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by

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Abstract

We empirically assess the role of environmental conditions at birth, namely, infant mortality (IMR), GDP per capita and income inequality in the year of birth in explaining average adult height for cohorts born between 1950 and 1980 in 20 Brazilian states. We find that there is a strong positive correlation between GDP per capita and adult height, even after controlling for: secular changes affecting both GDP per capita and adult height, constant differences across states, income inequality and IMR in the year of birth. The drop in IMR does not appear to be a relevant factor in explaining the Brazilian increase in average height. Moreover, IMR could have had a positive impact on average height of non-white women through selection: non-white women who survived in a year of birth with high IMR appear to be taller when they reach adulthood. We also find that income inequality in the year of birth is negatively associated with the average adult height of non-white women. While recent findings for a developed country like Spain suggest that disease, not food availability, was the constraining factor of human growth, at least after 1969, in Brazil, a developing country, food availability, not disease, appears to have been the constraining factor, at least after 1950.

Keywords: Mortality; Height; Income; Brazil.

JEL classification codes: I12; I18.

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1. Introduction

Secular rises in childhood and adult stature across successive birth cohorts suggest that early life environments play an important role in determining the individuals' stature (Battya et al., 2009). More specifically, food availability and disease exposure in the year of birth are likely to be major determinants of adult stature.

There is evidence that disease exposure is important in explaining average adult height, both across countries and across regions within a country. Across countries, Bozzoli, Deaton and Quintana-Domeque (2009) have shown that there is a strong inverse relationship between disease exposure early in life (proxied by postneonatal mortality (PNM) in the year of birth) and average height for cohorts born between 1950 and 1980 in developed countries (Europe and the US). Within a country, using regional data for Spain, Bosch, Bozzoli and Quintana-Domeque (2009) find a strong negative correlation between disease exposure early in life (proxied by infant mortality rate (IMR) in the year of birth) and average height for cohorts born between 1969 and 1986 in Spain.

Interestingly, neither Bozzoli et al. nor Bosch et al. find a role for income in the year of birth after accounting for PNM or IMR in explaining average adult height in European countries and the US. These findings suggest that exposure to disease, not food availability has been the constraint to human growth in these developed countries, at least after 1950. However, the findings in Deaton (2007) and Bozzoli, Deaton and Quintana-Domeque (2009) for developed countries, suggest that the relationship found for developed countries may be dramatically different in developing countries. In those poorer countries, food availability may indeed be a more important factor than exposure to disease in explaining human development expressed as adult height.

Previous empirical evidence for Brazil, a developing country, suggests that income in the year of birth is likely to be an important factor in explaining average adult height. Monasterio, Noguérol and Shikida (2006) using microdata on individual height report a positive effect of GDP at the year of birth on adult height. However, these authors do not control for exposure to disease in the year of birth.

This paper aims to provide empirical evidence of the effects of exposure to disease and food availability in the year of birth on average adult height using a panel of 4 birth cohorts (1950, 1960, 1970 and 1980) and 20 Brazilian states.

Brazil is an interesting case to be analyzed: Brazil has experienced important demographic changes in the second half of 20th Century, and it is a country that has been historically characterized by large differences in socioeconomic conditions across its regions. Despite the remarkable improvements of child health conditions over decades, the level of IMR in Brazil's Northeast (117‰) could be compared to the countries of Sub-Saharan Africa in 1980, while other Brazilian regions presented values substantially lower than in the Northeast region.

We find that there is a strong positive correlation between GDP per capita and adult height, even after controlling for: secular changes affecting both GDP per capita and adult height, constant differences across states, income inequality and infant mortality (IMR) in the year of birth. Interestingly, the drop in IMR does not appear to be a relevant factor in explaining the Brazilian increase in average height. Moreover, IMR could have had a positive impact on average height of non-white women through selection: non-white women who survived in a year of birth with high IMR appear to be taller when they reach adulthood. We also find that income inequality in the year of birth is negatively associated with the average adult height of non-white women.

While recent findings for a developed country like Spain suggest that exposure to disease, not food availability, was the constraining factor of human growth, at least after 1969, in Brazil, a developing country, food availability, not disease exposure, appears to have been the constraining factor, at least after 1950.

This paper is organized as follows. Section 2 presents a brief literature review. Section 3 describes the data sources. Section 4 shows the main results. Section 5 offers some robustness checks. Section 6 concludes.

2. Literature review

In the last fifteen years, the study of height has obtained a great notoriety in the Social Sciences, especially within Economics: adult stature has been well established as a biological indicator of the populations (Komlos and Baten, 1998; Fogel, 2004; Steckel, 2009). The analysis of the evolution of adult height in a population provides insights about the changes in the nutritional patterns and health conditions during childhood over time. Not surprisingly, Elo and Preston (1992) concluded that “Height is probably the single best indicator of nutritional conditions and disease environment of childhood. Like place and date, it is a summary measure of many health related circumstances and events, but it has the advantage of reflecting the experiences of an individual child”.

2.1 Early childhood and adult height

The adult height of an individual is determined early in life, more or less by age four, conditional on genetic height potential (Schultz, 2009). The correlation of child height with adult height is between 0.25 and 0.3 at birth, rises to between 0.7 and 0.8 at the age two, and increases only slowly thereafter (Schmidt, Jorgensen, and Michaelsen, 1995).

According to the literature on human growth, adult height is determined by cumulative *net nutrition* over the growing period, where *net nutrition* is the difference between the *gross nutrition* (food intake) and the claims on it through activity and disease (Eveleth and Tanner, 1990; Bogin, 2001; and Silventoinen, 2003). Chronically nutritional deprivation inevitably stunts adult height by as much as 10–15 cm, and possibly more in extreme situations (Steckel, 2009).

Although the variation between the heights of individuals within a subpopulation is indeed largely dependent on differences in their genetic endowments (Estrada et al., 2009), the variation between the means of groups of individuals (at least within an ethnically homogeneous population) reflects the cumulative nutritional, hygienic, disease, and stress experience of each of the groups (Tanner, 1994). The importance of environmental factors at birth (exposure to disease and economic conditions) has been acknowledged for more than 30 years. Malcolm (1974) concluded that differences in average height between populations are almost entirely the product of the environment, after a review of studies covering populations in Europe, New Guinea, and México.

Crimmins and Finch (2005) argue that individuals who have experienced less nutritional deprivation and less exposure to infectious diseases causing inflammation, especially as a child, are more likely to enjoy of better health conditions in adulthood. The exposure to infectious diseases (e.g. respiratory and diarrheal disease) and the availability of food during the childhood are important determinants of adult stature: usually, infant mortality rate (or post-neonatal mortality when the data are rich enough) is considered a proxy for exposure to infections among survivors (e.g., Forsdahl, 1977), and it has been found to be a strong predictor of the average (adult) height of the survivors (e.g., Sobral, 1990).

2.2 Scarring and selection effects

As emphasized by Deaton (2007), the disease and nutritional environment in childhood may have two opposite effects on adult height. First, a high-disease and low-nutritional environment increases the survival cutoff, so less children survive. This *selection* of children with low potential adult height, as measured by mortality rates, increases the average adult height of the survival population. Second, the children who survive experience a reduction in their final adult height that depends on the severity of the disease and nutritional environment in childhood. This *scarring* or *debilitation* effect reduces adult height among the survivors and works in the opposite direction to selection.

Deaton (2007) found supporting evidence of the *selection* effect in African countries. Bozzoli, Deaton and Quintana-Domeque (2009) develop a model of selection and scarring, in which the early life burden of nutrition and disease is not only responsible for mortality in childhood but also leaves a residue of long-term health risks for survivors, risks that express themselves in adult height, as well as in late-life disease. They found a strong inverse relationship between post-neonatal (one month to one year) mortality, interpreted as a measure of the disease and nutritional burden in childhood, and the mean height of those children as adult across a range of European countries and the United States. In the poorest and highest mortality countries of the world, child mortality is positively associated with adult height. Their results suggest that the *selection* dominates *scarring* at high mortality levels, and scarring dominates selection at low mortality levels.

Bozzoli, Deaton and Quintana-Domeque (2009) justify in part the African height "paradox" arguing that among poorest countries, highest mortality countries, there are distinct effects on adult height of both disease and of food availability, as represented by income, suggesting that early childhood development is constrained both by food and by disease in poor countries while, in now rich countries since 1950, the food constraint has not been important. More notably, the authors find that the *selection* effect can be stronger than the *scarring* effect at high levels of mortality and low levels of income.

Hatton (2009), using town-level panel data on heights of British school children reported by school medical inspectors from 1910 to 1950, finds some support for the *scarring* effect. Bosch, Bozzoli and Quintana-Domeque (2009), using data on 5 cohorts born between 1969 and 1986 in 17 Spanish regions, estimate also a negative association between IMR and average adult height. They also show that neither real GDP per capita nor income inequality in the year of birth explain average cohort height after accounting for infant mortality in the year of birth.

Contrasting these recent findings, Monasterio, Nogueról and Shikida (2005) report that real GDP per capita at the year of birth is an important predictor for adult height. They also verify substantial differences in average adult height among Brazilian regions. Despite the increase in Brazilian average height, people living in the North and Northeast regions do not converge to this average. These authors suggest that these regional differences in average heights are probably reflecting the persistent socio-economic differences across Brazilian regions. However, their study did not account for the effects of disease environment in the year of birth. The present study tries to circumvent this caveat.

3. Data

3.1. Data description

The data used in this study comes from the IBGE (Instituto Brasileiro de Geografia e Estatística). Infant Mortality Rates (IMRs) and resident populations are obtained from the Brazilian Statistics of the 20th Century[1]. GDPs and their implicit deflators can be found in the IPEADATA, the IPEA (Instituto de Pesquisa Econômica Aplicada) database[2].

Height data are obtained from the POF 2002-2003 (Pesquisa de Orçamentos Familiares 2002-2003) of the IBGE. Information in the POF was directly obtained from interviewed people in their respective households during nine consecutive days, between July of 2002 and June of 2003. The POF contains information about each individual living in the household such as age and date of birth, sex, color and race, schooling level, religion, current state of residence, employment status and sources of income.

Interestingly, height data in the POF are not self-reported, but directly measured. Individual's height was measured by using a graduated tape measure in millimeters, where fractions of centimeters were rounded to the nearest integer. Individuals aged 2 or above where measured in vertical position. Height measurements were submitted to the system of Critique and Imputation System for Quantitative Data (Crítica e Imputação para Dados Quantitativos, CIDAQ) to deal with potential measurement error and non-partial response related to height of individuals. The CIDAQ makes use of data transformation, multivariate treatment of data, robustness analysis of parameters, identification of potential outliers and missing values. Hence, with respect to previous

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[1] http://www.ibge.gov.br/seculoxx/default.shtm

[2] http://www.ipeadata.gov.br

studies (e.g., Bozzoli, Deaton and Quintana-Domeque, 2009; Bosch, Bozzoli and Quintana-Domeque, 2009), we are excluding the possibility of measurement error from self-reported information.

We are interested in the heights of interviewed individuals aged between 21 and 53 in 2002-2003, i.e. those who have already attained their adult stature by the time the survey was carried out, but who have not suffered from shrinkage due to aging. We compute average height at the year of birth by state (of current residence) for all sampled population and for some specific groups of individuals, such as males (white and non-white) and females (white and non-white).

Our final sample consists of three main variables: average adult cohort height, IMR in the year of birth and real GDP per capita in the year of birth at the state-cohort level. We have 20 Brazilian States[3] and 4 birth cohorts: 80 pooled cross-section time series observations. We restrict our analysis to 4 cohorts, the ones for which we have IMRs at the state level, available from the Brazilian Demographic Censuses (1950, 1960, 1970 and 1980). Although it would be interesting to perform our analysis decomposing IMR on neonatal mortality (NNM) and post-neonatal mortality (PNM), we have not been able to find data on either NNM or PNM disaggregated at the state level for the years before 1980.

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[3] Brazilian geographic regions and their States: **North** (Amazonas - AM and Pará - PA), **Northeast** (Maranhão - MA, Piauí - PI, Ceará - CE, Rio Grande do Norte - RN, Paraíba - PB, Pernambuco – PE, Alagoas - AL, Sergipe - SE and Bahia - BA), **Southeast** (Minas Gerais - MG, Espírito Santos - ES, Rio de Janeiro - RJ, and São Paulo - SP), **South** (Paraná - PR, Santa Catarina - SC, and Rio Grande do Sul - RS), and **Center-West** (Mato Grosso - MT and Goiás - GO).

3.2. A first look at the data

Average adult statures were calculated including only white, black and brown people. We excluded indigenous and yellow people since they are not representative in the POF's survey; they are less than 1% of the total sample. Our analysis of adult height distinguishes among white and non-white people (defined as brown plus black people). In the empirical analysis section, the analysis is carried out by race-gender.

Table 1 shows the average adult height, IMR and deflated real GDP per capita (R$, 2003=100) by state and birth cohort.

Table 1: Average Height, Infant Mortality Rate and real GDP per capita (R$, 2003=100) for selected years of birth cohorts and Brazilian States.

STATES	1950			1960			1970			1980		
	Height	IMR	GDP	Height	IMR	GDP	Height	IMR	GDP	Height	IMR	GDP
AM	161	154	997	162	119	1474	164	110	1886	164	67	5421
PA	160	147	636	163	114	1109	160	110	1327	164	74	3179
MA	156	151	355	160	133	552	162	132	721	161	106	1473
PI	161	147	293	160	137	396	162	130	573	161	96	1223
CE	159	166	556	161	175	734	161	157	865	163	140	2030
RN	161	199	666	161	198	949	162	177	906	165	147	2327
PB	160	195	616	162	193	879	162	175	783	164	151	1645
PE	160	194	813	161	185	1049	165	165	1477	167	137	2873
AL	161	185	555	162	182	794	163	168	1121	165	140	2329
SE	163	183	537	164	165	804	164	148	1255	165	106	2378
BA	161	167	559	162	150	884	165	133	1329	166	96	3196
MG	163	141	956	163	113	1272	165	110	1888	167	76	4911
ES	163	126	1097	163	96	1100	166	96	1927	167	61	5058
RJ	164	124	2903	164	91	3173	167	99	4853	167	76	8483
SP	166	128	2717	166	92	3344	167	94	5810	168	75	10505
PR	165	139	1656	165	104	1872	167	98	2052	168	72	5264
SC	167	112	1112	167	87	1507	167	85	2417	169	63	6321
RS	165	99	1542	164	69	2013	166	71	3380	168	48	7113
MT	164	110	2081	164	84	3816	166	96	4765	167	67	3707
GO	165	129	843	165	108	1093	166	107	1644	168	74	3798
BRAZIL	**162**	**135**	**1378**	**163**	**124**	**1770**	**164**	**115**	**2812**	**166**	**83**	**5861**

Source: IBGE, IPEADATA and authors' calculations from POF 2002-2003. Both variables are rounded to the nearest integer.

There are several aspects of the table that deserve special attention. First, there is a large difference in both average adult heights and infant mortality rates across states: the Northern and Northeastern states combine low adult average heights and high infant mortality rates, while the Southeastern, Southern and Center-Western states present high adult average heights and low infant mortality rates. For instance, over the birth cohorts, the Ceará state (Northeast region) has a range of values of average adult heights between 159 cm and 163 cm, and a decreasing range of values of IMR between 175‰ and 140‰ live births. The Santa Catarina state (South region) presents a range of values of average adult height between 166 cm and 169 cm, and its range of decreasing values of IMR is between 112‰ and 63‰ live births.

There is also a substantial regional disparity in real GDP per capita across Brazilian states. The average GDP per capita of the Southern, Southeastern and Center-Western states is around 2.6 times the average of GDP per capita of the Northern and Northeastern states over time. In 1950, North and Northeast regions accounted for 38.5% of the total Brazilian population and 16.4% of the total GDP, while the South, Southeast and Center-West regions accounted for 61.5% of the total Brazilian population and 83.6% of the total GDP. After 30 years, this scenario had not changed much. Indeed, it became a bit more dramatic: the percentage of people living in the North and Northeast regions fell 3.7 percentage points and the participation on total GDP fell 1.1 percentage points in 1980.

Given that the IMR at the year of birth in a region is a proxy of the disease exposure of the individuals born in that year in such a region, which is a relevant determinant of adult height, we should expect a negative relationship between average adult height and IMR. Figures 1 and 2 show this relationship, first, exploiting just state variation, and second, exploiting both state and cohort variation.

Fig. 1 Average height and IMR
(means by State over time)

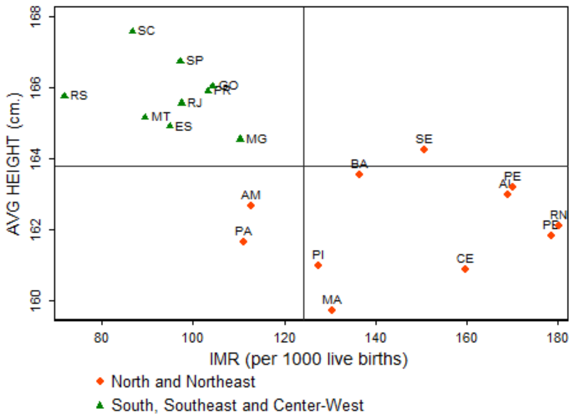
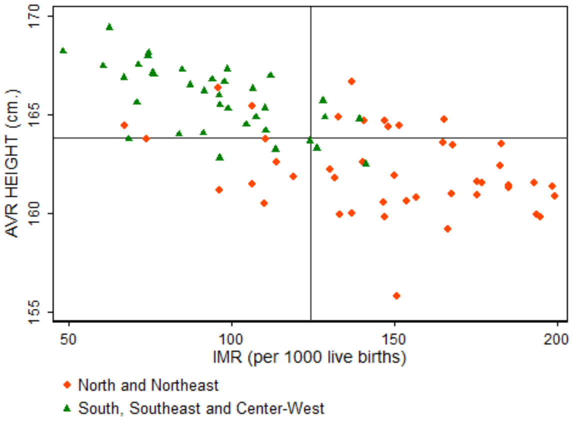


Fig. 2 Average height and IMR
(total sample)



The correlation between average adult height and IMR is approximately -0.70 for the total sample (exploiting state and cohort variation) and -0.65 when exploiting just state variation.

If the state GDP per capita in the year of birth serves as a proxy for the economic conditions in the corresponding state at the year of birth, we will expect that the state GDP per capita is positively related to the state adult average height, based on the hypothesis that gross nutrition is tied to income. Figures 3 and 4 show the relationship between the average adult height and the log natural of GDP per capita in the year of birth (exploiting state and cohort variation, and exploiting just state variation). From these graphs a clear picture emerges: rich Brazilian states are taller states, while poor Brazilian states are shorter states. The correlations between log (GDP) and average height are very similar whether exploiting only state variation (0.83) or making use of both cohort and state variation (0.82).

Fig. 3 Average height and GDP per capita (means by State over time)

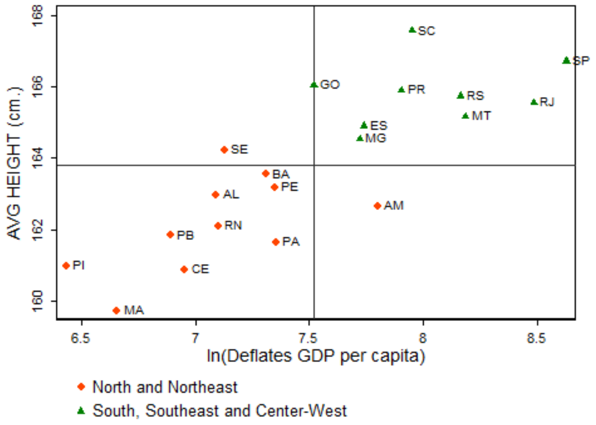
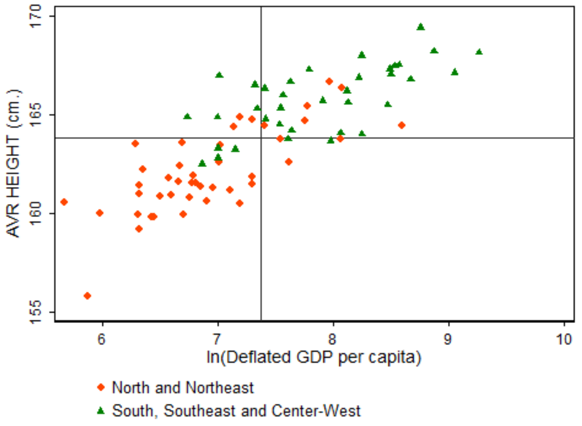


Fig. 4 Average height and GDP per capita (total sample)



It is also worth exploring the relationship between IMR and GDP in the year of birth. We find a strong contemporaneous correlation between the IMR and the log of GDP per capita. Figures 5 and 6 are scatter-plots of these two variables. Notice that the states of the North and Northeast region present low levels of GDP per capita and high rates of infant mortality, while states of the South, Southeast and Center-West region have high levels of GDP per capita combined with low rates of infant mortality. The correlation between these two variables is -0.77 (exploiting both state and cohort variation).

Fig. 5 IMR and GDP per capita
(means by State over time)

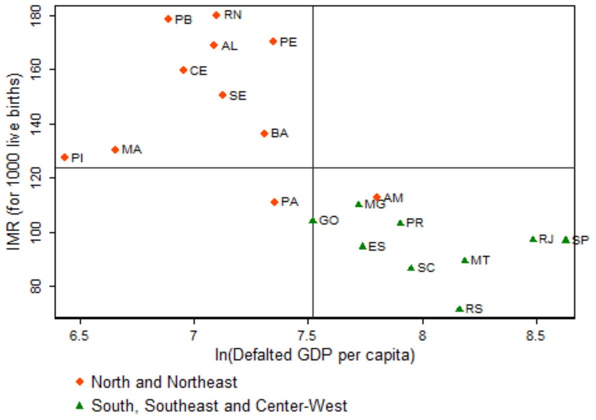
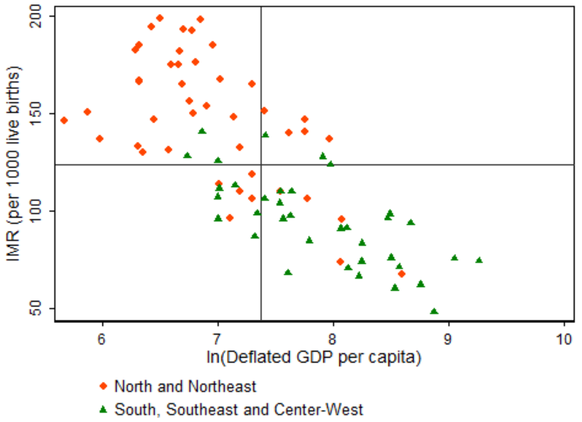


Fig. 6 IMR and GDP per capita
(total sample)



Until now we have focused on state variation. Now we focus on the cohort (time) variation. If we look at the evolution of the adult height, IMR and GDP per capita means (across states) over time (birth cohorts) some interesting patterns emerge. The average adult height and the log of the deflated GDP per capita are increasing over the birth cohorts, whereas the IMR is decreasing over time. Brazil has experienced a significantly decline in IMR during the second half of the 20th Century. In 1950, the IMR was at 135‰ live births, while it fell to 83‰ by 1980, decreasing 38.5% in thirty years. The largest reduction is found in the Amazonas state, around 56%, while the Ceará state had a reduction of only 16%. Moreover, the average reduction in IMR among the states from the South, Southeast and Center-West region was higher than the registered reduction among states from the North and Northeast region, respectively -44.8% and -33.8%. Nevertheless, at the beginning of the 1980's decade, Brazil presented a high rate of infant mortality in comparison to the European countries and the US (12.6 per 1,000 live births). Only the state of Rio Grande do Sul had an infant mortality rate below 50 per 1,000 live births in 1980, too much higher in comparison with the registered IMR in the developed countries in the same year.

Evolution over time of height, IMR and GDP (means across state by year)

Fig. 7 Average height and IMR, 1950-1980

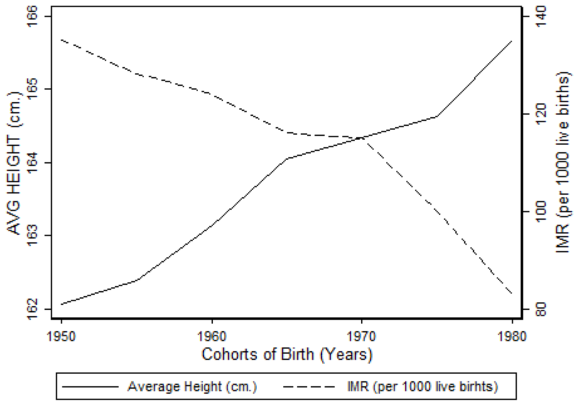
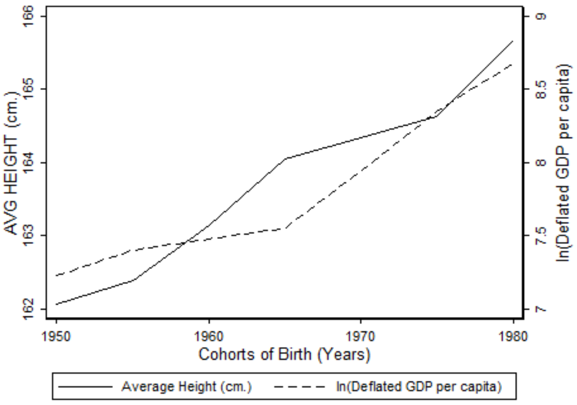


Fig. 8 Average height and GDP, 1950-1980



Brazil was one of the countries that presented a high speed of economic growth from 1950 to 1980. The deflated GDP per capita increased 325% in that period. Schultz (2009) argues that the fast economic growth in Brazil may explain the marked increase in height among younger women in Brazil compared with those in Ghana which experienced a little economic growth after its independence in 1957.

In the next section we assess the relative importance of IMR and GDP in the year of birth (i.e., economic and disease environment) in explaining adult stature in Brazil for the cohorts born between 1950 and 1980. To that end, we also need to pay attention to constant differences across Brazilian states and across cohorts (secular trends).

4. Empirical Analysis

This section analyzes the relationship between average adult height, IMR and GDP in the year of birth, accounting for both secular changes affecting average height, IMR and GDP (or controlling for constant differences across cohorts) and constant differences across Brazilian states or regions. The empirical analysis is carried out separately for men and women by race.

4.1. Average Height of Men: White and Non-White

Table 2 presents the estimates from several regressions of average height on GPD and IMR for white men. The estimates reveal that the log GDP per capita in the year of birth is positively associated with adult height. In 8 out of the 9 regressions the coefficient is positive and statistically significant. The only specification where the coefficient on the log GDP is not statistically significant turns out to be column (8), where we control for both state (20 dummy variables) and cohort (4 dummy variables) fixed effects. This indeed is not surprising. Given a sample size of 80 observations, identifying the association between log GDP and average height after removing both between-country and between-cohort variations is probably asking the data too much.

Things are quite different regarding the estimates of the coefficient on IMR. First, they do not allow us to detect a clear relationship between IMR and adult height. If anything, we find a positive association between IMR in the year of birth and adult height, statistically significant in columns (6), (7) and (9). This may indicate that, for white male, the selection effect dominates the scarring effect.

Table 2: Regressions of white male average height on IMR and GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IMR	-0.011	-0.010	-0.012	0.032	0.015	0.058**	0.029**	0.039	0.023*
	(0.009)	(0.009)	(0.009)	(0.022)	(0.011)	(0.025)	(0.013)	(0.032)	(0.013)
ln(GDP per capita)	2.214***	2.559***	2.624***	3.135***	2.389***	2.092**	1.757***	1.716	1.752***
	(0.432)	(0.494)	(0.498)	(0.793)	(0.407)	(0.955)	(0.513)	(1.192)	(0.552)
Time Trend		-0.363				1.034*	0.701*		
		(0.258)				(0.552)	(0.357)		
Cohort Dummies?	NO	NO	YES	NO	NO	NO	NO	YES	YES
State Dummies?	NO	NO	NO	YES	NO	YES	NO	YES	NO
Regional Dummies?	NO	NO	NO	NO	YES	NO	YES	NO	YES
F-test Cohort Dummies = 0			3.01**					1,82	2.3*
F-test State Dummies = 0				2.24***		2.38***		2.02**	
F-test Regional Dummies = 0					5.49***		6.04***		4.79***
R²	0.54	0.55	0.59	0.73	0.65	0.75	0.66	0.76	0.68
R² Adjusted	0.53	0.53	0.56	0.64	0.62	0.65	0.63	0.65	0.64
N	80	80	80	80	80	80	80	80	80

Notes: Heteroskedasticity robust standard errors are reported in parentheses. Time trend is defined as the cohort year of birth. Observations have been weighed using the number of individual observations that gave rise to the cohort-state (region) average.
*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 3: Regressions of non-white male average height on IMR and GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IMR	-0.002	-0.003	-0.003	-0.008	-0.001	0.002	-0.004	-0.003	-0.008
	(0.008)	(0.008)	(0.008)	(0.022)	(0.008)	(0.024)	(0.010)	(0.027)	(0.010)
ln(GDP per capita)	2.31***	2.586***	2.707***	1.606*	2.065***	1.139	2.207***	1.692	2.524***
	(0.389)	(0.445)	(0.442)	(0.862)	(0.352)	(0.991)	(0.486)	(1.081)	(0.507)
Time Trend		-0.31				0.439	-0.145		
		(0.244)				(0.458)	(0.341)		
Cohort Dummies?	NO	NO	YES	NO	NO	NO	NO	YES	YES
State Dummies?	NO	NO	NO	YES	NO	YES	NO	YES	NO
Regional Dummies?	NO	NO	NO	NO	YES	NO	YES	NO	YES
F-test Cohort Dummies = 0			2.03					1.26	1.74
F-test State Dummies = 0				2.66***		2.58***		2.45***	
F-test Regional Dummies = 0					5.98***		5.46***		5.56***
R²	0.52	0.53	0.56	0.74	0.64	0.75	0.64	0.76	0.66
R² Adjusted	0.51	0.51	0.53	0.65	0.61	0.65	0.60	0.66	0.62
N	80	80	80	80	80	80	80	80	80

Note: See Table 2.

In Table 3 we present the estimates from several regressions of average height on GPD and IMR for non-white men. Like in the previous case, the estimates reveal that the log GDP per capita in the year of birth is positively associated with adult height. In 7 out of the 9 regressions the coefficient is positive and statistically significant. However, the estimates regarding the coefficient on IMR suggest no relationship between IMR and adult height for non-white men. This contrasts with the possible selection effect found previously for white men.

4.2. Average Height of Men: White and Non-White

Table 4 presents the estimates from several regressions of average height on GPD and IMR for white women. The only robust finding in the table is the positive coefficient on the log GDP. In contrast, IMR appears to be negatively related to average adult height only when neither state nor regional dummy variables are included in the regressions.

Table 4: Regressions of white female average height on IMR and GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IMR	-0.017**	-0.017**	-0.017**	-0.026	0.004	-0.008	0.017	0.000	0.018
	(0.008)	(0.008)	(0.008)	(0.017)	(0.010)	(0.020)	(0.012)	(0.025)	(0.013)
ln(GDP per capita)	1.43***	1.494***	1.521***	0.927	1.799***	0.197	1.176**	-0.71	1.081**
	(0.398)	(0.461)	(0.483)	(0.612)	(0.390)	(0.747)	(0.487)	(0.938)	(0.531)
Time Trend		-0.065				0.721	0.692**		
		(0.234)				(0.436)	(0.334)		
Cohort Dummies?	NO	NO	YES	NO	NO	NO	NO	YES	YES
State Dummies?	NO	NO	NO	YES	NO	YES	NO	YES	NO
Regional Dummies?	NO	NO	NO	NO	YES	NO	YES	NO	YES
F-test Cohort Dummies = 0			0.25					1.77	1.47
F-test State Dummies = 0				4.32***		4.59***		4.69***	
F-test Regional Dummies = 0					3.53**		4.73***		4.47***
R^2	0.48	0.48	0.49	0.79	0.56	0.79	0.59	0.80	0.59
R^2 Adjusted	0.47	0.46	0.45	0.71	0.53	0.72	0.55	0.72	0.54
N	80	80	80	80	80	80	80	80	80

Note: See Table 2.

For non-white women, the results in Table 5 again indicate that the log GDP and average height are positive related, but also that there could be a mortality selection effect going on: the coefficient on IMR is positive and statistically significant in 5 out of 9 regressions.

Table 5: Regressions of non-white female average height on IMR and GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IMR	0.014*	0.015*	0.014*	-0.005	0.010	0.030	0.024**	0.026	0.019*
	(0.008)	(0.008)	(0.008)	(0.021)	(0.009)	(0.020)	(0.010)	(0.023)	(0.011)
ln(GDP per capita)	3.187***	2.916***	2.994***	2.462***	3.046***	0.714	2.249***	0.576	2.465***
	(0.397)	(0.438)	(0.437)	(0.822)	(0.374)	(0.848)	(0.485)	(0.935)	(0.517)
Time Trend		0.341				1.586***	0.81**		
		(0.238)				(0.391)	(0.328)		
Cohort Dummies?	NO	NO	YES	NO	NO	NO	NO	YES	YES
State Dummies?	NO	NO	NO	YES	NO	YES	NO	YES	NO
Regional Dummies?	NO	NO	NO	NO	YES	NO	YES	NO	YES
F-test Cohort Dummies = 0			1.84					6.15***	2.84**
F-test State Dummies = 0				2.96***		4.42***		4.19***	
F-test Regional Dummies = 0					4.35***		5.54***		5.12***
R^2	0.57	0.59	0.60	0.78	0.66	0.83	0.68	0.84	0.69
R^2 Adjusted	0.56	0.57	0.58	0.71	0.63	0.77	0.65	0.77	0.65
N	80	80	80	80	80	80	80	80	80

To sum up, our findings seem to suggest that:

(1) GDP (income) was the responsible of human growth in Brazil during the period 1950-1980 for both men and women, and white and non-white;

(2) IMR could have positive selective effects for some particular groups of the population: white men and non-white women.

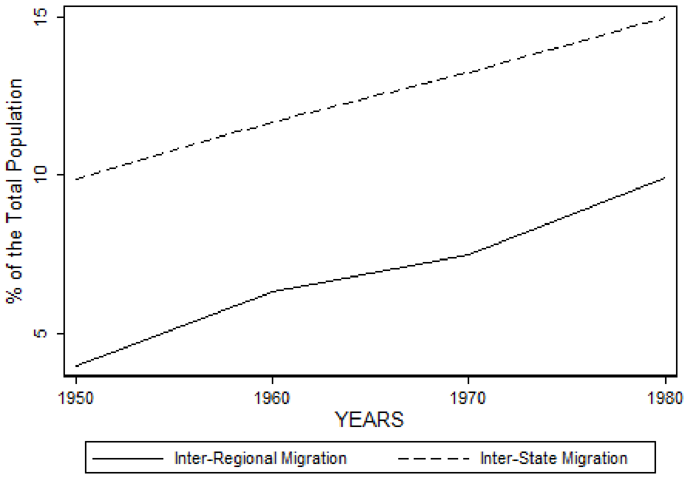
Although our findings appear to be sensible, there are at least three important caveats that one should take into account when interpreting them (Bosch, Bozzoli, and Quintana-Domeque, 2009). First, we do not have data on region of birth but region of current residence. Hence, we need to be aware of potential selective migration. Second, there could be omitted variables that are related to IMR, GDP and average height, such as income inequality. Finally, there could be nonmonotonicites (or nonlinearities) in the mortality-height relationship. We investigate the extent to what our results may be biased by these factors in the next section.

5. Robustness checks

5.1. Selective migration

Figure 9 shows the evolution of the migration flow in Brazil between 1950 and 1980, which is increasing over the entire period. This is intrinsically related to the regional development policies through the industrialization process of Brazil in the second half of the 20th Century (Oliveira, Ellery Jr. and Sandi, 2007). The inter-regional migrants represented approximately 40% of the total inter-state migration flow in 1950. After 1960s, the inter-regional migrants represented more than half of the total inter-state migrants, reaching 60% of total inter-state migrants in 1980.

Fig. 9 Evolution of the Migration Flow in Brazil over Time, 1950-1980



Figures 10 (and Figure 11) describe the evolution of the % of inter-regional immigrants (emigrants) in Brazil by region of destiny between 1950 and 1980. Between 1950 and 1975, the Southeast region experienced a strong concentration of the industrial activity, particularly in the São Paulo state. The increase in the labor force demand and the better structure of labor market transformed the Southeast Brazilian region in the main destination of the majority of the inter-regional migrants during this period. The Northeastern emigrants sustained this migration flow to the Southeast region, representing almost 84% of the total inter-regional immigrants in this region in 1960, according to the Brazilian Demography Census of IBGE.

Fig.10 % of Inter-regional Immigrants by Region of Destination in Brazil, 1950-1980

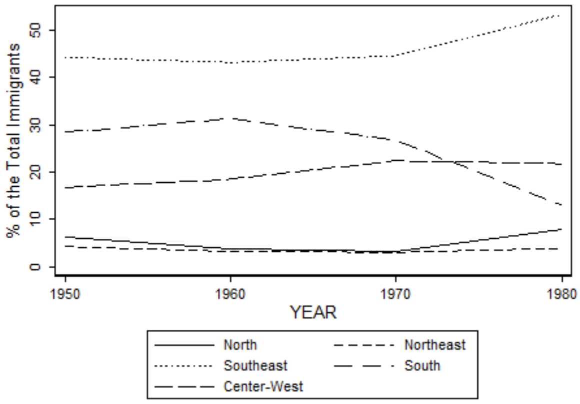
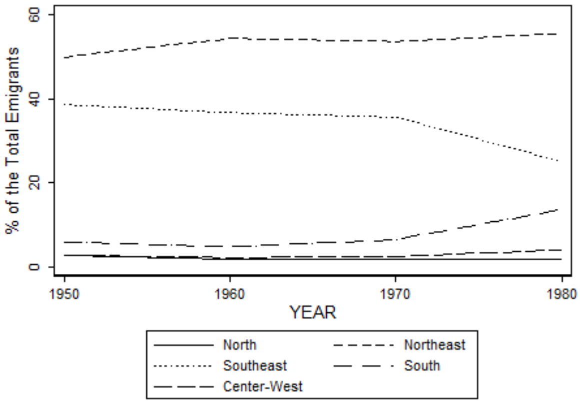


Fig.11 % of Inter-regional Emigrants by Region of Origin in Brazil, 1950-1980



Between 1975 and 1980, the government implemented subsidization policies stimulating the industrial activity in the regions with lower economic dynamism, mainly in the North and Northeast regions. At the same time, the State also stimulated the expansion of agriculture frontiers to the Center-West and North regions. The percentage of Northeastern emigrants stagnated around 54% of the total amount of inter-regional emigrants between 1960 and 1980, and the Center-West region registered successive increases in its percentage of inter-regional immigrants. Moreover, the percentage of inter-regional immigrants in the North region only registered an increase after 1970.

Although the implementation of development polices out of the Southeast region had stimulated the migration flow to the North and Center-West, the Southeast region stayed as the main destination of the Southern and Northeastern inter-regional migrants between 1975 and 1980.

Looking at Table 7, we observe that the Northeast region was the main region of departures. Over the time, the total number of emigrants from this region is approximately 15 times larger, on average, than the total number of immigrants from the other Brazilian regions.

Table 7: Ratio Emmigrant/Immigrants for Brazilian Regions, 1950-1980

Regions	**1950**	**1960**	**1970**	**1980**
North	0.43	0.51	0.56	0.21
Northeast	11.55	16.63	17.33	14.16
Southeast	0.87	0.85	0.80	0.47
South	0.21	0.15	0.24	1.05
Center-West	0.17	0.12	0.11	0.19

Source: Authors' calculations from Netto Jr. et al. (2003)

The Northeastern migrants are the most representative immigrants in the Southeast and North regions, while the Southeastern migrants are the most representative immigrants in the Center-West and South regions. According to Netto Jr. et al. (2003), between 1970 and 1980, the Southern immigrants experienced an increase in their participation out of the total immigrants in the North and Center-West region, while the participation of the Northeastern immigrants was decreasing in these regions during the same period. Moreover, the Southeastern immigrants reduced their participation among inter-regional immigrants in the Center-West and South regions, while they increased their participation in the total immigrants registered in the North region between 1970 and 1980.

Therefore, the inter-regional migration was intensive in Brazil between 1950 and 1980. We observe not only a migratory flow from the poorest region (Northeast) to the richest region (Southeast), but also a migration flow between poor regions (from Northeast to the North) and from the richest regions (Southeast and South regions) to the regions with the lowest population densities (Center-West and North regions). The Brazilian demographic phenomenon makes necessary to account for the fact that individuals living in a state (region) are likely to be born in a different state (region).

Table 8 shows the fraction of Brazilian residents in each State who were born in that State by selected years of birth. We make use of IBGE data from the Pesquisa Nacional de Amostra Domiciliar 2003 (PNAD). The PNAD is a yearly Brazilian household survey which contains information about migration, education, labor, income, etc. Interestingly, the PNAD allows us to identify the state where the individual is currently living and the state where the individual was born.

Table 8: Fraction of Brazilian residents in each State who were born in that State by selected years of birth

Geographic Region	State	1950	1960	1970	1980
NORTH	RO	0.272	0.184	0.194	0.389
	AC	0.875	0.821	0.844	0.887
	AM	0.731	0.772	0.816	0.867
	RR	0.300	0.357	0.250	0.334
	PA	0.696	0.635	0.710	0.813
	AP	0.555	0.238	0.510	0.660
	TO	0.483	0.386	0.567	0.770
NORTHEAST	MA	0.717	0.829	0.890	0.932
	PI	0.891	0.951	0.889	0.954
	CE	0.944	0.947	0.943	0.958
	RN	0.839	0.892	0.813	0.857
	PB	0.924	0.912	0.936	0.936
	PE	0.883	0.901	0.929	0.936
	AL	0.700	0.891	0.945	0.891
	SE	0.878	0.790	0.865	0.885
	BA	0.892	0.919	0.900	0.925
SOUTHEAST	MG	0.907	0.919	0.880	0.925
	ES	0.708	0.690	0.762	0.769
	RJ	0.700	0.812	0.852	0.915
	SP	0.636	0.634	0.653	0.813
SOUTH	PR	0.602	0.758	0.895	0.897
	SC	0.796	0.753	0.782	0.809
	RS	0.972	0.964	0.931	0.971
CENTER-WEST	MS	0.396	0.537	0.693	0.785
	MT	0.273	0.244	0.333	0.608
	GO	0.607	0.675	0.680	0.684
	DF	0.027	0.072	0.336	0.479

Source: Authors’ calculations from PNAD 2003/IBGE.

As shown by Bosch, Bozzoli and Quintana-Domeque (2009) failing to account for selective migration may lead to biased estimates. These authors propose an "adjustment method" when dealing with data that only has information on the *current state of residence* of the individual but not on his *state of birth*. Their method allows us to identify the effect of the relevant variable (GDP and/or IMR) in the year of birth on average adult height for those *individuals who were born in the region and stay there*, i.e., for those who do not migrate later on.[4]

Following the adjustment method for selective migration proposed by Bosch, Bozzoli and Quintana-Domeque (2009), we find again that GDP and average height are positively and significantly related for all the demographic groups: white and non-white men, white and non-white women. However, the evidence on the selective effect of IMR, the positive association between IMR and average height, is only found for non-white women (see tables A1-A4 in the online appendix: http://merlin.fae.ua.es/climent/appendix_Brazil.pdf).

5.2. Income inequality and nonlinearities between height, IMR and GDP

Bosch, Bozzoli and Quintana-Domeque (2009) discuss the importance of accounting for the presence of nonlinearities in the relationship between height, IMR and GDP and the role of income inequality in explaining average height. Running several regressions (not reported here), where average height was regressed on several combinations of IMR, IMR^2, GDP, GDP^2, and the interaction of IMR and GDP, we could not find evidence of nonlinearities.

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[4] Using another Brazilian dataset, we are implementing an alternative reweighting procedure: to reweight each individual observation with the "predicted probability" that the individual was born in a region *s* given that he/she is currently living in a region *k*.

We can also look at the association of income inequality with average adult height but at the price of a dramatic reduction in our sample size: from 80 to 40 observations. Interestingly, when we add income inequality (measured by the Theil index) and we follow the adjustment method for selective migration, we obtain similar findings: while GDP and average height are positively associated for all groups, the positive selective effect of IMR on average height is only found for non-white women (see tables A5-A8 in the online appendix: http://merlin.fae.ua.es/climent/appendix_Brazil.pdf/). Moreover, income inequality is negatively and statistically significant associated with average height only for non-white women.

6. Preliminary conclusions

We have examined the role of environmental conditions at birth, namely, infant mortality, GDP and income inequality, in explaining average adult height for cohorts born between 1950 and 1980 in 20 Brazilian states. Our preliminary results suggest that the GDP per capita in the year of birth, and not infant mortality in the year of birth, is the relevant factor in determining average adult stature in Brazil during the period 1950-1980. This finding, which is consistent with previous work using Brazilian data (Monasterio, Nogueról and Shikida, 2005), appears to be robust to selective migration, to the inclusion of income inequality, and to unobserved omitted variables that are constant across Brazilian states or across cohorts. Hence, it seems that in Brazil, during the period 1950-1980, food availability during childhood was more important in determining average adult height than exposure to disease.

Our analysis also shows three new interesting findings: (1) the drop in IMR does not appear to be a relevant factor in explaining the Brazilian increase in average height; (2) IMR could have had a positive impact on average height of non-white women through selection: non-white women who survived in a year of birth with high IMR appear to be taller when they reach adulthood (a finding that may be consistent with those in Deaton, 2007); (3) income inequality in the year of birth appears to be a strong predictor of average adult height for non-white women: income inequality in the year of birth is negatively associated with the average adult height of non-white women.

While in a *developed* country like Spain it seems that disease, not food availability, was the constraining factor of human growth, at least after 1969 (Bosch, Bozzoli and Quintana-Domeque, 2009), in a *developing* country like Brazil, food availability, not disease, appears to have been the constraining factor, at least after 1950.

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