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Two worlds apart: Determinants of height in late 18th century central Mexico☆

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ABSTRACT

Anthropometric literature on the American territories of the Hispanic monarchy before their independence is still scarce. We attempt to expand the field with a case study that includes some important novelties.

Albeit our main source, the military records of the *Censo de Revillagigedo* (conducted in the early 1790s), has already been used, the sample size and the geographical scope are unprecedented: 19,390 males of four ethnicities (*castizos*, *españoles*, *mestizos*, and *mulatos*) aged from 16 to 39 from 24 localities, including towns and villages scattered across central regions of the Viceroyalty of New Spain. We build a database that, complemented with information on resource endowments obtained from other sources, permits to analyze the determinants of height.

Our results show the importance of spatial differences as well as the significance of ethnicity, occupation, rurality, age and resource endowments as determinants of height. Unprivileged *mulatos* are only 0.5 cm shorter than, assumedly privileged, *españoles* in the "first world" (*El Bajío*) and 1.3 cm taller in the "second world" (Eastern Central Highlands). In turn, living in the "first world" implies being between nearly 1.5 cm and 5 cm taller than the inhabitants of the "second world". Our estimates of physical statures are placed within an international comparative context and offer a relatively "optimistic" picture.

1. Introduction

Anthropometric research on contemporary Iberian America is increasing in volume and quality.[1] Previous phases of the history of this part of the world (e.g., post-independence and late 19th-century decades, as well as the first half of the 20th-century) have also received some attention by practitioners of anthropometrics.[2] Some authors examine biological standards of living over periods that extend from the 19th-century to the present.[3] Interesting panoramic views of the anthropometric research conducted for diverse periods and places may be found in Steckel and Rose (2002), Baten and Carson (2010), and Salvatore et al. (2010). Nonetheless, the available knowledge about levels and trends of physical well-being indicators for early modern Spanish America is still very limited. In particular, only a few works deal with New Spain, the largest, most populated and richest among the American territories possessed by the Hispanic monarchy (see, Challú, 2009, 2010; Dobado and García, 2010, 2014; Grajales-Porras and López-Alonso, 2011).

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[1] Morales et al. (2004), Baltzer and Baten (2008), Acosta and Meisel (2013), Bozzoli and Quintana-Domeque (2014) and De Oliveira and Quintana-Domeque (2014).

[2] López-Alonso (2010), López-Alonso and Porras-Condey (2003), Salvatore (2004a,b, 2007, 2009a,b), Carson (2005, 2007), Baten et al. (2009); Salvatore et al. (2010) and Twrdek and Manzel (2010).

[3] Meisel and Vega (2007), Bejarano et al. (2009) and Núñez and Pérez (2015).

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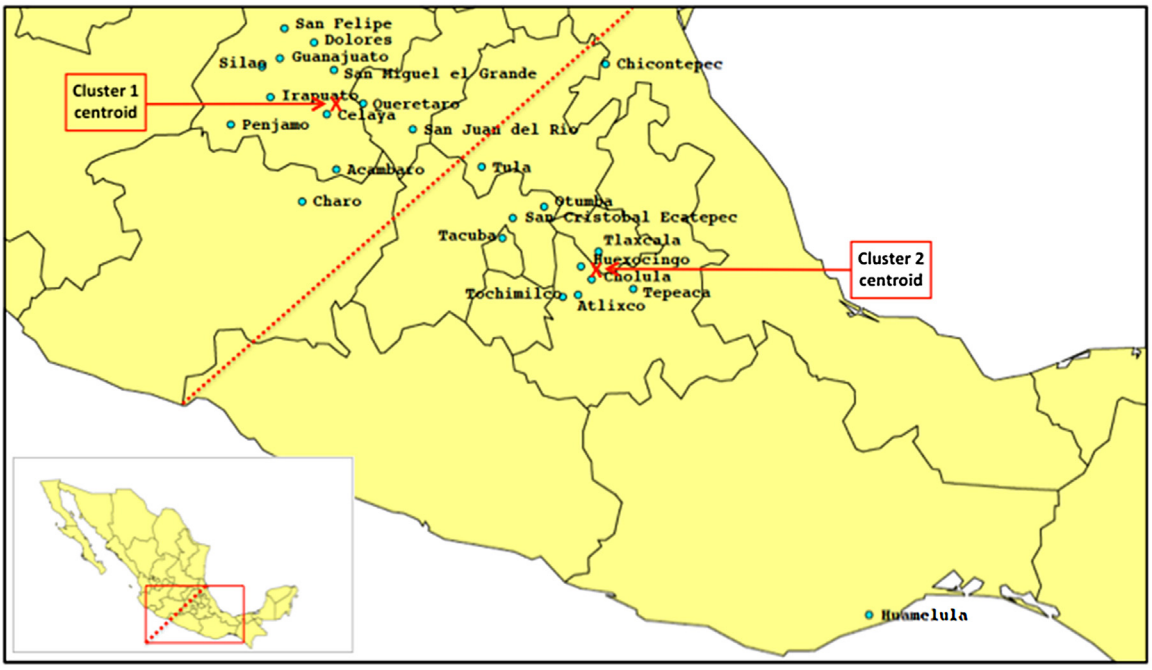

Map 1. Localities in the sample and cluster centroids.
Source: INEGI coordinates treated with MatLab.

The main objective of this paper is to further open the black box constituted by the biological living standards of central New Spain in the early 1790s. To do so, we estimate several models by means of Maximum-Likelihood (ML) under the assumption of a truncated normal distribution for height using data from the *Censo de Revillagigedo*.

Some novelties of our study are: (1) the sample is several orders of magnitude larger than in previous studies (N = 18,506, after discarding some incomplete observations); (2) it allows for a detailed examination of spatial differences by means of cluster analysis; and, (3) the explanatory power of new variables such as resource endowments and occupations is examined.

Our main results are: (1) non-Indians from central New Spain were taller than estimated in preceding studies; (2) they were not short when compared to some contemporary Europeans; (3) *españoles* and *mulatos* were taller than other groups[4]; (4) differences between ethnicities were not very important; (5) a significant urban penalty is found; (6) an "agrarian bonus" is perceptible, as working in non-agrarian activities penalized human growth even in rural areas; (7) occupation turned out to be a determinant of height; (8) variability in height across the two clusters of localities into which our sample may be divided was remarkable; and, (9) distance to a huge mining center (Guanajuato) had a negative influence on height in the most distant cluster while the effect of land availability per capita was positive in the other.

The rest of the paper is organized as follows: the second section deals with data; methods and econometric estimates are shown in the third section; a discussion of the results is presented in Section 4; the last section offers some final remarks.

2. Data

The data source is the *Censo de la Población de Nueva España*, known in the literature as the *Censo de Revillagigedo*.[5] The original documents are rich in information on height, age, ethnicity, occupation and other relevant characteristics (i.e., marital status, number of children, etc.). However, only a part of the male population was included in the military records that report heights. *Indios* were not measured since they were not compelled to perform military service. Thus, the heights found in military registers are those of the rest of the ethnicities comprising New Spain's population: *españoles* and *castas* (*mestizos*, *castizos*, and *mulatos*).[6] It is important to bear in mind that ethnic classification in New Spain was a matter of self-definition and social recognition as well as of genetics.[7]

According to Sánchez Santiró (2007), New Spain's population circa 1810 was ethnically distributed as follows: *indios*, 60%; *castas*,

[4] In the original documentation, individuals are mainly ascribed to one of these four groups or *calidades*: *españoles*, *castizos*, *mestizos* and *mulatos*. However, since the non-specialized reader is more familiar with the term *ethnicity*, we will use it hereinafter. Whether the distinction between ethnicities was based on purely physical characteristics is doubtful. In any case, it may be safely assumed that the members of a given ethnicity were more likely to have the expected phenotypical traits associated with that group than the individuals classified as belonging to the other ethnicities. Thus, albeit far from being perfect, the ethnic classification in the *Censo de Revillagigedo* contains very useful information. Additionally, socioeconomic conditions varied across ethnicities; on average, *españoles* were at the top of the ranking, *mulatos* were at the bottom, and *castizos* and *mestizos*, in this order, in between.

[5] Juan Vicente de Güemes, second count of Revillagigedo, was the Viceroy that commanded the realization of the first general census of the population of New Spain in 1790 (Castro, 1977). A detailed description of some of its main features can be found in Grajales-Porras and López-Alonso (2011). Further information on our source is supplied by the Archivo General de la Nación website under *Instituciones Coloniales/GobiernoVirreinal/Padrones*.

[6] *Españoles* were the "whites" born in Spain and in New Spain, *mestizos* were "*the son of white and Indian*" (Faulhaber, 1976) and *mulatos* were "*the product of whites and blacks*" (ibidem). *Castizos* were the mix of *mestizos* and *españoles*. A small number of *europeos* (whites born in Europe) and *negros* from diverse origins have been excluded from the sample.

[7] Notwithstanding, the probability of a given *indio* being genetically aboriginal, along with that of living (i.e., residing, dressing, eating, working, interacting with others, etc.) as was expected from an individual of his or her ethnic origin, was significantly higher than that of a member of other ethnicity. The same may be predicated of *mulatos, castizos*, *españoles* and *mestizos*.

Table 1
Basic statistics of the sample.

	Measured	%	Cluster 1	%	Cluster 2	%
Sample						
Ages 16 to 39 years	19,113	98.6	10,542	94.8	7,631	92.3
Other	277	1.4	577	5.2	640	7.7
Total	19,390	100.0	11,119	100.0	8,271	100.0
Ethnicity						
Español	9,546	49.2	6,251	56.2	3,295	39.8
Castizo	1,756	9.1	412	3.7	1,344	16.2
Mestizo	6,423	33.1	2,917	26.2	3,506	42.4
Mulato	1,613	8.3	1517	13.6	96	1.2
Europeos	25	0.1	4	0.0	21	0.3
Illegible or unclassified	27	0.1	18	0.2	9	0.1
Total	19,390	100.0	11,119	100.0	8,271	100.0
Rural/Urban						
Rural[a]	13,099	67.6	6792	61.1	6307	76.3
Urban[b]	6291	32.4	4327	38.9	1964	23.7
Total	19,390	100.0	11,119	100.0	8271	100.0
Sector						
Primary	7,043	36.3	5.144	46.3	1,899	23.0
Secondary	5,335	27.5	2.688	24.2	2,647	32.0
Tertiary	4,824	24.9	1.785	16.1	3,039	36.7
Illegible or unclassified	2,188	11.3	1,502	13.5	686	8.3
Total	19,390	100.0	11,119	100.0	8,271	100.0

[a] Rural: Locations labeled as villages, estates, ranches, glens and other suggesting rurality.
[b] Urban: Locations labeled as towns, boroughs, mines and other suggesting non-rurality.Source: Our elaboration on data from the Archivo General de la Nación, México.

22%; *españoles*, 18%.[8] Despite the exclusion of *Indios,* the sample covers a wide ethnic and socioeconomic spectrum: from the urban underclass –probably the poorest sector of the society- to the well-to-do farmers.

There is no self-selection in this case, since our data are "universal", unlike others suffering from significant selection bias (volunteer soldiers, prison inmates, etc.). The total number of individuals (males older than 15) registered in those 24 localities is 45,876, of which 19,390 (42.3%) were measured and declared "useful men" ("measured" hereinafter) since their height was above the minimum required (5 feet of 32.5 inch or 162.5 cm)[9] and their age from 16 to 39 years, included. Individuals classified as "exempt" amounted to 26,485 (57.7%). Of them, some 9,800 (21.4% of total) were older than 39 years, nearly 4,200 (9.2%) did not reach the Minimum Height Requirement (MHR), while roughly 9,500 (20.7%) were exempted for socioeconomic reasons (more than 5,000 were miners and the rest were classified as landowners, lawyers, physicians, public servants, military officers and other). Thus, many *mulatos,* working as miners in Guanajuato and, therefore, enjoying high living standards[10] and most of the members of the upper class were exempt. Therefore, a cautious interpretation of our results is needed.

Our database consists of 24 localities whose documentation was complete and accessible to the public at the Archivo General de la Nación de México. Several among the main towns of New Spain (e.g., Guanajuato and Querétaro), along with others of smaller size (Tlaxcala), as well as some villages and hamlets are included in the sample –see Map 1.

The sample shows an uneven geographical distribution. The central region of New Spain is clearly overrepresented. This region was the most populated and urbanized area of New Spain. It had also the highest density of population. Both urban and rural areas are included in the sample. Therefore we can contribute to the discussion regarding the existence of an urban penalty in preindustrial societies.[11]

Since the space shown in Map 1 is heterogeneous in many significant respects, we have clustered the 24 localities into two groups, namely, Cluster 1 and Cluster 2. The two clusters result from applying the *k*-means clustering method using longitude, latitude and altitude of every locality as the explanatory variables.[12] This, apparently simple, geographical division turns out to reveal the existence of two different, albeit contiguous, "worlds": both clusters clearly differed in terms of ethnic composition and economic structure –see Table 1. Some of those differences responded to the respective resource endowments (e.g., the existence of valuable silver deposits in Guanajuato –the main silver-mining district on Earth by late 18th- century- and the suitability for marketable food crop production of *El Bajío*). Others are the result of history (e.g., the final defeat in the second half of the 16th-century of the *Chichimeca* groups living in Cluster 1 at the hands of the Spaniards and their indigenous allies). Thus, Spaniards, other groups of *Indios*, black slaves and the mixed siblings of these ethnicities populated Cluster 1 nearly ex novo. This combination of resource endowments and history explains why Cluster 1 is ethnically more *español* and, especially, *mulato*, as well as less *mestizo* and *castizo* than Cluster 2. Likewise, in that part of the Central Highlands, indigenous communities (*pueblos de indios*) were always much more present than in Cluster 1: 42 *pueblos de indios* existing in the Intendancy of Guanajuato (Cluster 1) contrast with 1,248 and 731 in those of Mexico and Puebla (Cluster 2), respectively (Sánchez Santiró, 2007).

As a consequence, Cluster 1 (our "first world") was richer than Cluster 2 ("our second world"). The productivity of privately owned commercial agriculture (*haciendas* and *ranchos*) and mining (*reales de minas*) in Cluster 1 exceeded that of subsistence and communitarian farming (*pueblos de indios*) in Cluster 2. Guanajuato's economy, led by the rapidly growing mining sector, was more urban, complex, integrated, and productive than other regional economies –see Miño, (2001, 2010).[13] The Intendancies of Mexico and Puebla also played an important role in New Spain's economy. Notwithstanding, non-market oriented agriculture was much more common in Cluster 2, while mining played a relatively minor role. Both clusters clearly differed in terms of some variables, which were potentially influential in economic and biological welfare, such as population density, proximity to major mines, sectorial composition of the economic activity and institutional structure.

[8] However, ethnic distribution varied widely across New Spain: in the *Nuevo Reino de León,* nowadays northeastern Mexico, 64% of population was classified as *españoles* while less than 6% as *indios*; in the southern *Superintendancy of Oaxaca*, almost 90% of *indios* contrasts with a little more than 6% of *españoles*.
[9] The unit of measurement for military purposes within the Hispanic monarchy was the Paris foot, with one foot equivalent to twelve inches of 2.707 cm (Cámara, 2006). This is the measure used throughout the text.
[10] See Dobado and Marrero (2011) and Dobado and García (2010, 2014).
[11] See, e.g., Steckel and Floud (1997), Komlos and Baten (1998), A'Hearn (2003), Cinnirella (2008a, 2008b) and Coppola (2013).
[12] After several attempts we fixed *k*, the number of clusters, at 2. We did so as we first estimated our models with dummies for all of the localities and the result (significant differences only between two groups) motivated the choice of $k = 2$. This division turns out to have geographical and historical meanings *per se.* Cluster 1 coincides with the southeastern part of the region known as El Bajío, while Cluster 2 matches with the southeastern part of the Central Highlands. The frontier between the two clusters basically corresponds with the northeastern limit of the Mexica Empire.
[13] The real share of active males in the primary sector of Cluster 1 is overestimated in Table 1 because of the absence among the measured of more than 5,000 miners. The low share of males active in the primary sector of Cluster 2 is probably due to the fact that Indians carried out an important part of the agrarian activities.

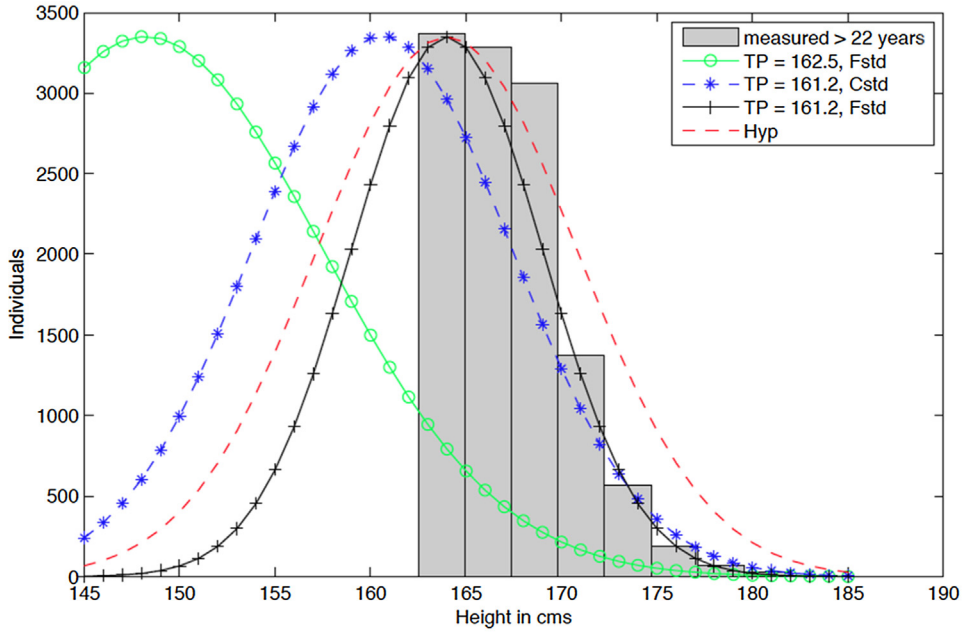

Fig. 1. Histogram of measured older than 22 and different fitted distributions.
TP stands for Truncation Point. Fstd and Cstd means not fixed and constrained (to 6.8 cm) standard deviation, respectively. Hyp is a hypothetical distribution with the same mean as the one estimated with our chosen model but a 6.8 standard deviation.

3. Methods and results

We perform a ML estimation of the parameters, which consists of assuming a normal distribution of the sample that was truncated from a specific value, named the truncation point. Although the MHR is 162.5 cm (5 feet), we tried different truncation points to choose the most adequate one in order to guarantee the reliability of the estimates and assess their sensibility to them. In our case, the conclusion of this analysis is that slight variations in the truncation point do not affect the significance of the parameters, although they affect their magnitude.

We finally choose a truncation point of 161.2 cm because of the following: (1) it is impossible to assert whether the lowest stature included in the subsample of measured was slightly above 159.9 cm (4 feet 11 in.) or whether the highest stature below HMR was slightly below 162.5 cm (5 feet); our choice, 161.2 cm, is in between the two above-mentioned heights; (2) the residuals obtained from setting 161.2 cm as the truncation point presents a mode around zero which implies that the mode of what is unexplained by the model seems to be no different from zero[14]; (3) A'Hearn (2004) recommends adjusting the truncation point, taking into account the rounding effect in measures[15]; and, (4) the estimated statures are similar to others reported in the literature for New Spain in the second half of the 18th-century (e.g., Challú, 2010; Grajales-Porras and López-Alonso, 2011) and Peru in the first half of the 19th-century (Baten et al., 2009). Fig. 1 complements this discussion about the selection of the truncation point.

The histograms of measured males may be seen in Figs. 2 and 3. Two important features may be observed: (1) the mode in Cluster 1 is higher than in Cluster 2; and, (2) the shape of both clusters is clearly different from each other.

Therefore, we proceed to estimate three models, namely, "*All*", "*Cluster 1*" and "*Cluster 2*". Each model provides two different estimations. In the first column, the standard deviation of the residuals is freely estimated, while in the second column it is fixed to the common 6.8 cm value (A'Hearn, 2004; Komlos, 2004) —see Table 2.

In all the cases, the standard deviation's value is significantly lower than 6.8 cm when it is freely estimated. This may be explained by the "missing density" in the right side of each of the histograms, probably corresponding to the exemptions for socio-economic reasons, which lowers the standard deviation as well as the estimate of the height means. This argument is compatible with the fact that the estimated standard deviation in model *Cluster 1* is lower than in model *Cluster 2*, which shows a smaller shortfall in the right side of its distribution because of its lesser share of exemptions.[16]

The unconstrained models are our specifications of choice for several reasons. According to A'Hearn (2004), the general

[14] This property is expected in a well-specified model when assuming symmetric distributions. Moreover, even if the truncated normal distribution is not symmetrical, the property holds when the truncation point is below the mode/mean of the unobserved symmetric normal distribution. Simulations showing this are available from the authors upon request.

[15] The adjustment proposed by A'Hearn (2004, footnote 7) leads to the same truncation point we use.

[16] Following the suggestion from a referee, we also estimate the same models shown in Table 2 truncating the sample at 61 inches (165.1 cm). The results show slightly higher statures and standard deviations closer to the common value 6.8, but the conclusion does not change substantially with respect to the values reported in Table 2, while reducing the sample size. Additionally, we run an estimation truncating at 61 inches in the left side and 64 inches (173.2 cm) in the right side. We do so trying to avoid: (i) the lumping of the Paris inch (particularly in the left side) and (ii) the carelessness in the measurement by census takers beyond 64 inches, being 63–64 inches the MHR for the grenadiers (in the right side). Again, the results do not change the conclusion, while the estimates seem less accurate due to the reduction in the sample size. Thus, Table 2 shows the most reliable estimates. The rest of the analysis is available from the authors upon request.

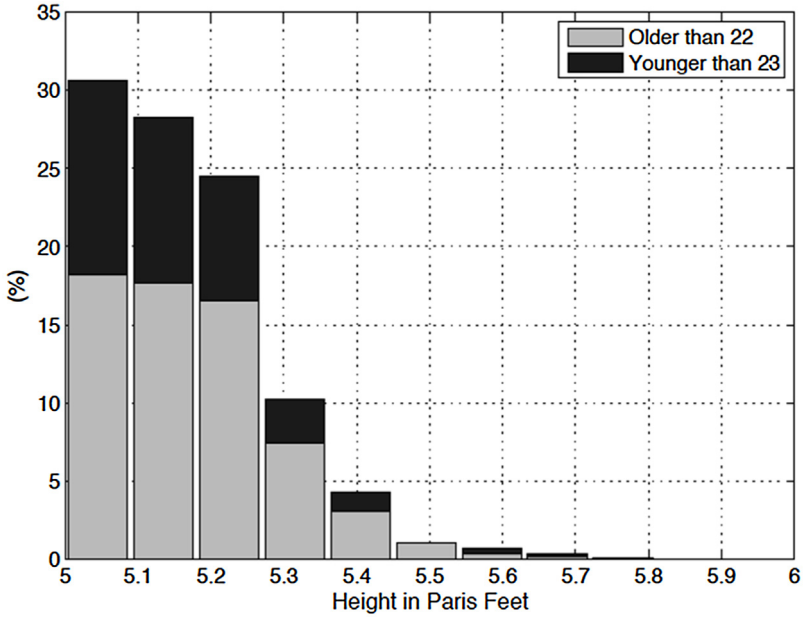

Fig. 2. Histogram of total measured in Paris feet.

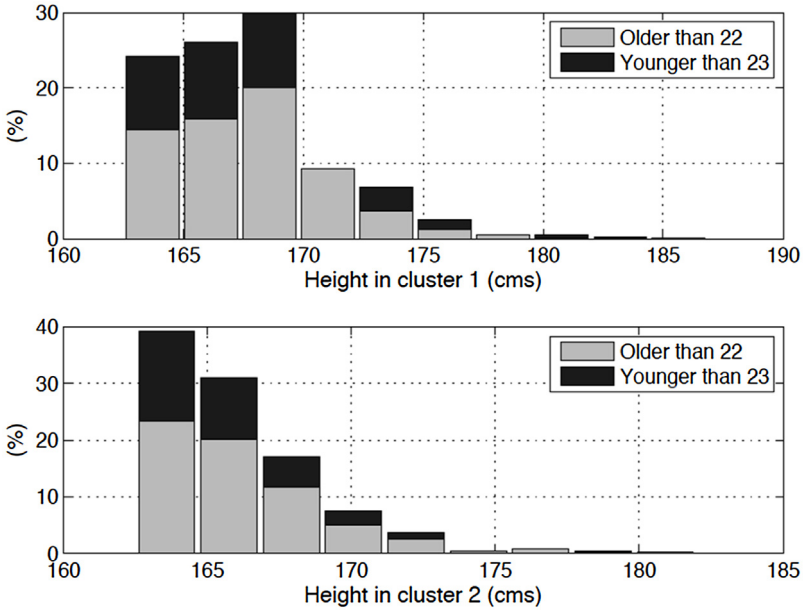

Fig. 3. Distribution of measured in the two clusters.

conditions of a preference for the constrained over the unconstrained estimation are: (1) small samples; (2) truncation points above or equal to the mean; and, (3) a true standard deviation close to the constrained value. As can be seen in Table 2, Table 3, Figs. 1–3, none of our samples fulfill these requirements.[17] Additionally, given that the truncated ML estimates are consistent, it is very unlikely that the unconstrained estimates deviate too much from the true height with such a large sample size. On the contrary, that could happen when a wrong restriction is included in the model. In this sense, Fig. 1 also complements the discussion about constraining the residual standard deviation.

The explanatory variables introduced in our models are: ethnicity (*castizo/español/mestizo/mulato*), economic sector (*primary/secondary/tertiary/unclassified*), residence (*rural/urban* and *Cluster 1/Cluster 2*), decade of birth *(1750s/1760s)*, age (*years of age*, if younger than 23) and resource endowments (*density* and *distToMine*). The economic sector and residence variables are taken

[17] Particularly: 1) our samples range between 7 and 18 times those considered as "large samples" by A'Hearn (2004), 2) the truncation point seems to be below the mean (although not far); and, 3) there is no evidence that the true standard deviation is close to 6.8; quite the contrary, it seems to be significantly lower.

Table 2
Models estimation (I): Economic sectors[a].

Sample	All		Cluster 1		Cluster 2	
Variable	Std not fixed	Std = 6.8	Std not fixed	Std = 6.8	Std not fixed	Std = 6.8
Constant	164.45*** (0.40)	160.33*** (0.75)	165.26*** (0.26)	161.07*** (0.51)	166.20*** (0.72)	164.18*** (1.33)
Ethnicity						
- Mulato	−0.34** (0.17)	−0.54** (0.31)	−0.54*** (0.17)	−0.90*** (0.34)	6.28*** (0.90)	8.72*** (1.33)
- Castizo	−1.12*** (0.19)	−1.79*** (0.36)	−1.57*** (0.33)	−2.67*** (0.68)	−1.15*** (0.28)	−1.64*** (0.44)
- Mestizo	−1.00*** (0.11)	−1.59*** (0.21)	−0.58*** (0.13)	−0.94*** (0.26)	−1.76*** (0.22)	−2.52*** (0.33)
Sector						
- Secondary	−0.87*** (0.14)	−1.37*** (0.26)	−0.84*** (0.17)	−1.41** (0.35)	−0.72*** (0.27)	−1.03*** (0.43)
- Tertiary	−0.21 (0.14)	−0.29 (0.25)	−0.36** (0.17)	−0.58* (0.35)	0.18 (0.26)	0.26 (0.41)
-Unclassified	0.07 (0.17)	0.15 (0.31)	−0.35* (0.19)	−0.57 (0.39)	1.27*** (0.37)	1.80*** (0.57)
Rural	1.75*** (0.12)	2.81*** (0.23)	1.94*** (0.15)	3.27*** (0.31)	1.00*** (0.26)	1.40*** (0.30)
1760s	−0.27* (0.13)	−0.42 (0.25)	−0.53*** (0.15)	−0.85*** (0.30)	0.21 (0.26)	0.40 (0.39)
Age						
- 16 years old	−4.23*** (0.30)	−6.99*** (0.57)	−3.47*** (0.33)	−5.93*** (0.67)	−6.32*** (0.70)	−9.38*** (1.05)
- 17 years old	−2.56*** (0.36)	−4.17*** (0.68)	−2.71*** (0.44)	−4.61*** (0.91)	−2.39*** (0.65)	−3.45*** (0.99)
- 18 years old	−1.95*** (0.22)	−3.12*** (0.41)	−2.38*** (0.26)	−3.99*** (0.52)	−1.17*** (0.45)	−1.69** (0.68)
- 19 years old	−1.15*** (0.28)	−1.83*** (0.52)	−1.56*** (0.33)	−2.61*** (0.66)	−0.47 (0.55)	−0.68 (0.84)
- 20 years old	−1.12*** (0.20)	−1.78*** (0.37)	−1.33*** (0.23)	−2.18*** (0.46)	−0.84** (0.41)	−1.21** (0.62)
- 21 years old	−0.54* (0.29)	−0.85 (0.54)	−0.93*** (0.34)	−1.50** (0.69)	−0.03 (0.58)	−0.05 (0.88)
- 22 years old	−0.58** (0.22)	−0.91** (0.41)	−0.95*** (0.26)	−1.55*** (0.51)	0.03 (0.45)	0.04 (0.68)
Cluster 1	1.03*** (0.31)	1.69*** (0.57)	–	–	–	–
Resources						
- Density	0.04 (0.03)	0.06 (0.05)	0.49*** (0.17)	0.80*** (0.36)	0.05 (0.04)	0.08 (0.06)
- DistToMine	−3.52*** (0.70)	−5.61*** (1.29)	1.72 (1.17)	2.84 (2.37)	−9.47*** (1.26)	−13.49*** (1.90)
Standard Dev.	4.65	–	4.34	–	5.30	–
# of obs.	18,506	18,506	10,525	10,525	7,981	7,981

[a] The omitted category for model "All" refers to *español*, *primary sector*, *urban*, born in *1750s*, *older than 22* and *younger than 40*, and living in *Cluster 2*. See Table 4 for heights of some illustrative groups. Standard errors are reported in parentheses.
* p-value < 0.1.
** p-value < 0.05.
*** p-value < 0.01.

from the information on occupation and location of the measured provided by the Censo.[18] For each cluster, *density* is calculated as the ratio between measured plus exempt (a proxy for the population of the 24 localities) and the current surface area of those localities, in tens of people per sq. km.[19] With this variable we attempt to capture the effect of land availability, likely a determinant of height. A second, and especially relevant in New Spain, dimension of factor endowments is silver deposits. Its influence as a determinant of height is studied through the variable *DistToMine*, which is defined as the shortest distance between each locality and Guanajuato, the world largest silver-producing mining district c. 1800, in thousands of kilometers.[20]

For every model in Tables 2 and 3, the constant must be carefully interpreted, as the continuous exogenous variables *density* and *distToMine* are included in the estimation. Therefore, the constant by itself is not the height of a specific reference group. Getting the height of a particular group requires some basic calculations. For instance, for model *All*, Table 2, the stature estimated of the group characterized as: *españoles*, employed in the *primary sector*, *urban*, *born in the 1750s* and *older than 22 but younger than 40* years, belonging to *Cluster 2* and living 453 km away from Guanajuato (particularly, in Cholula which is the closest village to the centroid of Cluster 2) is 162.86 cm[21] We will come back to this issue when discussing the results in Section 4.

According to the variables, we expect that: 1) given the supposedly high inequality of New Spain's society, ethnicity, which correlates with socioeconomic status, is significant and negative in all cases, especially for *mestizos* and *mulatos*; 2) *years of age* is significant and negative and has a decreasing coefficient between 16 and 22 years old; 3) *density*, based on the simple Malthusian view, is significant and negative; *distToMine*, following the neo-institutional assumption that mining in Hispanic America was a purely extractive economic activity, is significant and positive. We are less certain about what to expect from the other candidates as determinants of height. The main quantitative conclusions from the estimates shown in Table 2 are the following:

1. A clear majority of explanatory variables prove to be highly significant in all specifications. Only a few of them are not significant.

[18] Sectors comprise, respectively: *primary*, actives in farming and husbandry; *secondary*, actives in manufacturing and mining; *tertiary*, actives in services. *Rural* are locations labeled as villages, estates, ranches, glens and others suggesting rurality. *Urban* are locations labeled as towns, boroughs, mines and other suggesting non-rurality.

[19] The surface area is taken from the Instituto Nacional de Estadística, Geografía e Informática (INEGI). The only locality that currently does not exist as municipality is Tacuba, which is now part of Mexico City. Thus, a representative urban value of density for Cluster 2, such as that of Tlaxcala, has been attributed to Tlaxcala. *Density* is scaled to tens of people per km^2 in order to improve the stability of the ML estimation.

[20] Distance is calculated using https://www.google.es/maps. *DistToMine* is scaled to thousands of km to improve the stability of the ML estimation.

[21] This estimate comes from the constant in Table 2, model *All*, plus the coefficient *distToMine* times the distance from the centroid of Cluster 2 to Guanajuato's mine (in thousands of km): 164.45 −3.52 * 0.453 = 162.86 cm. In order to estimate the heights of any group we should include the effect *distToMine* in models *All* and *Cluster 2* and the effect *density* in model *Cluster 1* −see Tables 2–4.

Table 3
Models Estimation (II): Occupations[a].

Sample All		Sample Cluster 1		Sample Cluster 2	
Variable	Estimate	Variable	Estimate	Variable	Estimate
Constant	163.81***	**Constant**	164.64***	**Constant**	165.18***
Ethnicity		**Ethnicity**		**Ethnicity**	
- Mulato	−0.37**	- Mulato	−0.55***	- Mulato	3.17***
- Castizo	−1.12***	- Castizo	−1.59***	- Castizo	−1.13***
- Mestizo	−1.03***	- Mestizo	−0.57***	- Mestizo	−1.74***
Occupation[a]		**Occupation**[a]		**Occupation**[a]	
Farmer	0.47***	Farmer	0.63***	Weaver	−1.62***
Weaver	−0.80***	Muleteer	0.83***	*Campista*	−1.22***
Muleteer	−0.53**	Tailor	−0.08	Servant	1.39***
Servant	1.38***	Merchant	0.20	Muleteer	−2.18***
Campista	−0.74***	Servant	0.08	Merchant	−1.56***
Merchant	−0.67***	*Obrajero*	−0.47	Farmer	0.15
Tailor	−0.65**	Shoemaker	0.11	Tailor	−1.76***
Blacksmith	0.10	Blacksmith	0.53	Blacksmith	−0.82
Shoemaker	−0.20	Weaver	−0.40	Carpenter	−1.87**
Obrajero	−0.82**	Cigar maker	0.29	Baker	−3.12***
Carpenter	−1.21***	Carpenter	−0.88*	Shopkeeper	−2.40***
Baker	−1.46***	Baker	−0.59	Shoemaker	−0.59
Cigar maker	−0.03	Silversmith	0.13	Barber	−1.38
Silversmith	−0.54	Cowherd	0.99**	Tanner	2.04**
Rural	1.65***	**Rural**	1.92***	**Rural**	0.95***
1760s	−0.29**	**1760s**	−0.53***	**1760s**	0.15
Age		**Age**		**Age**	
- 16 years old	−4.29***	- 16 years old	−3.47***	- 16 years old	−6.24***
- 17 years old	−2.65***	- 17 years old	−2.75***	- 17 years old	−2.43***
- 18 years old	−2.03***	- 18 years old	−2.38***	- 18 years old	−1.31***
- 19 years old	−1.22***	- 19 years old	−1.56***	- 19 years old	−0.60
- 20 years old	−1.19***	- 20 years old	−1.34***	- 20 years old	−0.94**
- 21 years old	−0.66**	- 21 years old	−0.91***	- 21 years old	−0.26
- 22 years old	−0.67***	- 22 years old	−0.95***	- 22 years old	−0.09
Cluster 1	1.46***				
Resources		**Resources**		**Resources**	
- Density	0.01	- Density	0.45**	- Density	0.02
- DistToMine	−2.99***	- DistToMine	1.15	- DistToMine	−5.48***
Standard Dev.	4.62***	Standard Dev.	4.34***	Standard Dev.	5.13***
# of obs.	18,506	# of obs.	10,525	# of obs.	7,981

[a] The omitted category for "sample All" refers to *español*, *primary sector*, *urban*, born in *1750s*, *older than 22* and *younger than 40*, and living in *Cluster 2*. See Table 4 for heights of some illustrative groups.
* p-value < 0.1.
** p-value < 0.05.
*** p-value < 0.01.

2. Particularly interesting in our setting is the finding that the variable *Cluster 1* in model *All* is highly significant. This motivates the estimation of models *Cluster 1* and *Cluster 2* using their corresponding subsamples.
3. While some explanatory variables basically behave as previously hypothesized (e.g., *españoles* and *age*), others do not (e.g., *mulatos*, *density* and *distToMine*).

All these results will be discussed and contextualized in the next section. Previously, in order to check the robustness of our estimates, we substitute the economic sectors with the fourteen most frequent occupations in a new set of models –see Table 3.[22]

The new results are consistent with those shown in Table 2. As expected, *farmers*, the most numerous occupation group, is significant and has a positive sign, except in Cluster 2. This finding

Table 4
Estimated heights of some illustrative groups[a].

Key Variable	Cluster[b]		Additional specifications of the group[c]
	1	2	
Español	165.66	161.91	Primary Sector, urban
Mulato	165.12	163.16	Idem
Castizo	164.09	160.76	Idem
Mestizo	165.08	160.15	Idem
Secondary Sector	164.82	161.19	*Español*, urban
Tertiary Sector	165.30	161.91	*Español*, urban
Rural	167.60	162.91	*Español*, Primary Sector
Farmer	167.55	163.65	*Español*, rural
Muleteer	167.75	161.47	*Español*, rural
Servant	165.00	164.10	*Español*, urban
Carpenter	164.12	160.83	*Español*, urban

[a] We use the estimates from the unconstrained *Cluster 1* and *Cluster 2* models in Tables 2 and 3.
[b] All heights in Cluster 1 have been calculated as if the group were located in Celaya (closest locality to Centroid of Cluster 1) while those in Cluster 2 as if the group were located in Cholula (closest locality to Centroid of Cluster 2).
[c] All the groups are older than 22 and younger than 40 and were born in the 1750s.

is compatible with the notion of agrarian bonus. Most occupations in the secondary sector appear associated with relatively short heights. As for the tertiary sector, when the respective variables are significant, servants are clearly taller than muleteers. We will interpret these results in the next section.

In order to facilitate a user-friendly interpretation of the estimates shown in Tables 2 and Table 3 and their comparisons with others, Table 4 is reported. *Españoles* is the most frequent ethnicity in Table 4, as it is the reference in Tables 2 and 3.

4. Discussion of the results

The non-Indian population from the regions of central New Spain included in our sample turns out to be somewhat taller than estimated in previous studies (Challú, 2009, 2010; Grajales-Porras and López-Alonso, 2011).[23] This is especially true regarding Cluster 1–see Table 5.[24]

Moreover, individuals in our sample were not short when compared with many contemporary Europeans, in particular with samples from France, Italy, Portugal and Spain –see Table 6. Comparing with samples from the USA or northern Europe is less informative since it may be safely assumed that ancestors of *españoles* from New Spain were genetically closer to the populations of the above-mentioned four countries.[25] Additionally, with all its peculiarities, New Spain was less distant from France, Italy, Portugal and Spain than from the UK or the USA in terms of resource endowments, GDP per capita and institutions. Interestingly, height in Cluster 2, less similar to Latin Europe than Cluster 1 in all relevant respects, fares worse in the comparison.

An easy access to nutritious food (meat and dairy) might contribute to explaining why heights in New Spain are not so different to those of Latin Europe. If patterns of consumption in Mexico City –where "*any poor man eats meat*"[26]- can be extrapolated to other parts of New Spain, especially the Northern regions, it is very likely that the ingestion of animal proteins was

[22] We choose fourteen occupations as they represent most of the measured in each sample and have more than 100 individuals each. According to the dictionary of the *Real Academia Española* published in 2001, one of the two meanings of the term "*campista*", common in Honduras, is equivalent to shepherd or cowherd. This is the only meaning that makes sense in this context. Therefore, we had included all *campistas* in the primary sector for estimating the models shown in Table 2. *Obrajero* was an ill-defined occupation in relatively large, vertically integrated, workshops producing woolen cloth.

[23] Heights comparisons resulting from different estimates may be more difficult than it seems. The search for the appropriate terms of comparison requires making decisions that are not always easy. That is due to the fact that estimation models may be specified differently (i.e., dissimilarities in explanatory variables). However, in this case, the heterogeneity of estimates does not constitute a problem.
[24] In the comparison, only estimates with a significance of at least 5% are used.
[25] Novembre et al. (2008) find *"a close correspondence between genetic and geographic distances"* in Europe.
[26] Quoted by Quiroz, (2005 .

Table 5
Comparisons with other studies about New Spain.

Grajales & López (2011)	Model 3 (I)	Model 4 (II)
Atlixco, *mestizo*, middle-low class or occupation, 1750′s	155.4	153.4
Atlixco, *español*, middle-low class or occupation, 1750′s	158.8	157.2
Dobado & Garcia-Hiernaux (this paper)	(III)	(II)
Mestizo, secondary sector, rural, 1750′s, *Cluster 2* (Atlixco)	160.2	155.6
Español, secondary sector, rural, 1750′s, *Cluster 2* (Atlixco)	161.9	158.1
Challú (2010)	(IV)	
White, rural, 1751–1760, Northwest	165.9	
Dobado & Garcia-Hiernaux (this paper)	(III)	(II)
Español, rural, primary sector, 1750′s, *Cluster 1* (Celaya)	167.6	165.0

(I) Unconstrained (not reported). (II) Constrained (6.8 cm). (III) Unconstrained (4.34 cm). (IV) Unconstrained. (6.2 cm).Source: Our elaboration on data from Challú (2010) and Grajales-Porras and López-Alonso (2011).

Table 6
International comparisons.

Description	Heights	
Location: France	*Romorantin*[a]	*Dourdan*[a]
Agriculture, militia, 1750′s	160.0	166.4
Agriculture, soldiers, 1750′s	164.0	167.8
	Sélestat [a]	*Melun* [a]
Agricultural workers, 1780–1784	163.0	
Agricultural workers, 1780–1781		164.9
Location: Central Italy	*Model 2* [b]	*Model 3* [a]
Romagna, rural, agricultural laborer, <1785	164.6	
Lazio, rural, agricultural laborer, <1785		165.1
Location: Northern Italy	*Emilia/Papal* [c]	*Vicenza* [c]
Milano, farmers, rural/small towns, 1750–1754	163.1	168.8
Milano, farmers, rural/small towns, 1755–1759	162.1	167.8
Location: Portugal	*Trás-os-Montes*	*Algarve*
	Model 1 [d]	
Extremadura, unskilled workers, farmers and unknown, 1750	161.5	169.0
	Model 2 [e]	
Extremadura, unskilled workers, farmers and unknown, 1750	161.5	169.4
Location: Spain	Not fixed s.d.[b]	
Central region [g], farmers, 1768–1772	164.7	
Location: New Spain (Our estimates)	Fixed s.d.[a]	Not fixed s.d.[f]
Español, rural, primary sector, 1750′s, *Cluster 1* (Celaya)	165.0	167.6
Español, secondary sector, rural, 1750′s, *Cluster 2* (Cholula)	158.5	162.2

[a] Constrained s.d. (6.8).
[b] Unconstrained s.d. (6.7 cm).
[c] Constrained s.d. (5.9 cm).
[d] Recruitment regime 1776–1807, unreported s.d.
[e] Recruitment regime 1763–1764 and. 1776–1807, unreported s.d.
[f] Unconstrained s.d. (4.34 cm).
[g] The central province of Toledo in early nineteenth century included parts of contemporary neighboring provinces of Ávila, Badajoz, Cáceres, Ciudad Real, Cuenca, and Madrid.Source: Our elaboration with data from A'Hearn (2003), Heyberger (2007), Schubert and Koch (2011), Coppola (2013), García-Montero (2013) and Stolz et ?al. (2013).

higher than in Europe (Humboldt, 1822:1991; Quiroz, 2005; Dobado and García, 2010, 2014). The picture offered by Van Young (1989) for the important town of Guadalajara, located to the northwest of Mexico City, is consistent with this view. On the contrary, in Cuernavaca, not far from the capital to the south, meat consumption was lower (Barrett, 1974). As for dairy products, Humboldt observed that "*natives care very little for milk, butter and cheese*", while among "*castas*" –*españoles* could safely be added-, cheese "*is in great demand and forms quite a considerable branch of the domestic trade*".[27]

New Spain shares with Latin Europe –Portugal excluded- a north-south gradient in heights. In our case, this remark is consistent with findings by Challú (2010) for the central regions and by Dobado and García (2014) for regions located farther north and south from our clusters.

As above-mentioned, heights of most *mulatos* employed as miners and the elite (landowners, professionals, etc.) were not reported in the *Censo*. These two groups of exempt double in number that of individuals below the MHR and amount to nearly half of the measured. Therefore, albeit to an unknown extent, the non-Indian male population in our total sample (measured and exempt) was somewhat taller, especially in Cluster 1, than our estimates show since they are based only on measured.

As hypothesized, our estimates reveal the existence of differences in height across ethnic groups. *Españoles* and *mulatos* are close to each other in height –see Table 2, model *All*. In Cluster 2 the latter were even taller than the former- and both surpass the other two ethnicities. However, the coefficient of *mulatos* in Cluster

[27] Humboldt, 1822:1991, p. 300von Humboldt, 1822Humboldt, 1822:1991, p. 300 (our translation).

2 is affected by a negative correlation with *disToMine*: some of the small number of *mulatos* in Cluster 2 inhabited Huamelula, the most distant locality from Guanajuato (1369 km).[28] These results are unexpected if socioeconomic factors are considered the only explanation for the levels of biological welfare. Non-miner *mulatos*, and therefore measured, were the least empowered ethnic group in New Spain's society. Their socio-economic status openly contrasted with that of *españoles*. *Mulatos* were placed at the bottom of the hierarchical and mainly urban *República de españoles* and did not enjoy the protection offered by the subordinate *República de indios* to the indigenous population.[29] African slaves, from whom *mulatos* descended, were brought to New Spain because of their superior physical capability for carrying out hard work in mines and sugar plantations and their adaptability for residing in low, coastal, areas that surround the high central plateau where the indigenous population had traditionally been living.

Another unexpected finding is that *castizos*, supposedly the closest ethnic group to *españoles,* are shorter than *mestizos* in models *All* and *Cluster 1*. Unfortunately, we are doubtful about how to explain this result.

As in two "worlds" apart, all ethnicities are taller in Cluster 1 than in Cluster 2. The lesser difference between the two clusters corresponds to the *mulatos*. The four ethnicities in Cluster 1 are even taller than *españoles* in Cluster 2–see Table 4. This finding highlights the importance of spatial differences in heights in New Spain. In this case, two contiguous regions were separated by significant disparities in the average height of the four ethnicities and its dispersion. Cluster 2 has a lower average and a higher dispersion. Actually, differences between *españoles, mulatos* and *mestizos* are not statistically different from zero in Cluster 1, which suggest a high equality −higher, in any case, than in Cluster 2- in terms of biological living standards in that part of New Spain. It seems, then, that our initial hypothesis with respect to the variable ethnicity does not hold in Cluster 1 and not in its integrity in Cluster 2 either, at least as far as *mulatos* are concerned.

The finding that the gap between neighboring regions exceeds the one existing across ethnicities within clusters was unexpected and helps to understand the complexity of this territory of Bourbon America's society. In this respect, as mentioned above in relationship with the north-south gradient observed in 18th-century New Spain, Dobado and García (2010, 2014) find substantial differences in heights between far northern and far southern regions. Significant intra-territorial (i.e., within New Spain) and inter-territorial (i.e., coastal Venezuela versus New Spain) inequalities coexisted throughout Hispanic America. They persisted after the independence (Baten et al., 2009).

On the other hand, that African descendants were as tall as, or even taller than, other ethnicities, *españoles* or whites included, in spite of their generally below-average economic living conditions is also found in other studies for various spatial and time settings: 1) Atlixco and Tehuacán, two villages belonging to our Cluster 2, for the early 1790's (Grajales-Porras and López-Alonso, 2011); 2) Lima penitentiary between 1820 and 1880 (Twrdek and Manzel, 2010); 3) Brazil and Peru in the 19th-century (Baten et al., 2009); and, 4) contemporary Colombia (Meisel and Vega, 2007; Acosta and Meisel, 2013).

Results for Iberian America contrast with those obtained for the United States. Non-slave blacks, both males and females, were not taller than whites in 19th-century United States (Maloney and Carson, 2008; Carson, 2011) and their descendants are still, if not very significantly, shorter today, particularly in the case of females (Komlos, 2009). Thus, it might be the case that blacks were relatively better off in terms of biological welfare in Iberian America than in the United States. This outcome might be partially related to the comparatively high level of biological welfare enjoyed by North Americans of European descent.

All in all, despite the limits of our sample, the available information suggests that differences in height due to ethnic reasons did not reach a very intense level in New Spain society, or at least not as much as to deserve being so described by the juxtaposition of giants and pigmies used by Komlos (2005) for qualifying an extreme case of disparities in height observed in late-18th and early-19th England.

Another finding is that the active male population engaged in farming enjoyed an agrarian bonus since working in the secondary and, albeit to a lesser extent, the tertiary sector is associated with shorter heights. If occupations substitute for sectors, results do not vary. When they are significant, the signs of the estimates for occupations in the secondary sector (weaver, tailor, carpenter, baker and *obrajero*) are negative. On the contrary, *farmer* is significant and has a positive sign, except in Cluster 2. One more difference regarding the agrarian sector between the two clusters is that *cowherds* in Cluster 1 are relatively tall while *campistas* in Cluster 2 are relatively short. A plausible explanation for the agrarian bonus might be the easier access to food for individuals employed in agriculture and their families. However, this advantage seemed to be very unevenly distributed across regions. As to the tertiary sector, while muleteers were, except in Cluster 1, shorter than the reference, the opposite happens with servants. Probably, the latter also had access to healthier nutrition. In fact, an undetermined number of servants might work along with their masters in agrarian activities.

Not surprisingly, as it is consistent with the agrarian bonus, a significant urban penalty is found in New Spain as in other studies on the West.[30] Thus, central New Spain did not constitute an exception with respect to a Western anthropometric "quasi-constant" in pre-contemporary times. Within the framework of pre-industrial economies with imperfect market integration, physical proximity to food production was a significant asset in terms of biological welfare that is underestimated by conventional indicators (i.e., GDP per capita). Reinforcing the impression that two different, albeit contiguous, "worlds" coexisted, *rural* coefficient in Cluster 1 doubles that of Cluster 2. The agrarian productivity gap between the two clusters is the most likely explanation of such a disparity in the spatial distribution of the urban penalty.

Individuals born in the 1760s, especially in Cluster 1, were shorter than those of reference (born in the 1750s). Thus, given the time span of our sample, we cannot offer evidence regarding the notion of "Great Decline" in Mexican heights between 1730 and 1840. We find unsurprising and consistent estimates of the

[28] In Cluster 2 (see Table 2), *mulatos* were clearly taller than *españoles*. However, the sample of *mulatos* is small ($N_{C2} = 83$), not so in Cluster 1 ($N_{C1} = 1{,}455$). A smaller sample of *mulatos* in Cluster 2 affects the stability of that coefficient as can be seen when comparing the ethnicity estimates in Tables 2 and 3: all the coefficients are robust in sign and the values are very similar, except, relatively, for *mulatos* in Cluster 2.

[29] The *República of españoles* may be identified with the, mostly urban, "world" not included in the basically rural *República de indios*. The latter comprises the nearly 4,500 *pueblos de indios* that, circa 1800, enjoyed legal recognition by the authorities of the Viceroyalty and had indigenous representatives with a limited jurisdictional powers as well as a shared sense of belonging and some communitarian properties (i.e. land, among others) (Tanck, 2005). *Castas* ethnicities were the result of the melting pot represented by the towns and villages that comprised the *República de españoles*. As opposed to *españoles* and *indios*, *castas,* especially *mulatos*, were partly deprived of the legal protection offered by the Spanish law. By the late eighteenth century, the distinction between the two somewhat ideal "republics" was frequently unclear in everyday life.

[30] Challú (2010) finds a lower and less significant urban penalty before 1780.

differentials in height due to age in both clusters. That is to say: the younger, the shorter. However, in Cluster 1 individuals seem to grow until the age of 23, while the adult size is reached between 19 and 21 years in Cluster 2, where maturity in heights appeared sooner than in Cluster 1.

Additionally, the significant differences in factor endowments between the two clusters also played a role by favoring physical statures in Cluster 1. The unexpected estimates for *density* need some further explanation. The fact that it is significant and positive for *Cluster 1* is consistent with a higher agrarian productivity in that area resulting from more fertile soils, deeper market integration and the predominance of private ownership of land. In *Cluster 2*, more land per capita is not associated with taller heights. This finding might be explained by a relative scarcity of arable land. The equally unexpected estimates for *distToMine* also suggest a dualistic picture. It influences very negatively heights in Cluster 2, whose average distance to the mining district of Guanajuato is much larger than that of Cluster 1 (99 km versus 506 km). Thus, the positive economic effects of the proximity to large-scale mining (temporary or permanent employment at high wage rates and demand for agrarian and manufactures goods) were enjoyed to a lesser extent, if at all, in Cluster 2. In fact, it is the vicinity of several localities of Cluster 1 to Guanajuato that might explain the statistical non-significance of *distToMine* in this case. Celaya, Dolores, Irapuato, San Miguel el Grande and Silao evolved into a dynamic urban network within a circle of less than 100 km in radius centered on Guanajuato. The connection between large-scale mining and productive, market oriented, agriculture was remarked by Humboldt.[31] Thus, mining developed jointly with agriculture and facilitated higher economic and biological living standards to the inhabitants of Cluster 1. Another mine, Real del Monte, was in operation in Cluster 2, but its production was significantly smaller than in Guanajuato (roughly one fifth). Besides, its location was peripheral to the core of Cluster 2. In any case, there is no historical (or statistical) evidence suggesting an interaction between mining and the rest of the regional economy similar to the one existing in Cluster 1.

5. Final remarks

The main conclusions of our study may be summarized as follows: (1) the members of the four non-Indian ethnicities recorded in the *Censo de Revillagigedo w*ere taller than estimated in previous works on heights in central New Spain; (2) compared to some European countries (France, Italy, Portugal and Spain) they were not short, which offers a rather "optimistic" view on biological living standards in late-eighteenth century central Mexico; (3) *españoles* and −surprisingly- *mulatos* were taller than other ethnicities, in particular in Cluster 2–i.e., our "second world"-where the latter even surpass the former; (4) differences in height across non-Indian ethnicities were not very important, especially in Cluster 1 (i.e., our "first world"), where ethnic inequality in biological welfare is clearly lower; (5) as in other studies on preindustrial societies, an important urban penalty is found; (6) in consistency with conclusion (5), an "agrarian bonus" also existed, as working in non-agrarian activities was detrimental for height even in rural areas; (7) reinforcing conclusion (6), occupation, particularly farming in Cluster 1, proves to be a determinant of height; (8) variability in heights across space was remarkable, being significantly taller in Cluster 1 (the "first" of our two "worlds") than in Cluster 2 (the "second world"); and, (9) contrary to the "bad press" of mining in pre-independent Hispanic America, distance to the world's largest silver producer mining district (Guanajuato) had a negative effect on heights in Cluster 2 while that of land availability per capita was positive only in the most developed cluster, *El Bajío* or Cluster 1.

[31] "*In Mexico the best cultivated fields, those to bring to the mind of the traveler the beautiful plains of France, are those which extend from Salamanca towards Silao, Guanaxuato, and the Villa de Leon, and which surround the richest mines of the known world.*" Humboldt, 1822:1991, p. 238von Humboldt, 1822Humboldt, 1822:1991, p. 238 (our translation).

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