across the globe, and Gustaffson (2004) found a 7.2% relative height dimorphism in the cross-cultural analysis carried out. As observed, both indexes followed the same trend during the twentieth century. However, there is a variation in absolute dimorphism as it depends on the secular trend of heights, which has increased during the century.

[5] For anthropometric studies in Colombia, see Meisel and Vega (2007); Acosta and Meisel (2013); Meisel-Roca *et al.* (2019a); Meisel-Roca *et al.* (2019b).

[6] Some workers in the informal sector who did not require this document or people who lived in a very remote rural area could have been excluded from this sample. Moreover, the dataset did not include individuals accused of committing a crime but were not subject to a judicial decision since the General Archive did not authorize the digitalization of judicial record certificates for these individuals. As Meisel-Roca *et al.* (2019a) pointed out, this exclusion did not bias the sample because such 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.

[7] To have a balanced sample, Meisel-Roca *et al.* (2019a) digitized more boxes from the departments with a small number of observations (Amazonas, Arauca, Huila, Meta, Magdalena, San Andrés, and Chocó).

[8] We exclude occupations in the armed forces since the number of observations for women was low (only 51 cases). We also omitted heights below 120 cm since they could represent errors in the information on heights.

[9] Cámara (2015, 2018); Bogin *et al.* (2017) found similar results.

Table 1.
Definition of variables

Variables	Obs.	Definition	Mean	Std. Dev.
Sex	223,822	= 1 if male	0.57	0.49
Diseases				
Respiratory	223,822	Respiratory mortality rate per 1,000 inhabitants	83.05	58.67
Gastrointestinal	223,822	Gastrointestinal mortality rate per 1,000 inhabitants	57.07	43.94
Puerperal	223,822	Deaths from puerperal diseases per 100,000 live births	10.26	9.85
Occupation				
Unskilled	135,898	= 1 if worker did not have training	0.469	0.499
Skilled	135,898	= 1 if worker had training	0.314	0.464
Student	135,898	= 1 if individual is a student	0.218	0.413
Education				
Primary	200,913	= 1 if the individual has primary	0.217	0.412
Secondary	200,913	= 1 if the individual has secondary	0.522	0.500
Technical/Technician	200,913	= 1 if the individual has technical/technician education	0.068	0.252
University	200,913	= 1 if the individual has university	0.193	0.395
Birth cohort				
1920-1929	223,822	= 1 if the individual was born between 1920 and 1929	0.027	0.162
1930-1939	223,822	= 1 if the individual was born between 1930 and 1939	0.050	0.219
1940-1949	223,822	= 1 if the individual was born between 1940 and 1949	0.089	0.285
1950-1959	223,822	= 1 if the individual was born between 1950 and 1959	0.149	0.356
1960-1969	223,822	= 1 if the individual was born between 1960 and 1969	0.232	0.422
1970-1979	223,822	= 1 if the individual was born between 1970 and 1979	0.239	0.426
1980-1989	223,822	= 1 if the individual was born between 1980 and 1989	0.213	0.410
Urban controls				
Migration	173,140	= 1 if individual migrate	0.375	0.484
Top 20	223,822	= 1 if birth municipality was one of the top 20 population municipalities	0.425	0.494

Source: Authors' calculations.

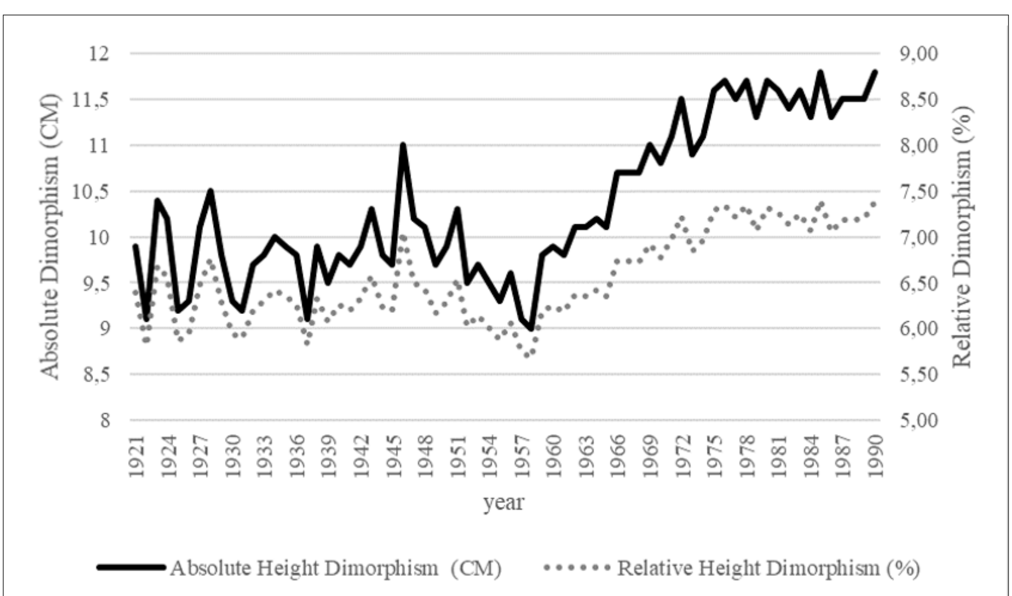

Figure 1. Absolute and relative gender height dimorphisms' trends by year of birth: Colombia, 1920-1990.
Source: Authors' calculations.

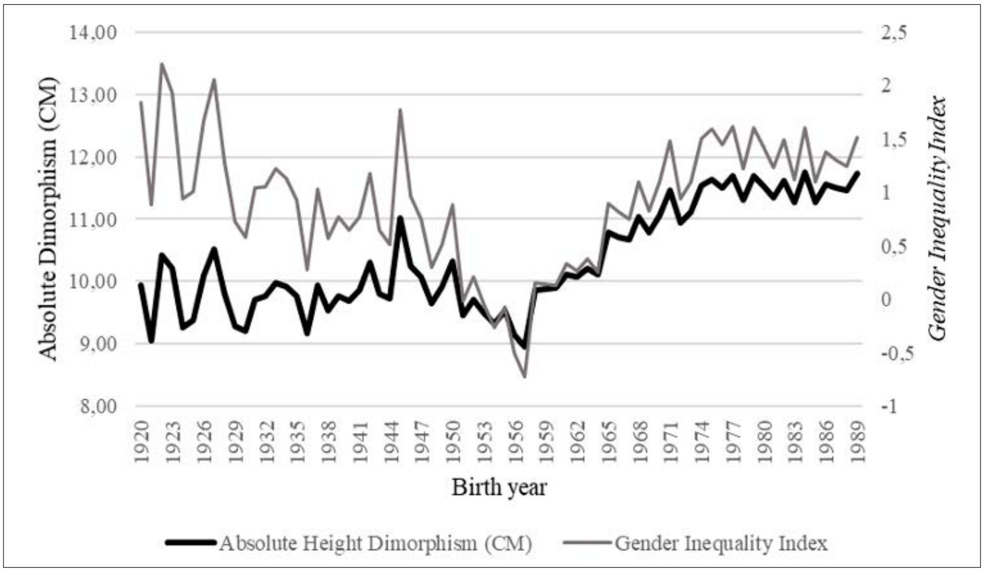

Figure 2. Absolute height dimorphism and Schwekendiek and Baten (2019)'s *Gender Inequality Index* for Colombia: 1920-1990.
Source: Authors' calculations.

For Colombia, we also calculate a Gender Inequality Index using the formula Schwekendiek and Baten (2019) proposed[10]. The gender inequality index presents a similar pattern to the evolution of dimorphism. Figure 2 shows a decreasing trend in gender inequality during the first half of the twentieth century, and an increasing trend since the 1960s. The results resemble the trend of gender inequality in countries like China and South Korea (Schwekendiek and Baten, 2019).

Further discussion will suggest that during the early 20th century, environmental stress could affect men's stature more than that of women. During these decades, Colombia continued to be a poor country, with a low level of education, low provision of public services, high mortality and fertility rates, and low life expectancy (Jaramillo-Echeverri *et al.*, 2019). However, socio-economic changes regarding labor participation, education, and women's roles slowly reduced gender inequality during the first half of the twentieth century (Iregui *et al.*, 2021).

On the other hand, during the second half of the twentieth century, men benefited more from the socio-economic and living standard improvements. Throughout this period, Colombia underwent a demographic transition, with a steep decline in fertility rates, a rapid epidemiological transformation, significant improvements in public health and sanitary conditions, better nutrition, and increased life expectancy at birth. Moreover, as Ramírez y Téllez (2007) pointed out, education coverage expanded at the end of the fifties given the increase of fiscal revenue assigned to this sector, which was possible due to the good economic conditions presented during those years[11]. Figure 3 reveals higher per capita income levels and rapid and sustained economic growth during the second half of the twentieth century until the 1999 crisis.

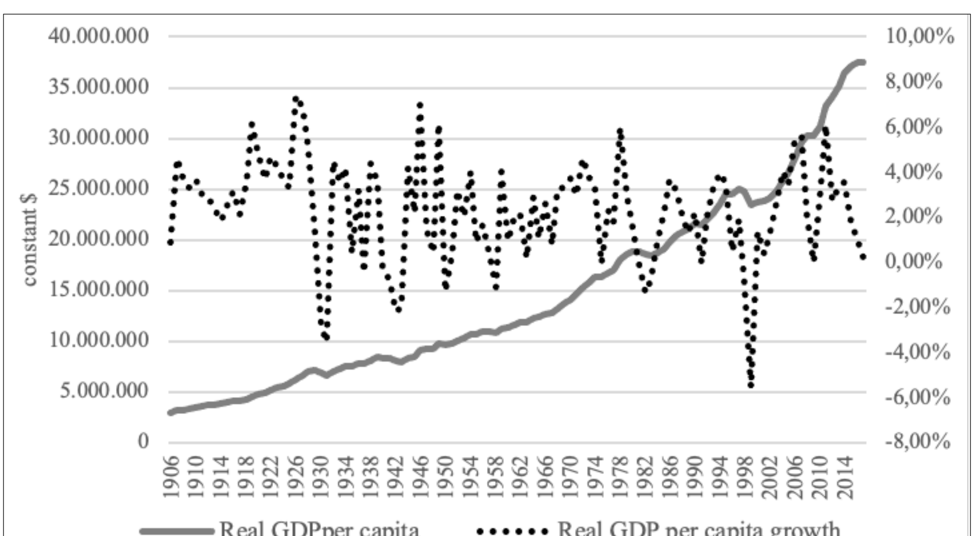

Figure 3. Real GDP per capita and Real GDP per capita growth, Colombia.
Source: Greco and Dane.

[10] *The Gender Inequality Index* is calculated using Schwekendiek and Baten's (2019) formula: $GII = H_i^M - H_i^F - (-33.75 + 0.27(H_i^{FM}))$ where: H_i^F stands for the female's height, H_i^M for the male's height and H_i^{FM} is the mean height when considering both sexes.

[11] According to Ramírez and Téllez (2007), public spending on education went from 1% of GDP in the late 1940s to 3% in the 1960s; and the 1958 Plebiscite established minimum spending on education to be equal to 10% of the central government's budget.

Figure 4 presents the long-run relationship between height dimorphism and real GDP per capita in the country. Low per capita income levels negatively correlated with dimorphism during the first decades of the twentieth century. However, the increments in per capita GDP observed during the second half of that century seem to benefit men's height more than women's, meaning that the gap between male and female stature increased despite improvements in GDP after the 1960s.

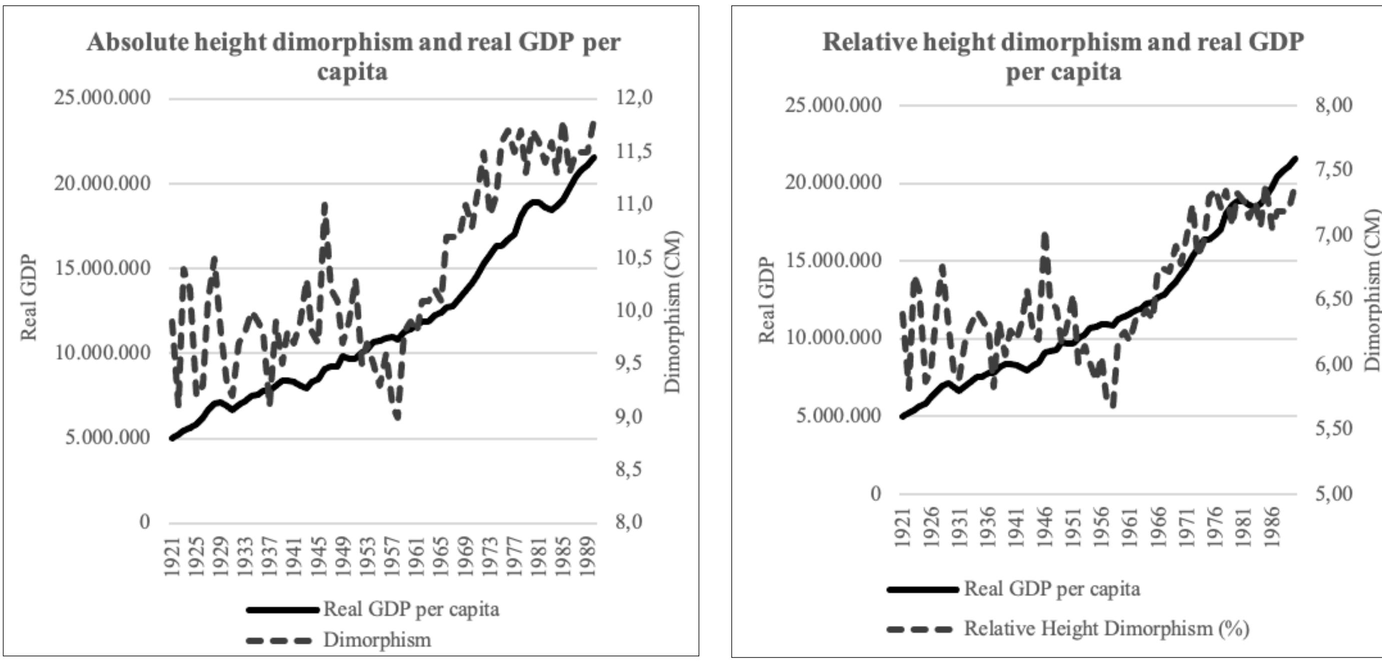

Figure 4. Relationship between height dimorphism and real per capita GDP, Colombia.
Source: Greco (2002) and own calculations.

3. Methodology

We use three strategies to unveil the relationship between gender height dimorphism and living standards. First, we perform a quantile analysis by estimating the socioeconomic determinants of stature for men and women. Second, we analyze the effects of the socioeconomic environment on the quantile's gender height dimorphism. Third, we exploit quantile regression methodology to test the eco-sensitivity hypothesis and discuss height inequalities.

For the selection of variables, we employ two machine learning methods. First, the best subset selection exhaustively explores all the possible combination models among variables and chooses the best specification that minimizes prediction error. For example, RMSE and some variants penalize the number of variables used in the model (BIC and AIC). In this case, for a model with 16 variables, it estimates 65.536 model specifications and chooses the best one based on previous metrics. Results show that the specification presented is an adequate one. We also use Lasso regression methodology, which penalizes the prediction error with the sum of the absolute value of the coefficients. This penalization shrinkages coefficients toward zero. Lasso variable selection is valid when datasets may show signs of high multicollinearity. By carrying out this analysis, we could identify that no variable's coefficient was omitted.

Quantile analysis on the determinants of men and women's height

We estimate the determinants of male's and female's height in Colombia during the twentieth century using quantile regression techniques, a statistical method for estimating and inferring the conditional quantile functions that offer a mechanism to estimate the median and the quantiles[12]. The quantile regression allows us to account for height distribution heterogeneity and control for unobservable effects associated with stature and let us estimate the determinants of height at different points of its distribution (Costa-Font and Gil, 2008)[13].

We include as explanatory variables observable characteristics such as occupation (unskilled, skilled, student) to account for individuals' capabilities; education (primary, secondary, technical/technician, and university) as an indicator of an individual's socioeconomic status (SES)[14]; and health measures (mortality rate from gastrointestinal infections, respiratory

[12] For a presentation of quantile regressions, see Koenker and Hallock (2001) and Hao and Naiman (2007).

[13] Quantile regression has been used in the anthropometric literature, where the distribution of the variables is mainly heterogeneous (Costa-Font and Gil, 2008; Ouyang *et al.*, 2015; Yirga *et al.*, 2018; Rahman *et al.*, 2020).

[14] See Bogin *et al.* (2017); Ayuda and Puche-Gil (2014); Blanden (2004).

diseases, and puerperal diseases in the department and year of birth). We also include the birth cohort decade, which stands for the environmental effects, urbanization (proxied by population size in the municipality of birth[15]), and migration.

We estimate the following equation separately for males and females:

Equation 1

$$Q^{\theta}(H_i | X_i) = \beta_0^{\theta} + \beta_1^{\theta} * Skilled_{id} + \beta_2^{\theta} * Student_{id} + \\ + \beta_3^{\theta} * Secondary_{id} + \beta_4^{\theta} * Technical_{id} + \beta_5^{\theta} * Tertiary_{id} + \\ + \beta^{\theta} * \varnothing_{id} + \gamma_d + \varepsilon_{id}^{\theta}$$

where H_i represents individual's height in centimeters, *i* represents the individual, *d* the department in which the individual was born, γ_d the departmental fixed effects, $0<\theta<1$ the proportion of the population having scores below the quantile at θ, $\varnothing$ is the vector of covariates that includes health measures, birth cohort decade, urbanization (top 20 larger municipalities), and a dummy variable that takes the value of 1 if individual migrated and 0, otherwise. Also, Q^{θ} is the conditional quantile or the θ quantile of the height density conditional on X_i. In this model specification β^{θ} $(k=1, 2, ..., k)$ refers to the marginal change in the θth quantile due to the change in the covariate (X_{ik})[16, 17]. For comparative purposes, we also estimated equation 1 using Ordinary Least Squares (OLS).

Quantile analysis on the determinants of absolute gender height dimorphism

We also analyze the socioeconomic determinants of absolute gender height dimorphism for the Colombian population. Following Costa-Font and Gil (2008, p. 7), men's and women's predicted height gap (absolute height dimorphism) can be compared at the different quantiles by considering a set of observable characteristics (X_i), as: $\widehat{Q}_{\theta}(H_i^M / X_i) - \widehat{Q}_{\theta}(H_i^F / X_i)$.

Where: H_i represents the individual's height, $\widehat{Q}_{\theta}$ is the θ quantile of the predicted height conditional on the socio-economic and environmental characteristics X_i, *M* represents males, and *F* females. It is important to consider that $\widehat{Q}_{\theta}$ will be a result of predicting the individual's height in the previous analysis.

As Costa-Font and Gil (2008), to decompose the absolute height dimorphism, it is assumed that the θth quantile of the error term is zero (Equation 2):

Equation 2

$$\widehat{Q}_{\theta}(H_i^M / X_i) - \widehat{Q}_{\theta}(H_i^F / X_i) = X_i(\widehat{\beta}_{\theta}^M - \widehat{\beta}_{\theta}^F) + \epsilon_i$$

Expanding Costa-Font and Gil (2008) analysis, this methodology suggests that by analyzing the estimated partial effects of socioeconomic factors on each gender's height ($\widehat{\beta}_{\theta}^M$ and $\widehat{\beta}_{\theta}^F$), one could approximate the total effect of the determinants on height dimorphism as the difference of male's and female's coefficients for the same quantile's determinant.

Testing the eco-sensitivity hypothesis and inequality analysis

To test the eco-sensitivity hypothesis, we estimate two quantile regression models (Equation 3):

Equation 3

$$Q^{\theta}(H_i | X_i) = \alpha_0^{\theta} + \alpha_1^{\theta} * Sex_i + \varepsilon_i^{\theta}$$

where H_i represents individual's height, *i* represents the individual, $0<\theta<1$ indicates the proportion of the population having scores below the quantile at θ, and *Sex* is a dummy variable that equals 1 if male, 0 otherwise[18].

For the first specification, we regress the individual's absolute height (H_i) with the sex dummy variable. In this regression, the sex coefficient can be interpreted as the mean difference in height between males and females. It can be understood as the absolute height dimorphism for each quantile. Second, we perform the same regression with the logarithmic of the individual's stature (H_i). In this regression, the sex coefficient is transformed to be interpreted as the difference in male and female height as a percentage of female's stature; that is, the relative gender height dimorphism.

By exploiting the advantages of quantile regression methodology, both models will help us test the eco-sensitivity hypothesis if the sex coefficient for a respective quantile is greater as the quantiles increase.

Finally, we extended our analysis by examining heights inequalities[19]. A standard measure to account for inequality is the quantile Q90:Q10 ratio, which divides the 90th quantile by the 10th (Foster *et al.*, 2013).

To approximate this index, we predicted men's and women's stature for the θ^{th} quantile using the equation's 1 vector of regression coefficients $\widehat{\beta}_{\theta}^J$ for each gender *J* (*J=M, F*) and a row vector of values for the independent variables $\overline{X}_{ik}$. These vectors are composed of the mean values of the covariates. There is a vector for every birth cohort decade *k*, in which the value associated with the *k* decade is 1 and 0 for the other decades. Then, we predicted the 90[th] to 10[th] height inequality ratio for both genders as presented in equation 4:

[15] Following Meisel-Roca *et al.* (2019a), we used as a proxy of urbanization the top 20 larger municipalities by population size. This variable is a dummy that takes the value of 1 if the municipality of birth is ranked among the top 20 according to its population size. It is important to mention that the municipalities ranked top 20 by population size varied over time.

[16] We estimate the models with fixed effects by departments, and the standard errors were calculated by bootstrapping with 200 replications

[17] Quantile regression was estimated through the method of moments (mm-quantile regression), proposed by Machado and Santos-Silva (2019), which has the advantage that it is applied to models with endogenous explanatory variables and for differencing fixed effects in panel data. We use the package MMQREG in Stata, programmed by these authors

[18] We use bootstrapping methods with 200 replications to calculate standard errors.

[19] Quantile regression methodology has been used in social research on inequalities to understand, for example, wage gaps (Chay and Honore, 1998), and income inequalities (Foster *et al.*, 2013). The main advantage of these regressions is that they disentangle between and within-group differences (Hao and Naiman, 2007).

Equation 4

$$RatioQ90:Q10_{Jk} = \frac{\widehat{Q}_{90}(H_{ik}^{j} \mid \overline{X}_{ik})}{\widehat{Q}_{10}(H_{ik}^{j} \mid \overline{X}_{ik})} = \frac{\overline{X}_{ik}(\widehat{\beta^{J}}_{90})}{\overline{X}_{ik}(\widehat{\beta^{J}}_{10})}$$

This measure is interpreted as how many times the tallest ones (90th quantile) are taller than the shortest individuals (10th wquantile).

4. Results

Quantile Estimations of the Determinants of Men and Women's Height

Tables 2 and 3 present the econometric results of the socioeconomic determinants of male and female height from the conditional quantile function (columns 1 to 5), respectively[20]. In the last column (6), we also report the results from the OLS estimations. Comparing the results, we observed that the relationship between the socioeconomic factors and males' and females' stature varies between quantiles. Therefore, the mean analysis provided by OLS is not adequate to address height's determinants, so we will only discuss the results of the quantile regressions.

Results indicate that mortality rates affect men's height more negatively at the top quantiles; this is consistent with the eco-sensitivity hypothesis, as taller males get a more significant penalization for adverse conditions such as a greater incidence of diseases. However, for females' stature, gastrointestinal and puerperal diseases may not be correlated with differentials in women's height across quantiles. Sexual dimorphism susceptibility and mortality may explain this result in infectious diseases[21]. According to Ortona *et al.* (2019): "Females have stronger innate and adaptive (humoral and cellular) immune responses in comparison to males" (p. 1). Also, genetic factors such as an extra X chromosome express several genes implicated in immunological processes. Libert *et al.* (2010) state that females present better survival rates than males since the X chromosome plays a significant role in responding to various immune challenges. Instead, the respiratory disease mortality rate seems to affect more females' stature than males' stature. Studies suggest that some respiratory diseases may affect women differently and with greater severity than men due to environmental, sociocultural, and occupational differences among sex (Pinkerton *et al.*, 2015). According to Liu *et al.* (2021), since women are more involved in domestic activities, they might be more exposed to household air pollution. In fact, according to the United Nations: "Indoor air pollution from using combustible fuels for household energy caused 4.3 million deaths in 2012, with women and girls accounting for 6 out of every 10 of these".[22]

All levels of education are positively related to higher stature for all quantiles. Compared with primary education, the reference category, men with secondary education are almost 2 cm higher, with technical/technological education 2.9 cm taller, and those with a university degree are 4.4 cm taller. As quantiles increase, males' technical and university education coefficients show a monotonically increasing trend. Taller men benefit more from better SES than the shorter ones. Then, the eco-sensitivity hypothesis holds since men benefit from the favorable living conditions and grow for more extended periods, resulting in greater final heights than the shorter ones.

Females with secondary education are up to 1.7 cm taller than the reference group, with technical/technological education up to 1.9 cm taller, and women with a university degree are up to 3.2 cm taller. The estimates of education are more significant among shorter women (Table 3). This monotonically decreasing trend across quantiles is observed for all levels of education. For the shorter ones, those who achieved university education are 3.2 cm taller than the reference group. In contrast, for the tallest ones, estimates suggest that they are only 2.6 cm higher.

The eco-sensitivity hypothesis may explain these results. Better economic living conditions would bring forward the menarche and anticipate closing the growth cycle for girls (Cámara, 2018; Yousefi *et al.*, 2013). In Colombia, Jansen *et al.* (2015) found an inverse association between education and family wealth with the age of menarche, which could explain the decreasing pattern across quantiles observed for all levels of education. Taller women are associated with better SES and could obtain larger nutritional improvements due to favorable economic conditions, anticipating the closing of the growing cycle.

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[20] Although the decision to use these quantiles might be arbitrary, it is traditional to use the 10, 25, 50, 75, and 90 in the literature (Costa-Font and Gil, 2008). However, we estimate quantile effects over sequential quantiles. That is, for every 5th quantile starting at the 5th to the 95th quantile. Results were robust and showed monotonicity among quantiles. Results are available upon request.

[21] See, Giefing-Kroll (2015).

[22] See United Nation's Sustainable Development Goals, goal 7 "Affordable and clean energy", https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Table 2.
Quantile regression results for the socioeconomic determinants of male's height

Variables	(1) quantile_10	(2) quantile_25	(3) quantile_50	(4) quantile_75	(5) quantile_90	(6) OLS
Mortality Rate:						
Respiratory	-0.0024	-0.0029	-0.0035**	-0.0041***	-0.0046***	-0.0035***
	(0.0024)	(0.0019)	(0.0016)	(0.0015)	(0.0018)	(0.0012)
Gastrointestinal	-0.0034	-0.0043*	-0.0052***	-0.0061***	-0.0070***	-0.0052***
	(0.0027)	(0.0022)	(0.0019)	(0.0021)	(0.0026)	(0.0015)
Puerperal	-0.0235	-0.0230	-0.0225	-0.0219	-0.0214	-0.0224***
	(0.0241)	(0.0206)	(0.0173)	(0.0146)	(0.0132)	(0.0068)
Education						
Primary	Ref	Ref	Ref	Ref	Ref	Ref
Secondary	1.997***	1.979***	1.960***	1.941***	1.922***	1.960***
	(0.161)	(0.128)	(0.102)	(0.0970)	(0.115)	(0.0801)
Technical	2.884***	2.888***	2.892***	2.896***	2.901***	2.892***
	(0.253)	(0.212)	(0.178)	(0.160)	(0.164)	(0.163)
University	4.353***	4.377***	4.402***	4.427***	4.453***	4.402***
	(0.304)	(0.255)	(0.213)	(0.188)	(0.190)	(0.109)
Occupation						
Unskilled	Ref	Ref	Ref	Ref	Ref	Ref
Skilled	0.338**	0.361***	0.387***	0.413***	0.439***	0.388***
	(0.147)	(0.112)	(0.0874)	(0.0874)	(0.113)	(0.0839)
Student	0.195	0.266	0.342**	0.421***	0.498***	0.344***
	(0.227)	(0.184)	(0.149)	(0.135)	(0.148)	(0.0861)
Birth Cohort						
1920	-0.424	-0.352	-0.273	-0.192	-0.114	-0.271
	(0.460)	(0.361)	(0.272)	(0.224)	(0.246)	(0.217)
1930	0.224	0.0876	-0.0589	-0.211	-0.358**	-0.0627
	(0.406)	(0.324)	(0.248)	(0.188)	(0.177)	(0.166)
1940	Ref	Ref	Ref	Ref	Ref	Ref
1950	-0.755***	-0.576***	-0.383**	-0.184	0.0104	-0.378***
	(0.213)	(0.182)	(0.157)	(0.138)	(0.135)	(0.130)
1960	0.692***	0.694***	0.695***	0.697***	0.699***	0.695***
	(0.266)	(0.217)	(0.180)	(0.167)	(0.186)	(0.156)
1970	1.496***	1.485***	1.474***	1.462***	1.451***	1.474***
	(0.301)	(0.253)	(0.219)	(0.208)	(0.227)	(0.204)
1980	1.684***	1.724***	1.767***	1.812***	1.855***	1.768***
	(0.371)	(0.309)	(0.274)	(0.282)	(0.331)	(0.239)
Migration	0.191*	0.243***	0.298***	0.356***	0.412***	0.300***
	(0.101)	(0.0820)	(0.0722)	(0.0772)	(0.0948)	(0.0634)
Top 20 rest (mun. size)	Ref	Ref	Ref	Ref	Ref	Ref
Top 20 (mun. size)	0.759***	0.823***	0.892***	0.963***	1.032***	0.894***
	(0.177)	(0.174)	(0.177)	(0.187)	(0.202)	(0.0797)
Constant	159.1***	162.8***	166.9***	171.0***	175.1***	167.0***
	(0.504)	(0.411)	(0.329)	(0.355)	(0.411)	(0.261)
Departmental Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50,907	50,907	50,907	50,907	50,907	50,907

Source: Authors' estimations. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Ref: reference group.

Table 3.

Quantile regression results for the socioeconomic determinants of female's height

VARIABLES	(1) quantile_10	(2) quantile_25	(3) quantile_50	(4) quantile_75	(5) quantile_90	(6) OLS
Mortality Rate:						
Respiratory	-0.0073**	-0.0079**	-0.0085***	-0.0091**	-0.0096**	-0.0085***
	(0.0031)	(0.0031)	(0.0033)	(0.0036)	(0.0040)	(0.0013)
Gastrointestinal	-0.0007	-0.0007	-0.0008	-0.0009	-0.0009	-0.0008
	(0.0035)	(0.0031)	(0.0031)	(0.0035)	(0.0041)	(0.0018)
Puerperal	-0.0062	-0.0054	-0.0044	-0.0035	-0.0027	-0.0044
	(0.0133)	(0.0093)	(0.0073)	(0.0099)	(0.0145)	(0.0076)
Education						
Primary	Ref	Ref	Ref	Ref	Ref	Ref
Secondary	1.750***	1.673***	1.586***	1.498***	1.416***	1.584***
	(0.186)	(0.166)	(0.161)	(0.177)	(0.204)	(0.0964)
Technical	1.993***	1.909***	1.816***	1.720***	1.632***	1.814***
	(0.248)	(0.225)	(0.223)	(0.249)	(0.289)	(0.148)
University	3.204***	3.065***	2.910***	2.752***	2.605***	2.907***
	(0.307)	(0.295)	(0.293)	(0.305)	(0.325)	(0.122)
Occupation						
Unskilled	Ref	Ref	Ref	Ref	Ref	Ref
Skilled	0.388***	0.449***	0.517***	0.586***	0.650***	0.518***
	(0.119)	(0.106)	(0.106)	(0.122)	(0.149)	(0.0865)
Student	0.750***	0.758***	0.768***	0.777***	0.786***	0.768***
	(0.146)	(0.132)	(0.125)	(0.128)	(0.141)	(0.0891)
Birth Cohort						
1920	0.182	0.0627	-0.0700	-0.205	-0.331	-0.0725
	(0.455)	(0.403)	(0.362)	(0.348)	(0.362)	(0.260)
1930	-0.189	-0.0516	0.102	0.260	0.405	0.105
	(0.329)	(0.284)	(0.276)	(0.317)	(0.388)	(0.187)
1940	Ref	Ref	Ref	Ref	Ref	Ref
1950	0.554*	0.512**	0.465***	0.418**	0.374*	0.465***
	(0.307)	(0.233)	(0.174)	(0.167)	(0.215)	(0.144)
1960	0.615*	0.652**	0.694***	0.736***	0.776***	0.695***
	(0.338)	(0.268)	(0.219)	(0.221)	(0.269)	(0.174)
1970	0.492	0.496	0.500	0.505*	0.509	0.500**
	(0.506)	(0.414)	(0.336)	(0.306)	(0.335)	(0.229)
1980	0.597	0.662	0.736*	0.811**	0.880**	0.737***
	(0.596)	(0.507)	(0.429)	(0.390)	(0.401)	(0.269)
Migration	0.331	0.343*	0.356**	0.370**	0.382**	0.356***
	(0.220)	(0.184)	(0.156)	(0.149)	(0.165)	(0.0735)
Top 20 rest (mun. size)	Ref	Ref	Ref	Ref	Ref	Ref
Top 20 (mun. size)	0.809***	0.767***	0.720***	0.671***	0.627***	0.719***
	(0.171)	(0.156)	(0.148)	(0.152)	(0.167)	(0.0883)
Constant	148.8***	152.5***	156.6***	160.7***	164.6***	156.6***
	(0.770)	(0.716)	(0.665)	(0.657)	(0.612)	(0.300)
Departmental fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	41,872	41,872	41,872	41,872	41,872	41,872

Source: Authors' estimations. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; Ref: reference group.

An individual's occupation also has an important relation with stature; these effects are more important for women than men. For both cases, as quantiles increase, the occupation coefficients increase too. For males, the results suggest a 0.34 cm difference in height among the skilled and unskilled workers (the reference group) for the shortest ones, while, for the tallest, the difference widens to 0.44 cm. For females, the shortest skilled women were about 0.38 cm higher than the unskilled ones, but the difference expands to 0.65 cm for the tallest.

For males, being a student does not represent a significant difference in stature for the shorter ones compared with the unskilled workers. However, there is a 0.5 cm difference in height for the tallest. For women, students are positively correlated with a higher stature for all the quantiles about 0.75 cm taller than the reference group.

The estimates of being a skilled worker or student, especially for women, may reflect the influence of human capital or abilities that contributes to efficiency in health production through health knowledge and better and healthier sanitary practices (Case and Paxson, 2006). Also, according to Schick and Steckel (2010), more capable individuals are associated with a better nutritional status.

For males and females, there are no significant differences in height between individuals born in the 1920s and 1930s compared to those born in the 1940s[23] (the reference group), except for the negative impact that the 1930s had on the tallest men.

Despite the economic growth observed in the 1920s, due to the insertion of the country in the international capital market and the increase of coffee exports, the population's living conditions did not increase considerably. España (2019) mentioned that the benefits of globalization and coffee expansion were not transferred to improving the living standards of the entire population. In the case of education, the author states that the persistence of racism and the economic elites prevented some regions in the country from transferring the benefits of the first globalization to better performance in education. Moreover, during the 1920s, the rise in government expenditures and the limited supply of primary goods contributed to increased prices that affected citizens' consumption and the quality of the population's diet (López-Uribe *et al.*, 2011). Also, the country's lack of a suitable sanitary public provision caused the expansion of epidemics and infections, affecting people's health (Jaramillo-Echeverri *et al.*, 2019).

In the 1930s and 1940s, the Great Depression and World War II affected the Colombian economy. The country's access to global markets was suddenly stopped, coffee exports fell, government investments slowed down, and prices increased, leading to slow advances in the standard of living. In fact, during the last years of the 1930s, the relative price of dairy, meat, tubers, and legumes increased (*Anales de Economía y Estadística*, 1940, p. 59). This rise in prices led to an unbalanced diet consumption among the population. For instance, 1,000 calories of chicken cost 0.5 pesos, while the same 1,000 calories worth of cereals such as rice or grains such as beans only cost 0.15 pesos (Socarras, 1939). Therefore, households had to substitute consumption for goods that provided high caloric quantities per unit of price, which led to poorer diets as these substitutes lacked some proteins, vitamins, and minerals. Consequently, undernourishment was an essential issue during these decades. The *Anales de Economía y Estadística* (1943 and 1949) present the results of two studies on nutrition levels for the population in Bogota and Medellin, respectively. The first examined the nutrition of 466 Bogota middle-class individuals in 1941. The results show that 20% of the middle class had adequate nutrition, and 30% suffered undernourishment. Among Bogota's working class, malnutrition was far more severe. According to a study that interviewed 1,172 individuals from 225 working-class families in 1936, 72% of the individuals suffered from undernourishment in Bogotá. The second study analyzed the nutrition in Medellin in 1938. The results show that 70% of the working class suffered from some degree of undernourishment. Both studies report that undernourishment was shared across individuals of the same family.

Interestingly, when comparing the 1930s with the reference group, we find a negative statistically significant impact on the tallest male's height, 0.36 cm shorter than those born in the 1940s, which could be explained by the difficult living conditions for individuals born during the 1930s, that seems to have affected more the tallest men. This result is in line with the eco-sensitivity hypothesis. On the contrary, there is no statistically significant result of being born during the 1930s on adult height for females, suggesting that females seem more resilient to adverse environmental conditions.

When we compare the stature of men born in 1950 with those born in 1940, we find that the shortest was up to 0.75 cm shorter than those born during the 1940s. There are no significant differences in stature for the top quantiles (the tallest). From 1949 to 1958, Colombia suffered from the widespread political conflict called *La Violencia*. Romero and Meisel (2019) estimated the death toll due to *La Violencia* to be 39,142; about 91% of these deaths correspond to men. The effects of *La Violencia* varied across regions and were more severe in rural areas, where socioeconomic conditions were more adverse than in urban areas. The authors estimated that *La Violencia* was more concentrated in the Andes region (Tolima, Huila, Santander, Norte de Santander, Caldas, Quindío, Risaralda, and Valle del Cauca) and was less intense in other areas such as the Caribbean. The negative impacts of this conflict were more substantial on rural peasants, who were forced to sell their crops and lands at low prices and were displaced from their lands[24]. Therefore, results suggest differential impacts of *La Violencia*, as shorter men were more affected by the harsh conditions derived from it. Instead, taller men, most of them living in the cities, might not have been affected directly by that conflict[25].

[23] We selected the 1940s birth cohort decade as the reference group since there were several economic transformations after that decade. Economic transition and early industrialization dramatically changed socioeconomic conditions. Also, urbanization demanded increased public goods such as schools, roads, and health infrastructure; and regional integration led to price convergence on the food derived from nutritional changes and a better diet.

[24] Turmoil emerged as rural guerrillas formed, and several skirmishes occurred across the bi-partisan supporters. For more details on the *La Violencia* period, see Picker (2013); Bailey (1967).

[25] Using the *Panel Municipal del CEDE* database, which contains information on the presence of violence in each municipality from 1948 to 1953, we estimate an auxiliary regression in which the heights of individuals born during the 1930s, 1940s, and 1950s depend on the interaction between sex, a dummy variable that equals one if the

Table 3 shows significant positive estimates on height for women born in 1950 compared to the reference group, especially for the shortest one. Women in the lower quantiles grew to 0.54 cm more than the reference group, while the tallest ones grew 0.37 cm more. This result may suggest that the *Violence* did not affect women as much as men. According to Iregui *et al.* (2021), from 1951 to 1964, the difference in life expectancy at birth between men and women increased by about five years, and the wage gap decreased due to the shortage of the male labor force.

Both men and women born during the 1960s are taller than the reference group in all quantiles. During the 1960s, the country's socioeconomic conditions improved considerably, especially for women, with more education, greater labor market access, public goods, and economic growth. Furthermore, in the mid-1960s, a demographic transition took place, from 6.7 children per woman to 3 at the end of the 1980s (Iregui *et al.,* 2021)[26].

The impact of the 1970s and 1980s birth cohort was higher for men than for women in all quantiles and higher in the distribution's right tail. In the 1970s, men grew 1.5 cm more than those in the reference group, while women grew 0.5 cm. For those born in the 1980s, men grew almost 1.9 cm more than the reference group, while women grew about 0.9 cm[27]. These results are consistent with the eco-sensitivity hypothesis, as men's stature benefits more from good environmental conditions than women. Good socioeconomic conditions would anticipate the closing of the growth cycle for girls as nutritional improvements due to economic growth could reduce the age of menarche (Cámara, 2018; Yosefi *et al.,* 2013). Villamor *et al.* (2009) estimated that the reduction in the age at menarche of Colombian women born between 1941 and 1989 was 0.55 years per decade. On the contrary, men mature slower than women; they have more time to grow and to expose to environmental conditions that influence their final height (Bogin *et al.,* 2017; Guntupalli and Baten, 2009).

Regarding urbanization, men and women born in the top 20 larger municipalities are taller than those born in smaller cities. Colombian case is different from those reported in the literature. For example, Komlos (1998) found a negative relationship between urbanization and stature in Europe and the United States, particularly during the nineteenth century. In contrast, the urbanization in Colombia during the second half of the twentieth century coincided with significant improvements in public health, sewerage, and food supply, improving the cities' environmental conditions.

Lastly, results suggest a correlation between those who migrated and higher stature for both men and women. Most migrated to larger cities, where living conditions and labor opportunities were better than their original residence. People also migrated to the cities due to the violence occurring in rural areas.

Total effects on gender height dimorphism

Figure 5 presents the results of the birth cohort effects on the predicted absolute gender height dimorphism[28]. The impact of the 1930s decade on dimorphism was negative among the tallest ones. As explained, this decade was characterized by difficult economic conditions. Furthermore, when comparing the 1950s decade with the reference group, environmental conditions suggest a more than 1 cm reduction in absolute height dimorphism. This result indicates that women benefited more from this decade, but men did not. One reason could be the adverse effects on men derived from *La Violencia* and its economic consequences[29]. Our findings are consistent with the anthropometric literature showing that heights and dimorphism shortens during war periods. For example, sexual stature dimorphism was lower among Spaniards whose infancy occurred during the Civil War (Costa-Font and Gil, 2008; Cámara, 2015).

The environmental effects on dimorphism are statistically significant for all quantiles in the 1970s, with an increase of almost 1 cm in absolute gender dimorphism. Similarly, in the 1980s, estimated dimorphism increased for all quantiles, higher than the estimate for the 1970s. This result is also consistent with other studies, which reveal that dimorphism has increased during the last decades of the twentieth century in most developed countries (Cámara, 2018).

individual's birthplace was affected by *La Violencia* and 0 otherwise, and the individual birth cohort decade. Results indicate that the individual height of those born in a municipality associated with *La Violencia* was 1.43 cm (S.E 0.656) shorter than those that were not. Also, this triple interaction estimates that absolute height dimorphism across individuals born in a municipality affected by *La Violencia* was 1.393 cm (S.E 1.185) lower. Results are available upon request.

[26] Mothers have many multiplier effects on the future generations living conditions, mainly via the health and living standards that future mothers will have (Osmani and Sen, 2003) and through the offspring's infant development (Koepke *et al.,* 2018).

[27] Interestingly, unlike the political violence of the 1950s, drug violence appears not to have affected men's height and thus did not contribute to the reduction of dimorphism. Drug violence increased homicides of young men substantially, especially between 1984 and 2000. Homicides of men, on average, accounted for 93% of total homicides in these years (https://www.policia.gov.co/revista-criminalidad/editorial?page=2). One of the reasons could be that drug violence occurred when the country experienced more significant economic development and higher standards of living than in the 1950s.

[28] The estimation was computed by the differences between male and female coefficients from equation 1.

[29] The estimates among the shortest are the expected since *La Violencia* affected more rural peasants, who had a lower height than the population in the city.

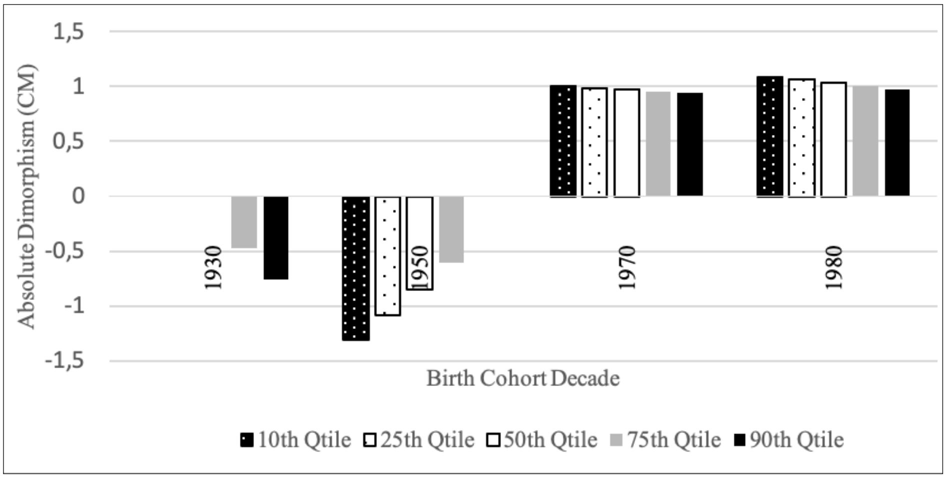

Figure 5. Estimated birth cohort effects on gender absolute height dimorphism across quantiles.

Source: Authors' calculations. Note: 1920's and 1960's results are not statistically significant; therefore, they are not presented in this figure.

The results in Figure 6 show a positive relationship between educational and dimorphism, which increases with the quantile. The absolute dimorphism for individuals with secondary education is between 0.2 and 0.5 cm higher for those with primary education. For technical/technological education, the estimated impact on height dimorphism increases substantially compared to the reference group, up to 1.27 cm among the tallest ones.

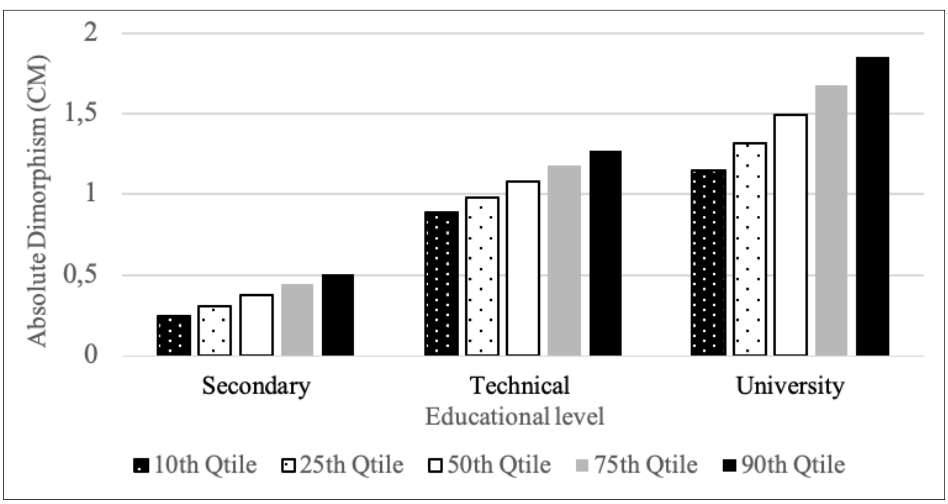

Figure 6. Estimated results of educational level on gender absolute dimorphism across quantiles

Source: Authors' calculations.

University presents the most significant result on dimorphism, with substantial differences between quantiles; the estimated impact was 1.14 cm for the shortest ones and 1.84 cm for the tallest. As education is associated with the family's socioeconomic status, individuals with more education would have a greater capacity to acquire better quality foods and nutrients and access better health services (Chanda *et al.*, 2008). These results follow the eco-sensitivity hypothesis: dimorphism increases across SES groups and as quantiles increase.

Results of the eco-sensitivity hypothesis and inequalities

Figures 7 and 8 plot the absolute and relative dimorphism for every quantile and provide the 95% certainty level confidence intervals. The results show that absolute dimorphism varies from 9 to 11.5 cm and that relative dimorphism was around 6.5% in Colombia during the twentieth century, like the height dimorphism values found by Cámara (2018) for the OCDE countries. Also, Colombia's absolute and relative dimorphism was greater among the tallest individuals, as the eco-sensitivity hypothesis suggests. This is a crucial finding as it gives robust statistical evidence for this hypothesis and explores this relationship in developing countries.

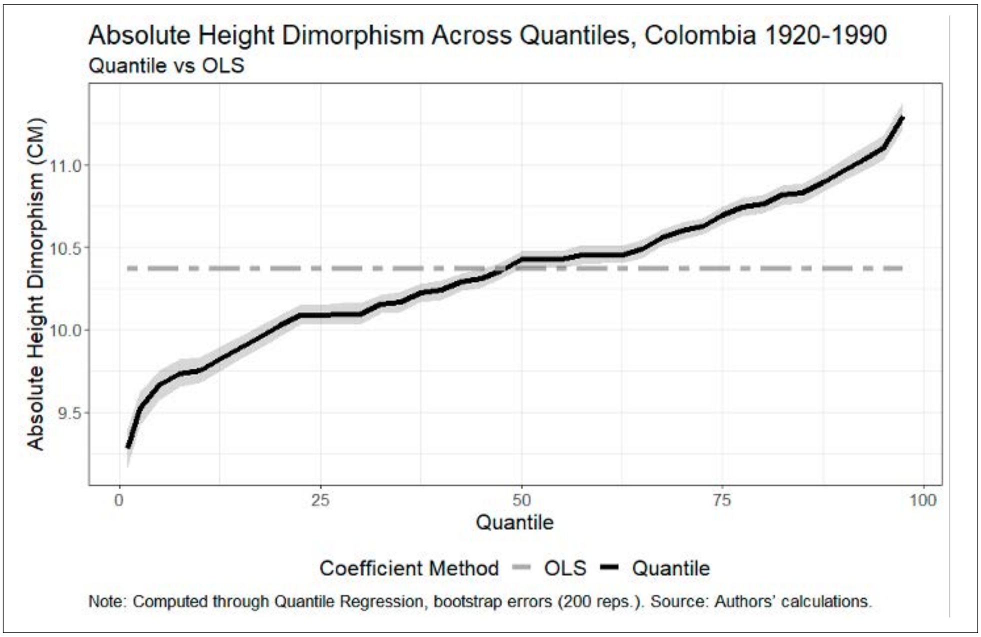

Figure 7. Absolute Height Dimorphism Across Quantiles, Colombia (1920.1990).

Note: Computed through Quantile Regression, bootstrap errors (200 reps.).

Source: Authors's calculations.

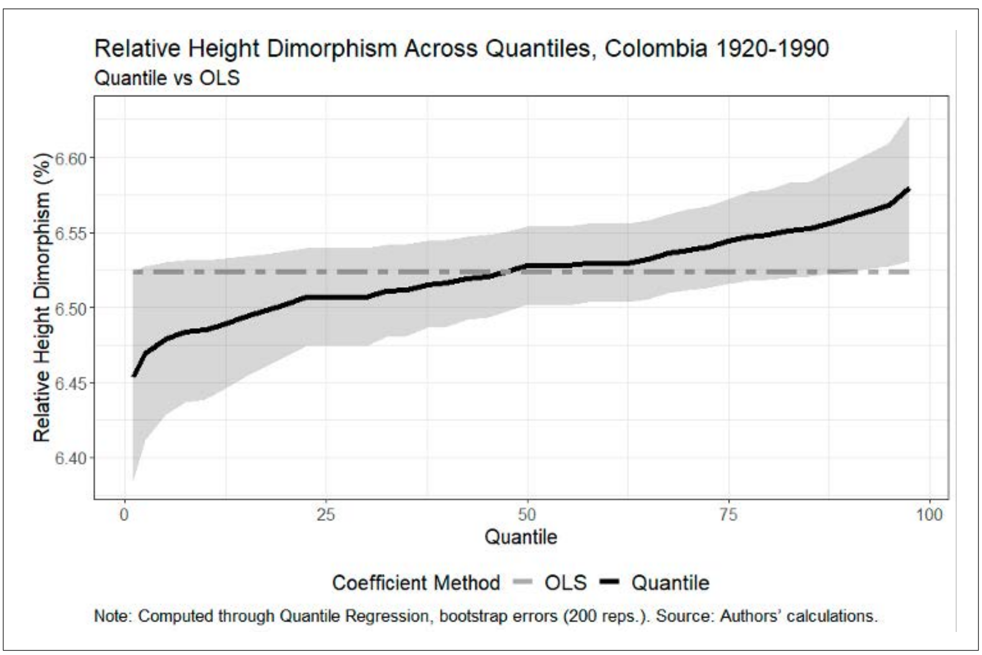

Figure 8. Relative Height Dimorphism Across Quantiles, Colombia (1920.1990).

Note: Computed through Quantile Regression, bootstrap errors (200 reps.).

Source: Authors's calculations.

Lastly, regarding inequalities, during the 20th century, the height inequality ratio (Q90:Q10) was higher for women than for men, meaning that the height differences between taller and shorter women are more significant than those for men. In the 1930s, the tallest women were 1.11 times taller than the shortest ones; in the 1980s, they were 1.108 times. In turn, the tallest men were 1.095 times higher than the shortest in the 1930s. In the 1950s, a peak occurred; the tallest men were 1.103 times taller than the shortest (Figure 9). Our hypothesis suggests differential effects of *La Violencia* among taller men associated with heterogeneity.

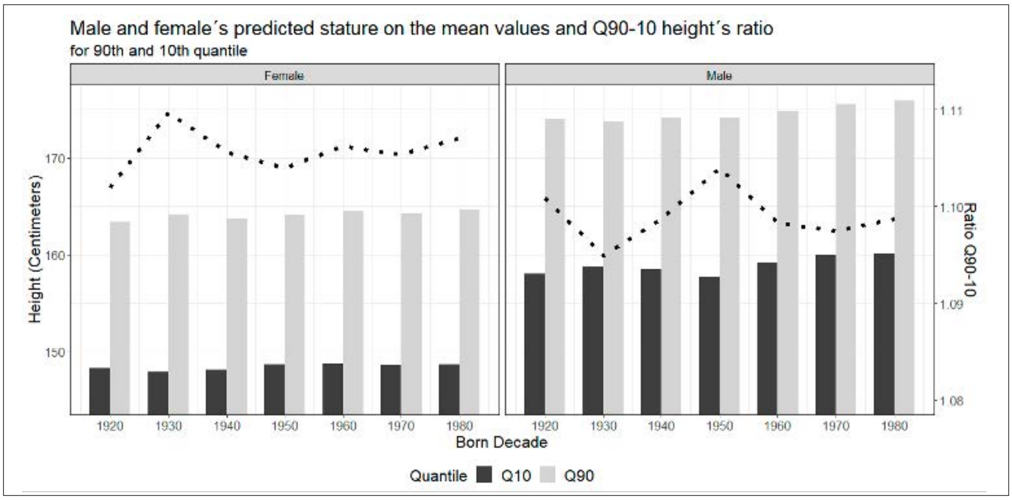

Figure 9. Male and female's predicted stature on the mean values and Q90-10 heght's ratio for 90h and 10th quantile.
Source: Authors' calculations.

5. Conclusions

In Colombia, gender height dimorphism reduced between 1920 and the end of the 1950s but increased from the second half of the twentieth century. These results support the eco-sensitivity hypothesis, where dimorphism decreases when the socioeconomic environment is adverse and increases with good economic conditions because men are less resilient during adverse environments. Instead, men can grow more in suitable environmental conditions, then dimorphism increases. Furthermore, Colombia's height dimorphism was greater among the tallest individuals.

Our results suggest that socioeconomic conditions did not significantly affect an individual's stature during the first decades of the twentieth century due to adverse environmental conditions that did not allow individuals to achieve their potential height. Between the 1960s and 1970s, socioeconomic transformations significantly increased females' biological welfare. However, the estimations suggest unequal benefits of these decades among women. Only the tallest ones, associated with unobserved heterogeneity highly related to the status, benefited from the structural changes. Instead, since the 1960s, all men have benefited from better living conditions.

Heterogeneity among height distribution is important. The results show that the height differences between taller and shorter women are more significant than those observed for men. Finally, there was an increasing trend of height inequality during the century, which may reflect differences in the opportunity to access better socioeconomic conditions among the population.

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Authors' contributions

All authors contributed equally to all sections of the paper. All authors read and approved the final manuscript.

References

Acosta, K. and Meisel, A. (2013). "Anthropometric Measurements by Ethnicity in Colombia, 1965-1990", *Economics and Human Biology*, 11 (4), 416-425.

Ayuda, M. I. and Puche-Gil, J. (2014). "Determinants of Height and Biological Inequality in Mediterranean Spain, 1859-1967", *Economics and Human Biology*, 15, 101-119.

Bailey, N. A. (1967). "La Violencia in Colombia", *Journal of Inter-American Studies*, 9 (4), 561-575.

Bassino, J. P. (2006). "Inequality in Japan, 1892-1941: Physical Stature, Income, and Health", *Economics and Human Biology,* 4 (1), 62-88.

Baten, J. and Murray, J. (2000). "Heights of Men and Women in 19th Century Bavaria: Economic, Nutritional, and Disease Influences", *Explorations in Economic History*, 37 (4), 351-369.

Blanden, J. (2004). "Family Income and Educational Attainment: A Review of Approaches and Evidence for Britain", *Oxford Review of Economic Policy*, 20 (2), 245-263.

Blum, M. (2014). "Estimating Male and Female Height Inequality", *Economics and Human Biology,* 14 (1), 103-108.

Bogin, B., Scheffler, C. and Hermanussen, M. (2017). "Global Effects of Income and Income Inequality on Adult Height and Sexual Dimorphism in Height", *American Journal of Human Biology*, 29 (2).

Cámara, A. D. (2015). "A Biosocial Approach to Living Conditions: Inter-Generational Changes of Stature Dimorphism in 20th-Century Spain", *Annals of Human Biology*, 42 (2), 167-177.

Cámara, A. D. (2018). "Sobre la asociación entre el dimorfismo sexual en estatura y el estado nutricional de hombres y mujeres en el largo plazo", *Nutrición Hospitalaria*, 35 (5).

Case, A. and Paxson, C. (2006). "Children's Health and Social Mobility. The Future of Children", *The Future of Children,* 16 (2), 151-173.

Castellucci, H., Viviani, C., Boccardo, G., Arezes, P., Bartsch, Á, Martínez, M. and Bragança, S. (2021). "Gender Inequality and Sexual Height Dimorphism in Chile", *Journal of Biosocial Science*, 53 (1), 38-54.

Costa-Font, J. and Gil, J. (2008). "Generational effects and gender height dimorphism in contemporary Spain", *Economics and Human Biology*, 6 (1), 1-18.

Chanda, A., Craig, L.A. and Treme, J. (2008). "Convergence (and Divergence) in the Biological Standard of Living in the USA, 1820-1900", *Cliometrica,* 2 (1), 19-48.

Challú, A. E. and Silva-Castañeda, S. (2016). "Towards an Anthropometric History of Latin America in the Second Half of the Twentieth Century", *Economics and Human Biology,* 23 (C), 226-234.

Chay, K. Y. and Honore, B. E. (1998). "Estimation of Semiparametric Censored Regression Models: An Application to Changes in Black-White Earnings Inequality During the 1960s", The *Journal of Human Resources*, 33 (1), 4-38.

Deaton, A. (2008). "Height, Health, and Inequality: The Distribution of Adult Heights in India", *American Economic Review*, 98 (2), 468-474.

Depauw, E. and Oxley, D. (2019). "Toddlers, Teenagers, and Terminal Heights: The Importance of Puberty for Male Adult Stature, Flanders, 1800-1876", *Economic History Review*, 72 (3), 925-952.

España-Eljaiek, I. (2019). "Development for the Center and Civilization for the Periphery: The First Globalization, Racial Exclusion and Regional School Development in Colombia", in Mitch, D., Cappelli, G. (eds.). *Globalization and the Rise of Mass Education.* Palgrave Studies in Economic History. Palgrave Macmillan.

Floud, R., Fogel, R., Harris, B. and Hong, S. (2011). *The Changing Body: Health, Nutrition, and Human Development in the Western World since 1700*. Cambridge: Cambridge University Press.

Floud, R., Fogel, R., Harris, B. and Hong, S. (2014). *Health, Mortality and the Standard of Living in Europe and North America since 1700*. Northampton, M. A.: Edward Elgar Publishing.

Foster, J., Seth, S. Lokshin, M. and Sajaia, Z. (2013). *A Unified Approach to Measuring Poverty and Inequality: Theory and Practice*. Washington, D. C.: World Bank.

Galofré-Vilà, G. (2018). "Growth and Maturity: A Quantitative Systematic Review and Network Analysis in Anthropometric History", *Economics and Human Biology*, 28, 107-118.

Giefing-Kröll, C., Berger, P., Lepperdinger, G. and Grubeck-Loebenstein, B. (2015). "How Sex and Age Affect Immune Responses, Susceptibility to Infections, and Response to Vaccination", *Aging Cell*, 14 (3), 309-321.

GRECO (2002). *El crecimiento económico colombiano en el siglo xx*. Bogotá: Banco de la República and Fondo de Cultura Económica,.

Guntupalli, A. and Moradi, A. (2009). "What does Gender Dimorphism in Stature Tell Us About Discrimination in Rural India, 1930-1975?", in Manoranjan, P., Premananda, B., Bholanath G. and Vasulu, T. S. (eds.). *Gender and Discrimination: Health, Nutritional Status, and Role of Women in India*. Oxford University Press India.

Guntupalli, A. and Baten, J. (2009). "Measuring Gender Well-being with Biological Welfare Indicators", in *Gender and Well-Being in Europe: Historical and Contemporary Perspectives,* Farnham, GB: Ashgate, pp. 43-58.

Gustafsson, A. and Lindenfors, P. (2004). "Human Size Evolution: no Allometric Relationship Between Male and Female Stature", *Journal of Human Evolution*, 47 (4), 253-266.

Gustafsson, A., Werdelin, L., Tullberg, B. and Lindenfors, P. (2007). "Stature and Sexual Stature Dimorphism in Sweden, From the 10th to the End of the 20th Century", *American Journal of Human Biology*, 19 (6), 861-870.

Hao, L. and Naiman, D. (2007). *Quantile Regression*. London: Sage.

Harris, B. (2009). "Anthropometric History, Gender and The Measurement of Well-Being", in Harris, B., Gálvez, L. and Machado, H. (eds.). *Gender and Wellbeing in Europe: Historical and Contemporary Perspectives*. Farnham, GB: Ashgate, pp. 59-84.

Iregui-Bohórquez, A. M., Melo-Becerra, L. A., Ramírez-Giraldo, M. T. and Tribin-Uribe A. M. (2021). *El camino hacia la igualdad de género en Colombia: todavía hay mucho por hacer*. Bogotá: Banco de la República.

Jansen, E., Herrán, O. and Villamor, E. (2015). "Trends and Correlates of Age at Menarche in Colombia: Results from A Nationally Representative Survey", *Economics and Human Biology,* 19, 138-144.

Jaramillo-Echeverri, J., Meisel-Roca, A. and Ramírez-Giraldo, M. T. (2019). "More Than 100 Years of Improvements in Living Standards: The Case of Colombia", *Cliometrica,* 13 (3), 1-44.

Koenker, R. and Hallock, K. (2001). "Quantile Regression", *The Journal of Economic Perspectives*, 15 (4), 143-156.

Koepke, N., Floris, J., Pfister, C., Rühli, F. and Staub, K. (2018). "Ladies first: Female and male adult height in Switzerland, 1770-1930", *Economics and Human Biology*, 29, 76-87.

Komlos, J. (1998). "Shrinking in a Growing Economy? The Mystery of Physical Stature during the Industrial Revolution", *The Journal of Economic History*, 58 (3), 779-802.

Komlos, J. (2003). *On the Biological Standard of Living of Eighteenth-Century Americans: Taller, Richer, Healthier*. Munich Discussion Paper, 2003-9.

Komlos, J. and Baten, J. (2004). "Looking Backward and Looking Forward: Anthropometric Research and the Development of Social Science History", *Social Science History* 28 (2), 191-210.

Komlos, J. and Kelly, I. (2016). *The Oxford Handbook of Economics and Human Biology*, Oxford University Press.

Libert, C., Dejager, L. and Pinheiro, I. (2010). "The X Chromosome in Immune Functions: when a Chromosome Makes the Difference", *Nature Reviews Immunology* 10 (8), 594-604.

Liu, T., Chen, R., Zheng, R., Li, L. and Wang, S. (2021). "Household Air Pollution from Solid Cooking Fuel Combustion and Female Breast Cancer", *Frontiers in Public Health,* 9, article 677851, 1-8.

López-Uribe, M. P, Castellanos, D. and Gaitán-Guerrero, L. (2011). *Mujeres en ascenso: dinámica del sistema educativo y del mercado laboral en Colombia, 1900-2000*.

Machado, J. and Santos-Silva, J. (2019). "Quantiles via moments", *Journal of Econometrics*, 213 (1), 45-173.

María-Dolores, R. and Martínez-Carrión, J. (2011). "The Relationship between Height and Economic Development in Spain, 1850-1958", *Economics and Human Biology*, 9 (1), 30-44.

Meisel, A. and Vega, M. (2007). "The Biological Standard of Living (and Its Convergence) in Colombia, 1870-2003: A Tropical Success Story", *Economics and Human Biology,* 5 (1), 100-122.

Meisel-Roca, A., Ramírez-Giraldo, M. T. and Santos-Cárdenas, D. (2019a). "Socioeconomic Determinants and Spatial Convergence of Biological Well-Being: The Case of Colombia, 1920-1990", *Revista de Historia Económica*, 37 (2), 297-338.

Meisel-Roca, A., Ramírez-Giraldo, M.T. and Santos-Cárdenas, D. (2019b). *Long Run Relationship between Biological Well-Being, and Economic Development in Colombia*. Red Investigadores de Economía, Working Papers, 24.

Ortona, E., Pierdominici, M. and Rider, V. (2019). Editorial: Sex Hormones and Gender Differences in Immune Responses. *Frontiers in Immunology*, 10, 1076.

Osmani, S. and Sen, A. (2003). "The Hidden Penalties of Gender Inequality: Fetal Origins of Ill-Health", *Economics and Human Biology,* 1 (1), 105-121.

Ouyang, Y., Wang, H., Su, C., Wang, Z., Song, Y., Xiao, Y., Du, W. and Zhang, B. (2015). "Use of Quantile Regression to Investigate Changes in The Body Mass Index Distribution of Chinese Adults Aged 18-60 Years: A Longitudinal Study", *BMC Public Health*, 15, 278.

Pinkerton, K., Harbaugh, M., Han, M., Le, S., Winkle, L., Martin, W., Kosgei, R., Carter, E., Sitkin, N., Smiley-Jewell, S. and George, M. (2015). "Women and Lung Disease. Sex Differences and Global Health Disparities", *American Journal of Respiratory and Critical Care Medicine*, 192 (1), 11-16.

Polícia Nacional. *Revista Criminalidad*. Disponible en: https://www.policia.gov.co/revista-criminalidad/editorial?page=2

Rahman, A. and Hossain, M. (2020). "Quantile Regression Approach to Estimating Prevalence and Determinants of Child Malnutrition", *Journal of Public Health*: *From Theory to Practice*, 28 (3), 1-28.

Ramírez, M. T. and Téllez, J. (2007). "La educación primaria y secundaria en Colombia en el siglo xx" in J. Robinson and M. Urrutia (eds), *Economía colombiana del siglo xx: un análisis cuantitativo*. Bogotá: Banco de la República; Fondo de Cultura Económica.

Romero, J. and Meisel, A. (2019). "Análisis demográfico de la violencia en Colombia", *Cuadernos de Historia Económica*, 50.

Schick, A. and Steckel, R. (2010). *Height as a Proxy for Cognitive and Non-Cognitive Ability*. NBER Working Paper, w16570.

Schwekendiek, D. and Baten, J. (2019). "Height Development of Men and Women from China, South Korea, and Taiwan during The Rapid Economic Transformation Period of the 1960s-1980s", *Economics and Human Biology*, 34, 169-180.

Socarrás, F. (1939). "Alimentación de la clase obrera en Bogotá", *Anales de Economía y Estadística,* 2 (5), 1-106.

Sohn, K. (2016). "Sexual Stature Dimorphism as an Indicator of Living Standards?", *Annals of Human Biology*, 43 (6), 537-541.

United Nations. Sustainable Development Goals, Goal 7 "Affordable and clean energy". Disponible en: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Yirga, A., Ayele, D. and Melesse, S. (2018). "Application of Quantile Regression: Modeling Body Mass Index in Ethiopia", *The Open Public Health Journal*, 11 (1), 221-233.

Yousefi, M., Karmaus, W., Zhang, H., Roberts, G., Matthews, S., Clayton, B., and Arshad, S. H. (2013). "Relationships Between Age of Puberty Onset and Height at Age 18 Years in Girls and Boys", *World Journal of Pediatrics*, 9 (3), 230-238.