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Agricultural Crisis and Biological Well-Being in Mexico, 1730-1835

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1. INTRODUCTION

Agricultural crises are a critical aspect in the course of Mexican history in the eighteenth and early nineteenth century. As social processes, changes in socioeconomic structure and political power affect the capacity of different sectors to devise strategies to react and adapt to climatic disasters, shortages, and food insecurity (García Acosta, 2006). This is especially apparent in the swift political-economic transformations experienced in Mexico in the last century of colonial domination and the first decades of the national era. These transformations included the increasing specialization of the economy, a more commercialized agricultural sector, political and economic reforms, and rising agricultural prices. As generalized rural insurrection broke out in 1810, and independence was gained in 1821, fights intensified for the autonomy of peasant communities, the definition of property rights, and the overall organization of economic and political life. Over this period, the balance of economic and political power between cities and countryside was dramatically changing, and trade became an increasingly important way to distribute the allocation of resources—and the means of subsistence. By examining long-run trends in biological well-

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being, cost of food, and climatic conditions, I seek to shed light on the unequal capacities of cities and the countryside to face food shortages and agricultural crises.

Agricultural crises were a common and regular presence well documented in the colonial period (Florescano, 1969; García Acosta, Pérez Zevallos & Molina del Villar, 2003). About every ten years, grain shortages were palpable, prices soared, and grain stocks were removed from poor districts to be sold in the cities with rich municipal granaries. From 1741 to 1810, eight such crises broke out in the Valley of Mexico and other areas following a decadal cycle, resulting in hunger, disease, and increased mortality (Florescano, 1969: 139, 161). The events of 1749-50, 1785-86, and 1809-10 were so harsh and widespread that they became known as *años de hambre* (famine years), but even in events of smaller dimension the outbreak of epidemics was common (Endfield, 2007). After 1780, food prices started an inflationary trend, while official documents show a rising awareness of food supply problems. Regular food shortages engendered a more systemic long-run subsistence crisis that constantly threatened the life of lower-class Mexicans. The documentary record of agricultural crises in the 1810s and after independence is sparser (Escobar Ohmstede, 2004), and may be perceived as a real improvement in living conditions (McCaa, 1993: 618). Still, we know of two strong but more regionally contained shortages in 1819 and 1828 that match Florescano's decadal sequence (Challú, 2007: 278-283).

While periodic disasters provide an insight into how nature, economic constraints, and policies and politics affected thousands of lives, I take a long-term look at chronic conditions. I traced annual variations in climate and the cost of food, found years in which conditions were harsher than normal, and assessed through statistical techniques how the climate-constrained availability and market-driven affordability of food affected both urban and rural populations. My analysis relies on datasets of human height, climate, and real food prices that span the colonial and national periods. Soldiers' heights serve as an indicator of the biological well-being of the population. If access to food declined significantly, then the nutritional status suffered, resulting in a lower adult stature for those who endured these conditions in their early years of life. The real cost of grain products in Mexico City became a key issue for the increasing number of Mexicans who depended on exchange entitlements (that is, on their income to procure food in the market)[1]. An established chronology of El Niño climatic events and three local tree-ring series from central Mexico help reconstruct the global events and local climatic conditions that affected agricultural output. In the statistical analysis, individual height is the variable to be explained,

1. A good overview on the entitlements approach can be found in Sen (1990).

while harsh climatic conditions and high real food prices at the time of birth of the individual are the independent explanatory factors. I discriminate the results in the urban and rural population to see how the reliance on markets and the territorial power of large cities influenced their vulnerability to agricultural crises vis-à-vis the rest of the country.

2. DATA AND METHODS

2.1. Heights

The height of adult men is the indicator I used to gauge changes in the biological well-being of the Mexican popular classes. I calculated average height through multivariate techniques from the measurements of soldiers enrolled in the late colonial and early national armies. The sources are the *filiaciones* (recruitment forms) found in Mexico's Archivo General de la Nación[2]. The dataset also includes socio-demographic descriptors such as family name, birthplace and residence, date of recruitment, age, and complexion; occupation, signature, and (to a lesser degree) racial categories were available in many cases[3].

Soldiers are an imperfect sample of the society at large. The source obviously excludes women and children, but also within the adult male population it over-represents some groups and under-represents others. First, people with noticeable health problems and who were shorter than the minimum standard were legally excluded; if recruited they were rejected in large proportions or could appeal to be removed from service. Second, some groups were excluded. In the colonial period, Indians were not allowed in the army, and the Spanish-descendent were preferred. Recruitment was also more intensive in urban areas. After independence, soldiers were more often dark skinned, less literate, and from rural areas, reflecting a more ample social basis of the army. However, there is no evidence in the dataset or the literature that suggests that the national army systematically tapped new types of recruits previously not present (albeit in smaller proportions) in the colonial army[4].

2. The collections from the AGN holding the records are as follows: Indiferente de Guerra, Archivo de Guerra y Marina, Archivo Histórico de Hacienda, Filipinas, Operaciones de Guerra, and Archivo de Guerra. A few records were located in the Archivo del Estado de San Luis Potosí, Gobernación collection.

3. For a complete description of the dataset, sources, recruitment rules, height requirements, and conversion units, see CHALLÚ (2007: 36-63).

4. On recruitment, see ARCHER (1977: 231-253) and DEPALO (1997: 31-33 and 74-80). On the resistance and lack of effectiveness of recruitment of indigenous peasants, see GUARDINO (2005: 253-4).

All height measurements were rounded to the inch to avoid the substantial heaping in more detailed measurements[5], and were converted to centimeters. Most of the military units used the Paris foot to measure height; after 1842, army units gradually switched to Burgos feet[6]. Soldiers included in the dataset were enrolled in an infantry unit of the permanent army or the militia, older than eighteen years, born in central Mexico, and taller than the observed minimum height requirement determined for the army unit[7]. Out of more than seven thousand originally collected, 3,236 cases met those standards. The average height by decade of birth of the resulting dataset is presented in Table 1.

TABLE 1

Average Height by Decade of Birth Central Mexico, 1732-1837 (in cm)

	Burgos-foot units		Paris-foot units		Truncated regression	
	Average	Frequency	Average	Frequency	Average	Frequency
1730s			171.1	23	167.2	23
1740s			170.2	285	165.2	285
1750s			168.6	348	160.0	348
1760s			169.0	113	165.2	113
1770s			167.8	154	162.4	154
1780s			168.2	209	163.7	209
1790s			167.8	148	162.8	148
1800s	161.8	59	167.5	193	161.2	252
1810s	162.2	329	167.5	372	161.0	701
1820s	161.6	580	166.7	225	159.5	805
1830s	161.2	193			159.0	198

Note: Burgos-foot units have a lower truncation point of 153 cm; Paris-foot units have a minimum of 162 cm, and 164.7 cm among those recruited before 1780. The truncated regression column reports fitted values of a truncated regression using the three truncation points; no control variables were used.
Source: See footnote 2.

5. Less than a half of the records provided a height measurement in lines (the subunit of an inch). This abnormal concentration of cases (known as heaping) tended to be more present after 1810, but it did not affect certain groups more than others.

6. The Paris foot or «pied de roi» was the equivalent of 32.45 centimeters. Its use as the measurement standard in Spain and Mexico is documented in CÁMARA-HUESO (2005) and CHALLÚ (2007: 51-53), respectively. As in Spain, it was gradually replaced with the Burgos (locally known as the Mexican) foot in the 1840s, which was equivalent to 27.86 cm.

7. The minimum height for most Paris-foot units was 162 cm (5 Paris feet). In some units of the 1760s and 1770s, the number of five-feet cases was low enough to warrant shifting the lower boundary one inch to 164.7 cm; and in the 1850s the only military unit using Paris feet did not enforce a minimum requirement. With the adoption of the Burgos foot, there was no minimum height enforced in practice. The lower boundary was set to 66 inches (153.1 cm) in order to avoid any confusion with cases measured in Paris feet.

I used truncated regression models to estimate the effect of climatic, price, and period variables on height, controlling for the changing socioeconomic and geographic composition of the population. Truncated regression is a maximum-likelihood technique to estimate unbiased coefficients assuming a normal distribution of heights that can only be partially observed (Komlos, 2004). Without the use of this or a similar technique, the coefficients are biased given that the height sample does not contain the whole range of heights of the population. Following A'Hearn (2004), the dispersion term was constrained at 6.86 cm (the well-known standard deviation of height in human populations) in order to improve the accuracy of the estimation. Stata 9's truncreg routine was used to calculate the models (StataCorp, 2005).

I used complexion and family names to control for socioeconomic variations. Complexion serves as an imperfect indicator of opportunities (or lack thereof) based on perceived race, and naming conventions were related to wealth, social prestige, and ethnic identification (Cope, 1994: 55-67). I simplified both in binary categories in order to have a high frequency of cases in each category and increase the reliability of the results. Complexion became white and dark skin, and family name was coded as frequent and infrequent occurrences[8].

Birth cohorts are used to trace height changes over time. In order to have a relatively large number of cases per group and hence gain more reliable insights about changes over generations, I classified cohorts as follows (number of cases in parentheses): 1732-1750 (392), 1751-1780 (554), 1781-1810 (635), 1811-1821 (853), 1822-1837 (802). An «age» variable was created to account for lineal height gain in puberty: age 18 is set to three, 19 to two, 20 to one, and 21 or older is set to zero. The reconstructed standard deviations of height among young and adult soldiers were not significantly different; the equal variance assumption of regression analysis thus holds.

I summarized the place of origin in three geographic areas based on John Tutino's regionalization. The North Central Plateau region includes the present-day states of Zacatecas, Aguascalientes, San Luis Potosí, Nayarit, Jalisco, Colima, Michoacán, and Guanajuato. The Central Highlands region includes Querétaro, Hidalgo, Mexico, Morelos and Guerrero, as well as the Federal District. The South encompasses Puebla, Oaxaca, and Veracruz. Around 1800, these regions had 30 percent, 55 percent, and 14 percent of the population of the viceroyalty (Tutino, 1986: 394-395), but soldiers in this dataset tended to come in larger numbers from the north central region[9].

8. Examples of frequent family names are Fernández, García, Hernández, Morales, Romero, and Vázquez.

9. On regional differences, see Moreno Toscano (1998) and Miño Grijalva (2001: 119-245).

Separate analyses were conducted for the entire population and for the urban and rural groups. Soldiers whose place of birth was a large city constitute what is loosely referred to as the urban population (count: 1,166 cases). All state and intendancy capitals are considered large cities. Their populations ranged from San Luis Potosí's 12,000 inhabitants to over 150,000 in Mexico City circa 1800. Population in these centers added up to about 10 percent of the total population of central Mexico[10]. The second subset, referred as the rural population, contains the rest of the cases (count: 2,070 cases), and includes soldiers from haciendas, villages, towns, and small cities.

TABLE 2

Truncated Regression Models of Height in Centimeters, by Rural and Urban Origin. Central Mexico, 1732-1837

	(1) Entire sample	(2) Countryside and towns	(3) Large Cities
1732-1750	Ref.	Ref.	Ref.
1751-1780	-2.41**	-2.12*	-2.34**
1781-1810	-1.93**	-1.97**	-1.86
1811-1821	-3.77**	-4.45**	-2.27**
1822-1837	-4.67**	-5.19**	-3.71**
Large city	0.79**	—	—
Central Highlands	Ref.	Ref.	Ref.
North Central Plateau	0.76*	1.15**	-0.16
South	-0.02	0.06	0.10
Dark skin	-2.19**	-2.06**	-2.21**
Infrequent family name	0.55	0.17	1.06*
Young age	-1.06**	-0.72*	-1.54**
Constant	165.03**	165.16**	165.39**
Sigma	6.86	6.86	6.86
Obs.	3,236	2,070	1,166

Notes: The constant represents a soldier 21 years of age or older, from the Central Highlands region, born on or before 1750, of white skin and a common surname, from a small town or countryside. One star denotes significance at the 10% level; two stars at the 5% level.
Source: See footnote 2.

Table 2 reports the results of the truncated regression models of height in centimeters for the entire population, as well as for the urban and rural subsets. Some well-known facts of the distribution of human height and some relationships demonstrated in previous work

10. The cities are: Guadalajara, Guanajuato, Mexico City, Oaxaca, Puebla, Querétaro, San Luis Potosí, Valladolid-Morelia, Veracruz and Zacatecas.

with the Mexican population provide a first check of the consistency of the results. Soldiers younger than 21 were shorter, and grew about a centimeter every year. Social and regional height gaps follow expected patterns: there is north-south gradient in height, although there is no height penalty in the southern region, as came to be expected later. Whiter skin and, to a lesser degree, uncommon family names were associated with higher stature. This correlation between social differentiation and height is expected given what we know of the Mexican population and others in this period. The estimated average height (ranging from 165 to 160 cm) is also within the range found in other studies of Mexico and Europe (Cámara-Hueso, 2007: 6-14; Kelly, 1947: 18; López-Alonso, 2007: 100)[11].

The most remarkable finding in Table 2 is the steep decline in height that points to a long-lived subsistence crisis. Using the estimates of the entire sample, height declined 4.67 cm from the second quarter of the eighteenth century to the 1820s and 1830s. The drop was steepest around the mid-1700s. Between 1780 and 1810, height recovered some ground against our expectation—epidemics and famines were more frequent in this period. The downward trend resumed in the 1810s and continued in the early national era.

Another finding is that there is no urban «penalty», as is commonly found in Europe and the United States, but the opposite. Comparing the changes across cohorts (columns 2 and 3), it is clear that cities and countryside started on similar levels and both experienced decline; after 1780 and more pronouncedly after 1810, the urban population did not lose height as much as its rural counterpart. Other variables show similarities and differences among the urban and rural population. Socioeconomic inequality is similar, in particular the 2-cm effect on height of a bright skin tone points to racial inequality. Family name has a stronger effect (1 cm) in large urban areas; this finding resonates well with what we know about social differentiation in urban plebeian groups. The urban population had no regional differences in height, while rural dwellers from the North Central Plateau were almost 1 cm taller than soldiers from the Central Highlands and the South. The regional gap in rural areas was likely related to more land availability in the North Central Plateau, even if population growth and diminishing returns were outstripping the resource advantage (Morin, 1979). One final difference is that height gain before adulthood was steeper in urban areas and flatter in the rural population. This fact suggests that a short child would have more opportunities to catch up during late puberty in urban areas than in rural environments.

11. Carson (2005: 413-5) reports a higher average stature, 167cm, among Mexican nationals imprisoned in the American Southwest in the late nineteenth century; although this population was largely based in the Northern states bordering with the United States.

The decline was noticeable in both subsets, but it was strongest among rural dwellers (steady decline of more than six centimeters, see column 3 of Table 2). The major difference is that in large cities there was a more pronounced recovery in the cohorts from 1781 to 1821, while among the rural dwellers height deteriorated faster in that time span. As a result of these diverging trends, the rural-urban height gap was reversed in the period. Up to 1780, rural soldiers were taller, but in the following generations they became shorter than their urban counterparts.

2.2. Real Food Prices, 1730-1835

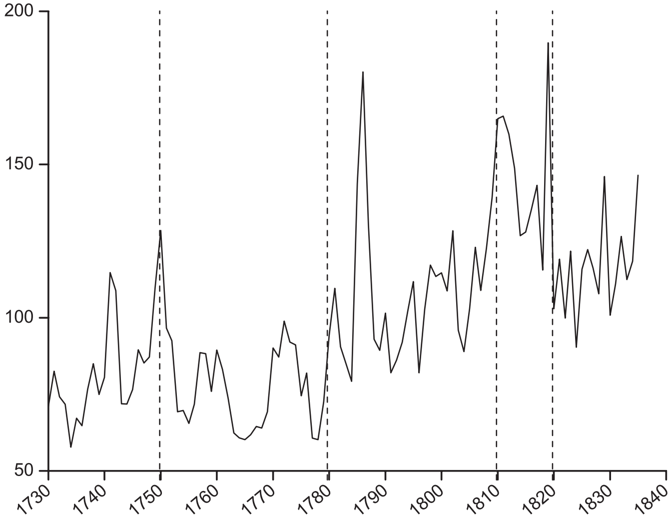
A real food price index stands for food prices divided by wage earnings. While other works have delved into the study of real prices and wages (Dobado, Gómez Galvarriato, & Williamson, 2008; Garner, 1993: 48; Van Young, 1987), this article is the first one to provide a real food price series that spans the late colonial and early national periods. The index relies on corn, wheat, and bean prices from Mexico City, as well as on male unskilled construction wages. These three grain products are the most representative of the Mexican lower-class diet, while unskilled construction is representative of a lower-class male urban occupation[12].

Corn was the quintessential Mesoamerican grain, and the single most important item in the consumer basket. Despite its higher price, wheat products were widely consumed as well, especially in the cities (Haslip-Viera, 1999: 32; Suárez Argüello, 1985: 124; Van Young, 1981: 62). Frijol beans complemented corn and were typically eaten with corn tortillas; together they provided the full range of proteins and hence made a diet feasible and healthy without the need of animal protein. Frijol and corn were grown interspersed in the same lot, and had similar environmental constraints (Ouweneel, 1996: 72-100; Super & Vargas, 2000). Several sources of price data informed the index: Corn and wheat prices before 1814 come from published sources using granary *(alhóndiga)* and bakers' periodical reports (Florescano, 1969; García-Acosta, 1988). Bean prices for 1801 and 1810-1835 were obtained from the weekly purchase receipts of Franciscan institutions; the same source provided scattered corn and flour observations in the 1810s and 1820s[13]. The lacunae in coverage were resolved by imputing the missing years from available information of related products, including some not used in the index such as *chile*, lard, rice, and flour[14]. Weights were established at 50 percent, 30 percent, and 20 percent for

12. For other work that also rely on unskilled construction wages to estimate popular earnings, see Haslip-Viera (1999: 27-29), and Van Young (1987).
13. See Appendix, Figure A.1 and Table A.1.
14. The Pearson correlations of these products with each other ranged from 0.72 to 0.96.

corn, wheat and bean respectively, based on existing qualitative and quantitative evidence. Because the three products functioned as a market and a productive system (Challú, 2007: 156-160). the imputation and the choice of relative weights do not alter the index in any remarkable way. Information on construction wages is abundant in receipts, budgets, and reports of repairs and new construction of municipal buildings, convents, garrisons, hospitals, jails, and temples[15].

FIGURE 1
Real Grain Price Index. Mexico City, 1730-1835



Notes: Vertical dashed lines mark the boundaries of birth cohorts used in the anthropometric analysis. Sources: See Appendix, Figure A.1 and Table A.1.

Figure 1 shows that real food prices were stable from the 1730s until the early 1780s, with remarkable spikes in certain years such as 1742 and 1750, both years of known shortages. In 1785, real prices peaked to the second highest point in the series, and afterward prices continued to climb into the 1810s. They went down in the 1820s and 1830s, but on average they were higher than the levels of the 1800s. The decadal cycle movements noted by Florescano in his corn price series (1720-1814), can be seen in this study's real price index as well. Its coverage into the 1830s show two more spikes in real prices in 1818 and 1829. Besides the cyclical spikes in prices, it is apparent that the inflationary trend in the price of food did not end at the end of the late colonial period, but extended into the early national era[16].

15. See Appendix, Figure A.1 and Table A.1.
16. Whether the food purchasing power of Mexican wages stood in international standards is another discussion, see Dobado (2007).

How representative are these data for other regions of Mexico? While prices certainly varied across regions, markets were also integrated and the economy was exposed to common factors (such as silver production). Therefore annual price movements were correlated across different markets (Challú, 2007: 205-209). The trend toward rising prices after 1780 was a factor present in other regions and products (García-Acosta, 1995: 185; Garner, 1985; Garner, 1993: 48). The trend in wages was similar in other major urban centers such as Guadalajara, Puebla, and San Luis Potosí: flat until the early 1810s, during which labor shortages due to the insurgency (and perhaps the astronomical price of food in these years) pushed wages up for the first time in a century[17]. Fragmentary information from the late colonial period points to a similar flat trend in nominal rural wages and a decline in rations and access to land (Van Young, 1981: 249-251; Garner, 1993: 81; Tutino, 1986: 61-82). After independence, the picture is more complicated. Tutino (1998) argues that there were improvements in rural living standards, yet the earnings among comparable categories of rural workers in defined regions show no upward trend in earnings before and after independence[18]. To summarize, there is reason to believe that, while certainly limited to one location, this real price series is representative of conditions in central Mexico.

2.3. Climate

With remarkable exceptions (Ouweneel, 1996: 78-89; Swan, 1981), historians have relied on documentary accounts of punctual, often-times large-scale, climatic events to understand the social dimensions of natural disasters (García Acosta, 2007; Endfield, 2007). Instead, this study relies on long-run annual series that are better at reconstructing the variations of climatic conditions that may not have reached disaster proportions but still affected the production of food[19]. I use a chronology of El Niño events and three regional series of tree-ring growth to reconstruct climatic trends.

17. See Van Young, 1981: 250-252 for wages in Guadalajara; Archivo Histórico del Estado de San Luis Potosí (Ayuntamiento and Intendencia collections); and Archivo General Municipal de Puebla (Tesorería series).

18. For instance, Humboldt mentioned a pay of 2.5 reales a day for hacienda peons in the cold region (central highlands) at the beginning of the nineteenth century (1814: 264), a customary rate that is referred to in other publications. Figures are reported by Maya (1982), Henao (1980), Herrera Feria (1990), Thomson (1978: 299) for the same region from the 1820s to the 1850s. In haciendas close to the city of San Luis Potosí, the total yearly compensation of a peon (including rations) was around 56-60 pesos/year, from 1783 to 1868 (Tutino, 1986: 357; Bazant, 1975: 95, 106, and 202).

19. See, for instance, De Waal's contemporary criticism for an understanding of famine that narrowly focuses on events of disastrous proportions and excessive mortality (2005: 23-32).

El Niño-Southern Oscillation (ENSO) is one of the most important and well studied global climatic circulation changes that affects rainfall and temperature—and as a consequence agricultural conditions over the world. El Niño is followed by La Niña, a westward shift in circulation patterns that typically produces the contrary effects. Among the most tried and methodologically straightforward reconstructions is Quinn and Neal's chronology based on circumstantial historical accounts that are consistent with the occurrence of El Niño (Quinn & Neal, 1992). The series is a benchmark in studies of El Niño events and has been corroborated with other data sources (e.g., tree-ring series, pressure differentials). Events are classified according to severity in an ordinal rank ranging from zero to six (where zero is no event and four and greater are events of strong magnitude).

Climate scientists and economists are providing insight into El Niño's general influence on climatic conditions and agricultural output in Mexico[20]. For instance, recent El Niño events were found to lower corn production by ten percent in the present-day state of Mexico and by five percent in Jalisco, and negatively impact bean production in Guerrero and Zacatecas (Tiscareño López *et al.,* 2003: 335). Precipitation is more concentrated in big storms in the El Niño phase, increasing the risk of erosion. Concentrated precipitation coexists with a tendency for drought in the summer during El Niño years (Magaña *et al.,* 2003) In strong events, the summer drought is followed by temperature declines in the spring (Tiscareño López *et al.,* 2003: 333), implying a greater risk of hail and frosts lethal for the corn and bean harvest (Ouweneel, 1996: 72-87).

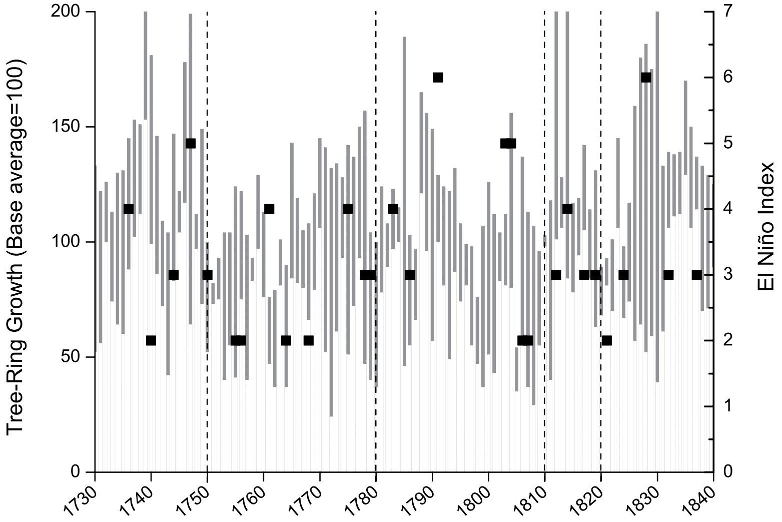
Recent tree-ring measurements in Mexico have led to a new understanding of long-term climatic patterns and their connection with historical events such as cycles of epidemic disease and famine (Acuña-Soto *et al.,* 2002; Therrell, 2005; Villanueva-Díaz *et al.,* 2006). The annual growth of a tree is related to local ecological and climatic conditions. For this reason, tree ring series have been used to reconstruct regional drought indices for the last five centuries, as well as rainfall and temperature (Villanueva-Díaz *et al.,* 2007). The latewood component of a ring is a darker section formed in late spring and summer, which makes it sensitive to the climatic conditions that influence the growth of corn and frijol beans. Recent work has used the Douglas-fir's latewood component in tree ring series to reconstruct warm-season precipitation and agricultural yields over long periods of time (Therrell *et al.,* 2002: 6.1; Therrell *et al.,* 2006: 497-498). Here I rely on series of latewood ring growth based on Douglas-fir trees from three sites: El Salto, Durango; Pi-

20. In the historical literature, references to El Niño in Mexico are not unusual, but specific studies are very limited; see, for instance, Davis (2001: 260-261), and Grove (2007: 85).

nal de Amole, in the boundary of Hidalgo and Mexico; and Villarreal, Veracruz[21]. The site selection loosely matches the regionalization of the anthropometric dataset; the use of a common tree species makes the data series more consistent.

FIGURE 2

El Niño Strength Index and Latewood Tree-Ring Growth. Central Mexico, 1730-1840



Notes: An El Niño index of six translates into a very strong event in Quinn & Neal's chronology; two is an event of moderate strength. Tree-ring growth is expressed as a range between the minimum and the maximum value of the three regional series used in the analysis. Vertical dashed lines mark the boundaries of birth cohorts used in the anthropometric analysis.

Sources: Quinn and Neal (1992); International Tree Ring Database, World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, <http://www.ncdc.noaa.gov/paleo/treering.html>.

Figure 2 plots the El Niño chronology and the range of the three tree ring series (where one hundred is the average annual growth). El Niño events of varying strengths were more frequent from 1803 to 1821 (nine in total, or about one every two years). However, ENSO events are not correlated to well-known agricultural crises. If the 1749-50, 1785-86, 1808-09, and the 1819 crises were surrounded or pointed by El Niño (and likely La Niña follow-ups), events of a similar or greater magnitude failed to produce similar catastrophes. Similarly, the tree-ring series do not point to any clear-cut relations with known episodes of agricultural crisis. For instance, the 1750s and 1760s were a lapse of slow tree growth in the warm season, yet this period is known for the relatively good harvests, at least in

21. The chronologies, constructed by Stahle, Therrell, Cleaveland, Villanueva-Díaz and Burns, are available in the International Tree Ring Database, World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, <http://www.ncdc.noaa.gov/paleo/treering.html> as datasets MEXI027, MEXI033, and MEXI037.

the Valley of Mexico (Gibson, 1964: 327). As pointed by other researchers, the wide dispersion of tree growth among the three sites is remarkable, suggesting the diverse experience of climatic conditions in the varied geography of central Mexico[22]. In 1785, known as the year of the famine, tree growth was half of the average (46 percent) in the central region (Pinal de Amole), 77 percent in the northwest (El Salto), but almost twice the average (189 percent) in the southeast (Villarreal). A similar spread characterized the shortage year of 1808: 29 percent, 107 percent, and 86 percent, respectively. The variation of local conditions and the lack of clear relationships with known disasters and food shortages present a different perspective on the influence of climate: one not framed by the prevailing narratives of widespread disasters, but on localized, even ordinary climatic variations that affected aggregate production, and as such posed regular constraints on material life. This view is consistent with Tutino's observation that the climatic conditions that triggered a famine were not exceptional, but instead were part of regular climatic disturbances to which the society lost its capacity to adapt (Tutino, 1986: p. 74).

3. CLIMATE, MARKETS, AND AVERAGE HEIGHT

The El Niño, tree-ring and real food price series were merged into the anthropometric dataset. Dummy variables assume a value of one when there is one year of adverse climatic conditions or high prices in a five-year moving window centered around the year of birth of a soldier. The El Niño variable for a given year was set to one if there was an El Niño event of at least a strong magnitude in a moving window of five years (60 years, out of 104 in this study, met this condition). The three tree-ring series were collapsed into one «tree ring growth» variable, which was set to one when at least one year of the regional series of the soldier's place of origin was below one standard deviation from the mean (45, 64, and 35 years for the central, north-central, and southeastern regions, respectively). Last but not least, the real price variable captures with a value of one the occurrence of real prices in excess of one standard deviation in the moving window. In short, the climate and price variables capture the effect of a year of harsh conditions in the early years of a person's life.

The truncated regression models estimating single and joint effects of adverse conditions in El Niño, tree ring, and real food prices are reported in Table 3. Columns 1 through 3 report the individual effects of the variables; column 4 reports a model considering them

22. A historical analysis of that variability in Ouweneel, 1996: 78-89. On the observed variability between tree-ring sites, see Villanueva-Díaz *et al.* (2006: 4) and Therrell *et al.* (2002: paragraphs 6.3 and 6.4).

jointly. In all cases, the sign of the coefficients is negative as expected: harsh conditions in the early years of life had negative effects on height. The effects, however, varied and the estimation lacks statistical significance in some cases. El Niño had a more limited (and not statistically significant) effect, while the occurrence of an adverse year in tree-ring growth and real prices had a more significant and pronounced penalty on height of around 0.8 to 1 cm. In all the specifications, the effects of the birth cohort periods follow the declining trajectory pointed out in Table 2, suggesting that, despite their measurable and remarkable impact, climate and prices do not explain the overall trajectory of height in the time period under study.

TABLE 3
Effects of Climate and Prices on Heights in Centimeters
(Truncated Regression Model) Central Mexico, 1732-1837

	(1)	(2)	(3)	(4)
El Niño	-0.41	—	—	-0.51
Tree ring growth	—	-0.85 **	—	-1.12 **
Real food prices	—	—	-0.83 *	-1.06 **
1732-1750	Ref.	Ref.	Ref.	Ref.
1751-1780	-2.56 **	-1.97 **	-2.69 **	-2.37 **
1781-1810	-1.93 **	-1.49 **	-1.77 **	-1.15
1811-1821	-3.83 **	-3.60 **	-3.28 **	-2.99 **
1822-1837	-4.76 **	-4.52 **	-4.68 **	-4.62 **
Large city	0.80 **	0.76 *	0.79 **	0.77 **
Central Highlands	Ref.	Ref.	Ref.	Ref.
North Central Plateau	0.74 *	1.10 **	0.80 **	1.25 **
South	0.00	0.09	0.07	0.24
Dark skin	-2.20 **	-2.16 **	-2.19 **	-2.16 **
Infrequent surname	0.54	0.55	0.55	0.53
Age (21-age)	-1.04 **	-1.08 **	-0.99 **	-0.98 **
Constant	165.26 **	165.00 **	165.34 **	165.67 **
Sigma	6.86	6.86	6.86	6.86
Observations	3,236	3,236	3,236	3,236

Notes: The constant represents a soldier 21 years of age or older, from the Central Highlands region, born on or before 1750, of white skin and a common surname, from a small town or countryside, who has not experienced adverse climatic conditions in the early years of life. One star denotes significance at the ten percent level; two stars at the five percent level.
Source: see text.

The model using the three variables (column 4) calculates the effects jointly and is key to gauging the importance of distributive factors affecting access to food against the importance of aggregate food availability. It isolates the macro- and micro-climatic effects holding price changes constant, and vice versa. Climatic variables reflect real and expected changes in the supply of food. El Niño increases the volatility of conditions and affects regions differently; while it may not have impacted local production, it affected production elsewhere and could raise the expectation of a shortage. Tree ring growth in the warm season (as measured in the latewood component) approximates how much the climate affects yields in a region. If market entitlements are marginal in the way to secure food, then the expectation is that the climatic variables have a stronger, negative effect on height holding real prices constant. By contrast, if real prices still have a strong effect, it implies that the allocation of food via the market is a significant factor affecting people's living conditions. The effects in the combined model are similar to the individual-effect models, with no co-linearity affecting the results. Tree ring growth and real food prices had comparable significant effects, both slightly higher than one centimeter. In conclusion, climatic shocks and high food prices exacted a measurable toll in biological well-being, even if they did not explain the long-run trajectory of heights over time.

Climate and price effects are broken down by the rural or urban origin of the soldiers to assess different vulnerabilities and responses to agricultural crises. Table 4 reports the results of the combined model of climatic and price effects for the urban and rural population as defined previously in Table 2. The breakdown is meant to identify how much territorial power over agricultural hinterlands could have cushioned or further exposed large city dwellers to climatic shocks compared to the rest of the country; it is also meant to gauge the importance of market access to food in the two environments and hence gain a better appreciation of the importance of aggregate food availability and distributional factors in nutritional status.

The effects of adverse climatic and price conditions on height have all the expected negative signs, although the magnitude and statistical significance vary notably. In the large city population, the effects of tree ring growth is noticeable but not significant (-0.6 cm). El Niño and real food prices, by contrast, had a stronger effect, -1.1 and -1.3 cm, respectively. Conversely, the effects of regional climatic conditions were pronounced and significant in the rural areas, reaching -1.3 cm, while El Niño events had a much more reduced effect in rural areas. Real food prices had a noticeable effect of -0.88 cm, but the estimation lacks statistical significance (z=1.49, p=0.137). Despite the difference in magnitude, the importance of real prices in the two groups is remarkable and highlights the bearing of the market in shaping access to food. As found in the entire sample, the use of climate and price variables only slightly change the coefficients of the birth cohorts, suggesting that these variables do little to explain the overall decline in height.

TABLE 4
Effects of Climatic Factors and Food Prices on Large City and Rural Dwellers

	(1) Towns and Rural	(2) Large Cities
El Niño	-0.19	-1.09 *
Tree growth	-1.34 **	-0.61
Real food prices	-0.88	-1.32 *
1732-1750	Ref.	Ref.
1751-1780	-1.82	-2.90 **
1781-1810	-1.07	-1.30
1811-1821	-3.60 **	-1.55
1822-1837	-4.89 **	-3.94 **
North Central Plateau	1.81 **	0.10
Central Highlands	Ref.	Ref.
South	0.40	0.24
Dark skin	-2.02 **	-2.22 **
Infrequent surname	0.17	0.99 *
Age (21-age)	-0.72 *	-1.32 **
Constant	165.44 **	166.53 **
Sigma	6.86	6.86
Obs.	2,070	1,166

Notes: The constant represents a soldier 21 years of age or older, from the Central Highlands region, born on or before 1750, of white skin and a common surname, who has not experienced adverse climatic conditions in the early years of life. One star denotes significance at the ten percent level; two stars at the five percent level.
Source: See text.

4. DISCUSSION AND CONCLUSIONS

Trends in biological well-being, real food prices, and climatic trends help to more precisely draw the boundaries of the well-documented decline in living conditions of the late colonial era, and bring new elements to the assessment of living conditions in the first two decades after independence, a period marked by very limited data sources. The historical literature shows a consensus in assessing the last decades of the colonial period as one of decline in living standards, if not in general economic conditions. The assessment of the early national period (and even the decade of rural insurrection, the 1810s) is a more contentious matter, ranging from pessimistic views (Coatsworth, 1978) to a more optimistic revisionism that has suggested that production and access to food improved as the economy reoriented toward subsistence agriculture (McCaa, 2000: 288; Tutino, 1998: 406-407).

The long-run decline in height and the rise in the cost of food both point to an erosion in the living standards of the popular sectors that extends into the early national era. By the end of the period, real food prices were higher than those paid in the late eighteenth century and almost fifty percent more than the prices before 1780. Height decline began earlier, in the 1750s and extended into the 1830s. This decline in living standards stands in contrast to the optimistic view of the post-independence period, and is consistent with the idea of a century of stagnation, extending to the 1850s or 1860s, as outlined in Brading and Wu (1973).

The general decline corresponded with a widening gap between the stature of urban and rural dwellers. Over the several birth cohorts under study, the height of soldiers from large cities declined less than those from rural areas. On average, the population from large cities was taller than their counterparts from the countryside and small towns, in contrast with the usual finding of an urban penalty in eighteenth and nineteenth century Europe and the United States. Other research dealing with the population in northern Mexico in the mid and late nineteenth century, however, has found no significant difference between farmers and the rest, in contrast with more pronounced differences among Americans from western states (Carson, 2005: 414).

Climatic trends are not part of the erosion in living standards. In fact, climatic conditions were not harsher in any particular lapse of the period under study[23]. Moreover, the wide spread of local climatic conditions attests to the regional variability of climatic experiences, highlighting that regions could complement each other in response to local local food shortages. Hence the there was an ample range of societal response to climatic disasters. The lack of correlation between the increase in real grain prices and climatic conditions suggests that social and economic causes underlay the decline in market entitlements to food more than did climatic conditions. Among those causes, the increasing demand of marketable food by the enlarging urban, mining, and non-agricultural sector (at least until 1810) and by rural dwellers who had more precarious access to land (Garner, 1993; Miño, 2001; Tutino, 1986).

Finally, this work sheds light on the debates about the importance of climate, entitlements, and markets in the access to food that historical peasant societies (and in Mexico in particular) had. The occurrence of adverse climatic conditions in the first years of life had measurable negative effects on biological well-being, as gauged by human height, giving credence to the idea that shocks in aggregate availability of food were significant fac-

23. In contrast with SWAN's conclusion (1981: 645).

tors (Arnold, 1988; Tauger, 2003; Tilly, 1983). The shock of local climatic conditions, measured by the tree ring variable, was more important to the native populations of rural areas and small towns. This likely reflects the nature of the entitlements of this group, which was more closely tied to land access. By contrast, in the large cities this factor is of smaller importance. The impact on height of strong El Niño events experienced in the early years of life is, overall, smaller and less significant, but it is more pronounced in large cities. This suggests that cities cast a wider net to secure their supply, and while their population was not as vulnerable to local harvest conditions, the macro conditions affected its supply. The finding of a significant effect of real food prices on height is even more relevant. It counters entrenched views that markets were too fragmentary or matter little as a way to access food (Ouweneel, 1996: 118-9). The effect is certainly stronger in the large city sample, but it is also pronounced in the rest of the population albeit with a higher uncertainty due to its lower statistical significance). In connection to structural changes in the society that pointed to a greater importance of the division of labor, commercialization, and urbanization (at least until independence), the affordability of food, along with its aggregate availability, became then a key factor in biological well-being in eighteenth and early nineteenth century Mexico.

By relying on anthropometric data to gauge the impact of agricultural crisis, and bringing new evidence to the record of agricultural crisis in the form of real food prices and annual climatic series, this article has sought to move away from the most well-known events of agricultural crisis, and instead shifted attention to the more regular occurrences of regional and macro climatic anomalies, and grain price hikes that, while they may not have triggered massive starvation and death, still shaped nutritional conditions and strongly affected the material well-being of the Mexican popular classes.

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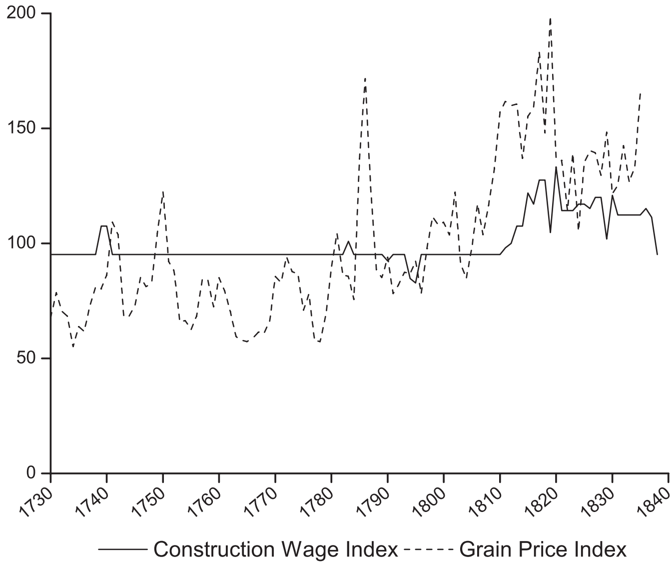
APPENDIX

FIGURE A.1

Nominal Wage and Grain Price Indices. Mexico City, 1730-1838.



Sources: Grain prices were obtained from Florescano (1969), Florescano and San Vicente (1985: 305-306), García-Acosta (1988), and Convento Grande de San Francisco, «Libro de recibo y gasto de enfermería 1810-1836», and Hospital de San Pedro, «Libro de recibos y gastos del mismo 1824-1853», in Biblioteca Nacional, Fondo Reservado, Manuscritos, Ms 1038 and 1562, respectively. The wage sources were scattered across collections of different archives: Archivo General de la Nación (collections Bienes Nacionales, Hospital de Jesús, Hospitales, Policía y Empedrados, Templos y Conventos), Archivo Histórico del Distrito Federal (section Ayuntamiento), Archivo de la Secretaría de Salubridad del Distrito Federal, and Fondo Reservado de la Biblioteca Nacional (Manuscritos collection).

TABLE A.1
Annual Wage and Grain Price Indices (Base average = 100). Mexico City, 1730-1838

Year	NCW	NGP	RGP	Year	NCW	NGP	RGP	Year	NCW	NGP	RGP
1730	95	68	71	1767	95	61	65	1804	95	85	89
1731	95	79	83	1768	95	61	64	1805	95	98	103
1732	95	71	74	1769	95	66	69	1806	95	117	123
1733	95	68	72	1770	95	86	90	1807	95	104	109
1734	95	55	58	1771	95	83	87	1808	95	117	123
1735	95	64	67	1772	95	94	99	1809	95	133	139
1736	95	62	65	1773	95	88	92	1810	95	157	165
1737	95	73	77	1774	95	87	91	1811	98	162	165
1738	95	81	85	1775	95	71	75	1812	100	160	160
1739	108	80	75	1776	95	78	82	1813	108	161	149
1740	108	86	80	1777	95	58	61	1814	108	137	127
1741	95	109	115	1778	95	57	60	1815	122	155	127
1742	95	104	109	1779	95	69	73	1816	117	159	136
1743	95	68	72	1780	95	90	94	1817	128	183	144
1744	95	68	72	1781	95	104	110	1818	128	148	116
1745	95	73	77	1782	95	86	91	1819	105	199	190
1746	95	85	90	1783	101	86	85	1820	133	137	103
1747	95	81	85	1784	95	75	79	1821	114	136	119
1748	95	83	87	1785	95	137	144	1822	114	114	100
1749	95	105	110	1786	95	172	180	1823	114	139	122
1750	95	122	129	1787	95	124	131	1824	117	105	90
1751	95	92	97	1788	95	89	93	1825	117	135	115
1752	95	88	93	1789	95	85	89	1826	115	140	122
1753	95	66	69	1790	92	94	102	1827	120	139	116
1754	95	66	70	1791	95	78	82	1828	120	130	108
1755	95	62	66	1792	95	82	86	1829	102	148	146
1756	95	68	72	1793	95	88	92	1830	121	122	101
1757	95	84	89	1794	85	87	102	1831	112	125	111
1758	95	84	88	1795	83	92	111	1832	112	143	127
1759	95	72	76	1796	95	78	82	1833	112	127	113
1760	95	85	89	1797	95	98	103	1834	112	133	119
1761	95	79	83	1798	95	112	117	1835	112	165	147
1762	95	70	74	1799	95	108	114	1836	115		
1763	95	59	62	1800	95	109	115	1837	111		
1764	95	58	61	1801	95	104	109	1838	95		
1765	95	57	60	1802	95	122	128				
1766	95	59	62	1803	95	91	96				

Notes: NCW stands for the nominal construction wage index, NGP for the nominal grain price index. For both, the base is average = 100. RGP stands for real grain price index and is the division of NCW and NGP. Source: See Figure A.1.