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The Impact of Altitude on Infant Health in South America

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Abstract

Previous Studies have reported that altitude reduces birth weight in South America. However, much remains unknown about the heterogeneities in altitude effects by fetal health endowments and about the effects in various ranges of altitude. This study estimates the effects of altitude on the means and quantiles of birth weight and gestational age separately for two large samples of infants from South America born at altitude ranges of 5-1,280 meters and 1,854-3,600 meters. The study finds significant negative effects of increasing altitude on birth weight and gestational age in the lower altitude range and on birth weight in the higher altitude range. The effects of altitude are overall larger for infants with very low fetal health endowments compared to infants with high endowments. Adding other relevant inputs overall reduces the effects of altitude. The study finds differences in the effects of several inputs between the two-altitude ranges. The study findings are informative for residential policies and infant health policy programs in South America and have implications for future research.

Keywords

Altitude; infant health; birth weight; South America; quantile regression

1.1 Introduction

Several studies have evaluated the role of altitude in infant and child health, with a particular focus on physical growth outcomes, and found negative effects of altitude on birth weight in several populations in the United States (Unger et al, 1988), South America (Hartinger et al, 2006), and other populations (Moore, 2001). Altitude may constrain fetal growth through fetal exposure to hypoxia or low oxygen levels (Grahn and Kratchman, 1963; Ballew and Haas, 1986; Zamudio et al, 2006). Studies have also found larger effects of altitude on birth weight and maternal blood and oxygen flow into the fetus among individuals who do not

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have an ancestry of inhabiting high altitudes relative to individuals with this ancestry, such as European versus Andean ancestry in South America, providing support for the direct biologic effects of altitude (Julian et al, 2007; Bennett et al, 2008; Postigo et al, 2009; Julian et al, 2009).

Altitude may also indirectly affect birth weight through impacting social and economic pathways that affect infant health. Altitude may constrain agricultural production and increase the costs of transportation of fresh food products which may result in maternal nutritional deficiencies (Niermeyer et al, 1995; Cook et al, 2005; Niermeyer, 2008). Altitude may also reduce social and economic growth in certain areas by increasing communication and development costs. However, the effects of altitude on economic growth may vary between populations. For example, several large and developed cities are at high altitudes in South America.[1] Very few studies have evaluated the role of socioeconomic factors in the relationship between altitude and infant health. These studies have found persisting effects of altitude on birth weight after accounting for socioeconomic characteristics (Giussani et al, 2001; Lopez-Camelo et al, 2006).

Birth outcomes are important infant health measures and are major predictors of child development, future health and human capital (Anderson and Doyle 2003; Frankel et al, 1996; Gluckman, 2008; Victora et al, 2008; Currie, 2009). Given that several populations live on high altitudes worldwide, especially in South America, evaluating the impact of altitude on birth outcomes is very important for identifying any potential health risks due to living on higher altitudes and informing public policies and programs to reduce these risks.

Previous studies have generally focused on assessing the effects of very high altitudes, which may apply to a small number of areas and populations, yet studies of the impact of altitude changes within ranges of altitudes at which several large populations reside are less common. For example, very few studies have evaluated the effects of altitude changes below 2,000 meters on infant health. A thorough estimation of the effects of altitude at various altitude levels is also important for identifying potential non-linear effects of altitude on health.

South American populations are particularly suited for studying the impact of altitude on infant health. The wide within and between country variations in altitude in South America and the large percentages of the populations residing at high altitudes increase the power and the generalizability of such studies. Several large cities in South America are at altitudes between 2,500 and 3,600 meters.[2] Further, significant variation in socioeconomic and demographic characteristics exists in South American populations, allowing for evaluating the extent to which these factors explain the effects of altitude on infant health.

1.2 Study's Contribution

The study estimates the effects of altitude on birth weight and gestational age in South America and makes several contributions to understanding the impact of altitude on infant health. The study's multi-country sample is one of the largest and most representative samples for such studies and has extensive variation in residential altitude. This allows for estimating the effects of altitude across several South American populations and wide altitude ranges. Unlike several previous studies that focused on isolated geographic areas

[1]Significant variation may exist in economic development between cities at high altitude. For example, the average economic growth in Bogota (2,640 meters) in Colombia may exceed that in Quito (2850 meters) in Ecuador, which in turn may exceed that in La Paz in Bolivia (3,600 meters).

[2]In addition to the cities in footnote 1, several smaller cities are also located at high altitudes such as Ibarra (2,620 meters) and Azogues (about 2,883 meters) in Ecuador, Cochabamba (2,558 meters) in Bolivia, Cusco (3,300 meters) in Peru and others.

with extreme differences in altitude, we evaluate the marginal effects of altitude between 5 and 1,280 meters and between 1,854 and 3,600 meters. Also, the study accounts for several relevant inputs that may correlate with both birth outcomes and altitude. The majority of previous studies has accounted for a limited number of such factors and may have suffered from omitted variable bias.

The study employs quantile regression for estimating the effects of altitude at multiple locations of the conditional distributions of birth outcomes. Previous studies have estimated the effects of altitude on the means of birth outcomes. Such effects may not be representative of the effects of altitude at other locations of the outcome distributions. Estimating the effects of altitude at multiple quantiles of the outcome distributions evaluates the potential heterogeneity in the effects of altitude by the net level of unobserved fetal health endowments that determine the child's rank on the conditional distributions of birth outcomes (Wehby et al, 2009a).

2. Methods

2.1 Analytical framework

We model infant health as a reduced-form production function of residential altitude and other observed relevant factors for infant health. Specifically, we use the following model:

$$\text{infant health} = f\left(\textit{altitude}, \text{maternal health}, \text{socioeconomics}, \text{demographics}, \text{healthcare characteristics}\right). \tag{1}$$

Altitude may influence infant health indirectly through its impact on some of the factors in equation (1). However, altitude may also correlate with these factors due to potential self-selection into altitude based on human capital and health (such as efficiency in household production of health, preferences for living and work environments, ancestry, and physical ability). In this case, omitting these factors from the model may result in omitted variable bias in estimating the effects of altitude. Therefore, we estimate the effects of altitude accounting for these factors. However, in order to gauge the extent to which such factors explain the effects of altitude, we also estimate a nested specification that excludes these factors from the model. We evaluate equation (1) using a continuous measure of altitude separately for the two altitude ranges observed in the study sample: 5-1,280 meters and 1,854-3,600 meters.

2.2 Study Sample

The study sample includes 63,946 infants born in South America between 1982 and 2008. Of the total sample, 5,803 infants were born in Bolivia, Colombia and Ecuador at altitudes between 1,854 and 3,600 meters, and 58,143 infants were born in Argentina, Brazil, Chile and Colombia at altitudes between 5 and 1,280 meters. The infants were born in 117 healthcare institutions (primarily hospitals) that are affiliated with the Latin American Collaborative Study of Congenital Anomalies (ECLAMC), which is a surveillance program of birth defects in affiliated hospitals (Castilla and Orioli, 2004).

Health professionals, primarily pediatricians, at the healthcare institutions affiliated with ECLAMC identify infants with birth defects and a sample of infants without birth defects who they match to affected infants by date and institution of birth and sex.[3] For each infant with a birth defect, the health professionals identify the first infant born without birth defects

[3]Institutions and health professionals voluntarily join ECLAMC. The health professionals receive standard training and attend yearly retraining and scientific ECLAMC meetings.

at the same institution, on the same date, and of the same sex and enroll that infant into the ECLAMC program before discharge from the healthcare institution after birth.[4] The health professionals obtain data on birth outcomes, prenatal factors, socioeconomic and demographic characteristics, and other variables for all enrolled infants through interviews with the mothers prior to discharge after delivery and through abstraction from the medical records.[5]

We only include infants without birth defects in the study sample as several studies have suggested that altitude impacts the risk of certain birth defects (Poletta et al, 2007; Castilla et al, 1999; Orioli et al, 2003) and several birth defects may reduce birth weight and gestational age (Wehby et al, 2009b, 2009c). The sample includes singleton live births with birth weight between 500 and 6,000 grams and gestational age between 19.5 and 46.5 weeks in order to avoid data collection errors.[6]

The study sample has a wide geographic and socioeconomic diversity and is one of the largest samples for studying infant health production in South America. The matched selection of unaffected infants to the infants with birth defects as described above reduces any potential bias in identifying the unaffected sample based on birth weight or related characteristics.[7] The majority of births in the study countries are born in healthcare institutions.[8]

2.3 Study Measures

We measure infant health by birth weight in grams and gestational age in weeks[9]. Maternal health characteristics include indicators for any acute (such as the flu) and chronic (such as diabetes or hypertension) illnesses during pregnancy. We also include indicators for maternal pregnancy history (numbers of previous live births and stillbirths/miscarriages, difficulty with conception) and exposure to physical shocks during pregnancy.

We measure socioeconomic status with an index of maternal education and occupational status using principal component analysis (PCA) with maximum likelihood estimation of the polychoric correlations between the latent variables of the observed ordinal scales of education and occupational status (Kolenihov and Angeles, 2004).[10] Education and occupational status are both domains of socioeconomic status and may have important effects on health. PCA is a common approach to aggregate multiple indicators of household wealth and socioeconomic status into a single index (Filmer and Pritchett, 2001; Paxson and

[4]About 95% of the potential control subjects enroll in the ECLAMC program (Participation in ECLAMC, personal communication with Eduardo E. Castilla, ECLAMC Coordinator, on December, December 4, 2009). If a potential control subject does not enroll in the study, the health professionals identify the next eligible infant, based on the same matching criteria for potential enrollment into the study.

[5]Health professionals collect data using the same methods across all hospitals and transmit the data to ECLAMC's headquarters in Brazil (Rio de Janeiro) and Argentina (Buenos Aires) for data entry, quality checking, and storage. Several studies of maternal and infant health have used this data source (Wehby et al, 2009a, 2009b, 2009c, 2009d).

[6]Such restrictions are common in birth outcome studies (Warner, 1995, 1998; Conway and Deb, 2005).

[7]Population-level data on birth outcomes are not easily accessible for all the study countries. The rates of LBW in the samples from Argentina and Brazil are overall comparable to those in other studies using other samples from these countries (Goldani et al. 2004a; Kramer et al. 2005). Access to population-level data on other study variables is limited. Some of the available population-level socioeconomic characteristics in Brazil are overall comparable to the ECLAMC sample. For example, about 44% of the population age 0-4 years in 2000 have African ancestry based on self-reported race (IBGE, 2000a). About 41 and 43% of the ECLAMC births in Brazil in 1999 and 2000, respectively, have African ancestry. About 49% of women age 20-39 in 2000 have not completed primary school (IBGE, 2000b). About 45.9% of mothers in the ECLAMC sample in 2000 in Brazil have not completed primary school.

[8]Skilled health professionals attend about 99%, 61%, 97%, 100%, 96%, and 80% of births in Argentina, Bolivia, Brazil, Chile, Colombia and Ecuador, respectively (WHO database: http://www.who.int/whosis/data/Search.jsp). The majority of these are likely to be institutional births. The estimates are for year 2005 for all countries except for Bolivia (2003) and Brazil (2004). To our knowledge, there are no available data on these rates at the community level and on the characteristics of home births in order to compare to the study sample. The study results are generalizable to the population of infants born in healthcare institutions.

[9]Gestational age is the time between the birth date and the date of last menstrual period.

Schady, 2007). In PCA, the first principal component explains the maximum variance in the index variables. We construct the index using the scoring coefficients of the first principal component as weights for the categories of education and occupational status, under the assumption that long-term socioeconomic status explains the maximum variance in education and occupational status. The first principal component explains about 80% and 71.3% of the variance in the lower and higher altitude range samples, respectively.[11]

We include maternal age, infant's sex and ethnic ancestry in the model.[12] We also include characteristics of the healthcare institution of birth that may relate to access and quality of healthcare in the communities of the study infants. These are institutional university affiliation, type (maternity hospital, general hospital, and other facility including multi-clinic facility), and ownership (public including national, provincial, and other public, and private).[13] The model also includes time effects in order to account for any changes in birth outcomes over time as well as country fixed effects in order to account for differences between the study countries in birth outcomes and altitude. Table 1 reports the distribution of the study variables.

2.4 Model Estimation

We estimate the health production function by OLS for "mean effects" and by quantile regression (QR) for "quantile effects". QR estimates the effects of altitude at quantiles of the conditional outcome distributions. The QR model evaluates the heterogeneities in the effects of altitude and the other model inputs by the net level of unobserved fetal health endowments (including biologic, socioeconomic, and environmental factors) that determine the infant's rank on the conditional distributions of birth weight and gestational age. We represent the model as follows (following Chernozhukov and Hansen, 2005):

$$H = \mathrm{Q}\,(A, \mathbf{X}, U)\,,\ \text{where } \mathrm{U}\tilde{}(0,1)\,, \tag{2}$$

where H represents birth weight (or gestational age), A represents altitude and $\mathbf{X}$ includes the other covariates described above. For quantile q (0<q<1), Q(A, $\mathbf{X}$,q) is the conditional qth quantile of H, and U is a uniformly distributed "unobserved" endowment level that determines the infant's location on the conditional distribution of H. QR estimates the effects of A and $\mathbf{X}$ on Q holding U constant at q, and evaluates the heterogeneity in these effects by q (or U):

$$\mathrm{H} = \mathrm{Q}\left(\alpha_{0q} + \beta_q A + \mathbf{X}\lambda_q\right), \tag{3}$$

where β is the effect of altitude and $\boldsymbol{\lambda}$ is a vector of the effects of the other model variables on the qth conditional quantile of H.

[10]The education measure includes the following eight categories (illiterate, literate without formal schooling, incomplete primary school, completed primary school, incomplete secondary school, completed secondary school, incomplete university, and completed university). Occupation status includes the following eight categories (housewife, unemployed, unqualified worker, qualified worker, independent worker, clerk, boss/owner, and professional/executive). The PCA index does not impose the restriction that education has no direct effects on health. It only incorporates its effects as part of the socioeconomic status index.

[11]Table A1 reports the first principal component scoring coefficients in the two samples.

[12]The mother reports the ancestries of the child. Several children have multiple ancestries. We include non-mutually exclusive indicators for each ancestry.

[13]Direct measures of healthcare supply/quality at the community-level are not readily available.

We estimate the QR model for quantiles 0.1, 0.25, 0.5, 0.75 and 0.9 using standard QR (Koenker and Bassett, 1978; Koenker and Hallock, 2001) which minimizes the sum of weighted absolute deviations between the conditioned and actual *H* for each q:

$$\min\left[q\sum_{Hi\geq Qi}^{n}|Hi-Qi|+(1-q)\sum_{Hi<Qi}^{n}|Hi-Qi|\right]. \quad (4)$$

We estimate the variance-covariance matrix for OLS by a Huber-type estimator that accounts for clustering of the sample within the healthcare institutions of birth (Moulton, 1986; Wooldridge et al, 2002). We estimate the variance-covariance matrix of the quantile regression model by bootstrap with 500 replications and test the significance of differences in quantile effects using standard Wald tests (Hao and Naiman, 2007).

3. Results

3.1 “Mean Effects” of Altitude

Tables 2 and 3 report the OLS coefficients in the 5-1,280 and 1,854-3,600 meter ranges, respectively. Altitude has significant negative effects on birth weight and gestational age in the 5-1,280 meter range but has significant negative effects only on birth weight in the higher meter range. The effects of altitude on birth weight are slightly larger (in absolute value) in the lower than the higher altitude range. In the full specification, altitude reduces birth weight by about 9 grams and gestational age by 0.04 weeks per 100 meters in the 5-1,280 meter sample. In the 1,854-3,600 meter range, altitude reduces birth weight by about 7 grams per 100 meters. The model inputs explain up to one third of the unadjusted effects of altitude (nested specification).

3.2 Quantile Effects of Altitude

3.2.a 5-1280 Meter Range—Table 4 reports the marginal effects of altitude on the conditional quantiles of birth weight and gestational age in the 5-1,280 meter range.[14] Altitude has significant negative effects at the five quantiles of birth weight with significantly larger effects at the 0.1 quantile. In the full specification, altitude reduces the 0.1 and 0.9 quantiles by about 10 and 7 grams, respectively, per 100 meters. The model inputs explain more than one third of the unadjusted effects of altitude at lower quantiles.

Altitude has significant negative effects on gestational age quantiles with significantly larger effects at the 0.1 quantile. In the full specification, altitude reduces the 0.1 and 0.9 quantiles by about 0.08 and 0.03 weeks, respectively, per 100 meters. The model inputs explain about one third of the unadjusted effect of altitude at quantile 0.1.

3.2.b 1,854-3,600 Meter Range—Table 5 reports the quantile effects of altitude in the 1,854-3,600 meter range.[15] In the full specification, altitude reduces the 0.1, 0.25 and 0.75 conditional quantiles of birth weight by about 13, 6 and 9 grams, respectively, per 100 meters (effects at the 0.1 and 0.25 quantiles are marginally significant) but has insignificant effects on the other quantiles. Differences in effects between quantiles are insignificant. The model inputs explain more than half of the unadjusted effect of altitude at quantile 0.5. Unlike other quantiles, the negative effect of altitude at the 0.1 quantile is larger in the full

[14]Table A2 in the Appendix reports the full quantile regression coefficients of the birth weight production function for the 5-1,280 meter range. The full results for the gestational age function are available from the authors upon request.

[15]Table A3 in the Appendix reports the full quantile regression coefficients of the birth weight production function for the 1,854-3,600 meter range. The full results for the gestational age function are available from the authors upon request.

than the nested specification. Altitude has overall insignificant effects on gestational age quantiles.

3.3 Effects of Other Inputs on Birth Weight

We focus on comparing the effects of the other inputs on birth weight between the two altitude ranges. Maternal acute illnesses have small negative effects on birth weight mean in both altitude ranges, but have significant effects at lower quantiles in the 5-1,280 meter range and insignificant quantile effects in the higher altitude range. Chronic illnesses have significant negative effects on birth weight only in the 5-1,280 meter range with larger effects at lower quantiles. Difficulty in conception has larger negative effects in the higher altitude range especially at lower quantiles. The number of previous live births has larger positive effects at the mean in the lower altitude range, and has insignificant effects at lower quantiles in the 1854-3600 meter range. The number of miscarriages/stillbirths has negative effects on birth weight only in the 5-1,280 meter range with decreasing effects by the quantile order.

Socioeconomic status has a similar small positive effect on birth weight mean but opposite patterns of quantile effects in the two altitude ranges – effects decrease (increase) in the lower (higher) altitude range by the quantile order. Maternal age has overall similar significant diminishing marginal positive effects (with age) and decreasing effects by the quantile order in both altitude ranges. Male children have higher birth weight than females with increasing differences by the quantile order in both altitude ranges. Child's African ancestry has a significant negative effect only in the 5-1,280 meter range with decreasing effects by the quantile order. Native ancestry has small positive effects in the 5-1,280 meter range but negative effects in the higher altitude range at the mean and lower quantiles.

The effects of some healthcare institution characteristics also vary between the two altitude samples. Non-teaching status has larger positive effects at high quantiles in the 1,854-3,600 meter range than the lower range. In the 5-1,280 meter range, infants born in maternity hospitals and in “other institutions” have larger and lower birth weight, respectively, than those in general hospitals, but there are no such differences in the higher altitude range. There are also some differences in the effects of institution ownership between the two altitude ranges.

4. Discussion

The study identifies negative effects of altitude increases on birth weight in South America in both low (5-1,280 meters) and high (1,854-3,600 meters) altitude ranges. The study finds a decrease in birth weight mean of about 270-280 grams with moving from sea-level (5 meters) up to 3,600 meters.[16] Larger decreases may occur at lower birth weight quantiles of about 400-420 grams in the 0.1 quantile. Altitude may have larger negative effects among infants with poor fetal health endowments (i.e. those at the left margins of the birth outcome distributions) and may increase infant health disparities by widening the ranges between low and high quantiles of birth weight (and gestational age in the lower altitude range).

The results suggest that altitude affects both gestational age and fetal growth in lower altitude ranges, but that it primarily affects fetal growth at higher altitude ranges. The offsetting in the negative effects of altitude on gestational age at higher altitude ranges may be due to compensatory effects such as potential reductions in environmental pollution. Gragnolati and Marini (2006) have found lower negative effects of very high (≥ 3500

[16]We estimate this effect using the marginal effects of altitude in the two altitude ranges from the full specification and assuming the marginal effects of altitude between 1,280 and 1,854 meters to be alternatively equal to those in the lower or upper altitude ranges.

meters) compared to high altitude (2500-<3500 meters) on the child's height in Peru, suggesting similar compensatory effects with altitude. We need further work to identify such compensatory effects.

The study estimates are overall comparable to previous studies which report effects on birth weight mean. However, the estimates from the full specification are somewhat lower than previous study estimates. This may be due to accounting in this study for several relevant inputs for birth outcomes. Those studies have reported decreases of about 102-130 gram in birth weight mean with 1,000-meter increases above 1,000 or 2,000 meters in Colorado (Jensen and Moore, 1997) and Peru (Mortola et al, 2000). The estimates of altitude effects in the unadjusted models of our study are comparable to those estimates.

Maternal health, socioeconomic, demographic and healthcare characteristics likely explain a significant part of the negative effects of altitude on birth outcomes. Given that self-selection into residing on higher altitude may contribute to the relation between altitude and these factors, excluding such factors may result in a biased estimation of the effects of altitude on infant health. The results suggest overall adverse self-selection into higher altitude, with a higher propensity to reside on higher altitudes with lower health and socioeconomic endowments, which may result in overestimation of the negative effects of altitude.[17]

The study suggests offsets or increases in the effects of certain inputs with altitude. Examples include the reduction in the negative effects of chronic illnesses and previous miscarriages/stillbirths and the increase in the negative effects of difficulty in conception the higher altitude range. Mean-effect analysis may mask these interactions when the effects of these inputs vary by unobserved fetal health endowments, such as the offsetting of positive effects of socioeconomic status for infants with poor endowments in the higher altitude range and for infants with high endowments in the lower altitude range. This may be due to a more constrained supply of market-based factors for infant health production such as quality healthcare in the higher altitude sample, and consequently, a larger role for socioeconomic status in household versus market production of infant health.[18] The impact of number of live births on widening the gap in birth weight between infants with poor and high fetal health endowments in the higher altitude range may be due to a higher maternal time component in childcare costs at higher altitudes, where having more children may reduce maternal time allocations to fetal health production and offset the benefits of the pregnancy information capital for pregnancies with low endowments. Further work is important for evaluating how the effects of relevant inputs may vary with altitude.

The study has implications for public policies aiming at enhancing infant health and for residential policies that may have consequential effects on infant health. To our knowledge, no previous studies have documented the observed negative effects of altitude increases in low altitude ranges (5-1,280 meters in this study) in part due to using arbitrarily categorized measures of altitude with lower altitudes as a reference category and due to limited altitude variations in those studies. The study highlights the importance of considering the adverse

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[17]The direction of the bias may depend on the net level of the unobserved endowments that impact infant health. The increase in the negative effects of altitude at the 0.1 conditional quantile of birth weight in the higher altitude range when adding the other model inputs suggests a positive bias for children with very low fetal health endowments in this sample. This suggests factors that are positively (negatively) correlated with altitude and have positive (negative) effects on the 0.1 quantile of birth weight.

[18]The effectiveness of socioeconomic status in household production of infant health may be higher for pregnancies with high fetal health endowments (i.e. for pregnancies that are less impacted by substituting away from market production of fetal/infant health). On the other side, socioeconomic status in the lower altitude sample may increase maternal efficiency in market production of infant health such as through prenatal care, which has larger returns for infants with poorer fetal health endowments. These results suggest complementarity and substitution effects between socioeconomic status and net “unobserved” fetal health endowment levels in the higher and lower altitude ranges, respectively.

effects of altitude increases on infant health in both high and lower altitude ranges when evaluating the costs and returns of residential policies that increase residence on higher altitudes (such as tax-credit programs to inhabit less populated areas at higher altitudes).

The study highlights the importance of designing interventions that have large effects for infants with low fetal health endowments in order to reduce altitude-related gaps in birth weight between infants born at low and high birth weight quantiles. The study results also suggest that policies may have different effects in different altitude ranges. Focusing on maternal education or employment programs alone may increase birth weight disparities in populations represented in the higher altitude sample due to potentially larger returns for infants with high endowments, but may have opposite effects in populations represented in the lower altitude sample.

The study suggests several questions for future research. These include identifying the role of healthcare provider distribution and quality of care in contributing to the effects of altitude on infant health and the impacts of human capital, household production of health, as well as area-level economic characteristics (economic growth, labor market conditions, and schooling systems) on the relationship between altitude and infant health. Finally, evaluating the effects of altitude on postnatal, child and adult health outcomes is essential for evaluating the long term effects of altitude and identifying needs for and ways of intervening to reduce negative effects.

In conclusion, the study finds negative effects of altitude on birth weight and gestational age in low altitude ranges and on birth weight in high altitude ranges. The effects are overall larger for infants with low fetal health endowments. Excluding relevant maternal health, socioeconomic, demographic, and healthcare characteristics may result overall in overestimation of the negative effects of altitude. The study suggests offsets and increases in the effects of certain inputs between the two altitude ranges and highlights several implications for public policy and future research.

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Appendix

Table A1

Principal Component Analysis Scoring Coefficients of the Socioeconomic Status Index

Socioeconomic status components	5-1280 meter range	1854-3600 meter range
Maternal education		
None - illiterate	−0.36	−0.51
None - literate	0.38	0.14
Primary - incomplete	0.52	0.29
Primary - complete	0.69	0.42
Secondary - incomplete	0.78	0.48
Secondary - complete	1.03	0.76
University - incomplete	1.38	1.14
University - complete	1.68	1.45
Maternal employment/occupational level		
Housework	−1.86	−1.79
Unemployed	−1.56	−1.48
Unqualified worker (blue collar)	−0.84	−1.03
Qualified worker (blue collar)	−0.26	−0.54
Independent worker	0.16	−0.11
Clerk (white collar)	0.66	0.34
Boss, chief, owner	1.15	0.74
Professional, executive	1.55	1.24

Note: This table includes the scoring coefficients of the first principal component that we use to construct the socioeconomic status index.

Table A2

Quantile Regression Coefficients of the Birth Weight Production Function – 5-1,280 Meter Range

	Quantiles									
	0.1	**0.1**	**0.25**	**0.25**	**0.5**	**0.5**	**0.75**	**0.75**	**0.9**	**0.9**
Altitude	−16.6^{***c} (1.85)	−9.60^{***b} (2.02)	−10.1^{***c} (1.10)	−5.91^{***b} (1.22)	−9.45^{***c} (0.84)	−7.49^{***b} (1.05)	−9.47^{***c} (0.99)	−8.58^{***b} (1.17)	−8.33^{***c} (1.21)	−7.39^{***b} (1.53)
Acute illnesses		−75.0^{***c} (11.8)		−30.3^{***c} (6.58)		−4.35^{c} (5.60)		−4.8^{c} (6.11)		−0.71^{c} (8.10)
Chronic illnesses		−125.3^{***c} (17.3)		−67.1^{***c} (10.0)		−43.9^{***c} (8.00)		−20.2^{**c} (8.34)		4.04^{c} (10.1)
Conception difficulty		−47.7** (21.4)		−24.7** (11.8)		−11.1 (9.55)		−7.63 (10.7)		−1.06 (13.2)
Live births		17.1^{***b} (2.86)		11.0^{***b} (2.11)		12.1^{***b} (1.72)		15.4^{***b} (1.74)		17.2^{***b} (2.36)
Miscarriages/ stillbirths		−48.9^{***c} (9.97)		−14.3^{***c} (5.12)		−8.82^{**c} (3.78)		−7.14^{*c} (4.21)		4.8^{c} (5.34)
Physical shocks		−21.4 (41.9)		3.39 (18.0)		−25.4 (17.8)		−17.7 (15.6)		−14.2 (22.3)
SES		25.0^{***c} (5.38)		14.9^{***c} (3.36)		11.9^{***c} (2.88)		8.23^{***c} (2.89)		0.93^{c} (3.79)
Maternal age		52.2*** (6.07)		42.8*** (3.61)		37.4*** (3.09)		37.5*** (3.30)		41.0*** (4.00)
Maternal age squared		−0.93^{***b} (0.11)		−0.72^{***b} (0.067)		−0.58^{***b} (0.056)		−0.56^{***b} (0.060)		−0.6^{***b} (0.072)
Male		65.0^{***c} (9.70)		94.7^{***c} (5.82)		111.4^{***c} (4.94)		123.8^{***c} (5.54)		140.1^{***c} (7.24)
African ancestry		−102.9^{***c} (19.3)		−75.3^{***c} (11.6)		−55.8^{***c} (9.31)		−45.6^{***c} (9.75)		−29.1^{**c} (12.1)
Native ancestry		21.2 (15.6)		17.1* (9.18)		15.2** (7.40)		6.36 (7.59)		9.49 (11.1)
European Latin ancestry		13.3 (11.5)		10.9 (6.70)		19.0*** (5.25)		8.14 (6.38)		−0.37 (7.77)
European non-Latin ancestry		14.9 (18.4)		20.7** (10.2)		29.8*** (8.98)		12.1 (9.15)		21.9* (12.5)
Other ancestry		90.0^{**c} (37.3)		−22.7^{c} (29.9)		−76.2^{**c} (32.0)		−28.4^{c} (23.8)		−46.8^{c} (41.4)
No university affiliation		26.2** (12.1)		18.1*** (6.96)		14.0** (5.94)		14.8** (6.58)		14.0 (8.52)

	Quantiles									
	0.1	0.1	0.25	0.25	0.5	0.5	0.75	0.75	0.9	0.9
Maternity hospital		50.5*** (14.5)		47.0*** (8.37)		36.0*** (7.23)		27.2*** (7.50)		26.8** (10.9)
Other institution		−71.5* b (37.5)		−94.7*** b (28.3)		−68.9** b (30.3)		3.53 b (28.8)		16.9 b (27.6)
Private institution		−4.51 (28.6)		−32.6* (18.7)		−47.2** (18.6)		−46.8*** (17.5)		−19.6 (24.3)
State/ Province institution		−125.4*** (22.1)		−71.1*** (12.5)		−28.3** (12.1)		−4.79 (12.4)		−3.85 (17.1)
Local public institution		−93.1***a (21.5)		−60.3*** a (11.7)		−36.6*** a (11.3)		−30.7** a (12.3)		−34.1** a (15.2)
Brazil	−149.5*** (13.2)	−130.2*** (16.8)	−110.0*** (7.70)	−96.3*** (10.5)	−81.0*** (6.39)	−66.0*** (9.35)	−80.0*** (7.39)	−54.7*** (9.39)	−79.5*** (8.97)	−46.9*** (12.9)
Chile	198.8*** (13.9)	72.7*** (25.8)	150.1*** (7.73)	78.3*** (14.6)	143.4*** (7.39)	106.0*** (14.6)	124.6*** (8.30)	117.9*** (14.9)	116.5*** (10.5)	114.7*** (19.0)
Colombia	−184.9*** (43.4)	−241.5*** (45.5)	−203.9*** (40.6)	−193.6*** (30.8)	−121.1*** (21.3)	−98.4*** (25.5)	−145.0*** (27.2)	−99.4*** (24.3)	−137.3*** (29.5)	−91.3** (37.2)
Birth year 1983	30.0 (43.4)	8.70 (48.3)	−50.0* (27.9)	−53.9* (30.7)	−27.8 (25.8)	−41.0* (24.0)	−48.7* (27.1)	−29.9 (27.5)	−8.17 (33.1)	0.081 (40.2)
Birth year 1984	30.0 (47.1)	37.2 (45.5)	−40.5 (28.9)	−36.7 (26.6)	−30.9 (26.4)	−49.2* (27.7)	−37.0 (26.2)	−18.7 (27.6)	−20.0 (36.9)	−23.9 (44.1)
Birth year 1985	−20.0 (50.8)	−7.69 (55.3)	−30.6 (25.4)	−51.6* (29.0)	−50.0** (22.8)	−58.4** (25.4)	−80.0*** (27.6)	−54.5** (26.9)	−46.9 (36.7)	−35.8 (41.3)
Birth year 1986	33.4 (47.4)	23.3 (44.3)	−20.5 (28.1)	−34.2 (28.2)	−24.5 (24.0)	−32.0 (27.3)	−18.2 (29.0)	−17.6 (30.7)	10.00 (34.6)	16.9 (39.5)
Birth year 1987	10.0 (51.8)	−2.30 (57.8)	−40.5 (28.5)	−36.7 (29.2)	−50.6** (24.7)	−72.8*** (27.4)	−78.7*** (29.9)	−47.9 (34.4)	−70.0* (36.8)	−36.8 (41.6)
Birth year 1988	−60.0 (65.1)	−70.2 (53.3)	−60.5** (29.0)	−74.7** (34.5)	−27.8 (29.6)	−45.9* (26.5)	−48.2** (22.7)	−30.1 (31.1)	−10.0 (35.6)	−1.72 (45.4)
Birth year 1989	−82.8* (45.4)	−63.8 (52.1)	−50.6 (32.3)	−80.8** (32.5)	−37.8 (26.0)	−53.6** (24.0)	−48.7 (33.8)	−74.8*** (28.6)	−60.0* (35.7)	−47.9 (39.7)
Birth year 1990	−10.00 (44.3)	−16.6 (46.3)	−17.1 (26.6)	−33.1 (27.9)	−20.9 (26.5)	−44.7 (27.9)	−40.0 (24.6)	−37.8 (27.6)	−40.0 (34.5)	−34.0 (37.5)
Birth year 1991	60.0 (38.2)	48.3 (38.4)	−17.1 (26.2)	−32.6 (27.5)	−0.57 (23.5)	−18.4 (23.2)	−48.7** (22.6)	−25.8 (23.8)	20.0 (37.3)	53.5 (44.0)
Birth year 1992	30.0 (40.9)	−5.67 (45.0)	−17.0 (23.6)	−27.6 (27.9)	−0.000025 (19.8)	−17.1 (20.6)	−1.78 (22.6)	−1.56 (24.6)	13.1 (29.6)	13.9 (34.0)
Birth year 1993	10.0 (45.7)	10.2 (43.8)	−12.0 (21.3)	−16.4 (28.3)	1.05 (22.6)	−6.92 (24.1)	−16.9 (24.6)	5.20 (23.2)	50.0 (33.8)	52.4 (36.2)

	Quantiles									
	0.1	**0.1**	**0.25**	**0.25**	**0.5**	**0.5**	**0.75**	**0.75**	**0.9**	**0.9**
Birth year 1994	0.000027 (43.1)	−7.48 (45.3)	−0.61 (19.9)	4.36 (26.3)	−0.57 (19.8)	−4.76 (20.8)	−10.00 (23.3)	23.8 (25.5)	30.0 (33.8)	64.3 (40.5)
Birth year 1995	23.4 (38.1)	46.8 (41.0)	−5.24 (24.2)	−13.0 (26.0)	−10.9 (23.3)	−21.2 (21.0)	−22.8 (23.9)	−2.43 (24.6)	13.8 (35.5)	36.5 (35.1)
Birth year 1996	−4.50 (39.3)	20.9 (40.3)	−50.0** (23.8)	−30.4 (26.4)	−24.5 (23.2)	−28.6 (20.9)	−38.2 (26.0)	−22.6 (23.8)	30.5 (30.2)	45.3 (35.0)
Birth year 1997	23.4 (41.7)	44.9 (42.6)	−5.00 (24.1)	11.8 (29.3)	−0.57 (22.2)	−2.32 (22.3)	−12.6 (24.1)	8.91 (23.8)	−5.25 (29.6)	25.5 (37.4)
Birth year 1998	17.5 (40.9)	22.8 (41.4)	−11.0 (22.5)	−3.73 (26.9)	−14.5 (20.8)	−14.7 (20.5)	−46.4** (20.7)	−6.64 (23.6)	−13.2 (31.4)	15.9 (34.4)
Birth year 1999	30.0 (37.9)	58.4 (40.5)	−0.61 (18.7)	9.51 (25.7)	−0.57 (19.8)	−0.068 (20.0)	−12.6 (22.0)	14.7 (23.7)	10.00 (27.2)	35.2 (34.8)
Birth year 2000	22.0 (37.9)	45.7 (38.7)	−0.61 (21.0)	14.6 (25.1)	2.27 (19.8)	5.53 (20.4)	−16.9 (20.9)	4.51 (22.1)	1.08 (27.9)	31.6 (33.1)
Birth year 2001	50.0 (33.0)	76.8** (36.6)	−0.10 (21.3)	22.1 (24.5)	6.02 (19.0)	8.34 (20.2)	−8.73 (20.3)	12.6 (22.2)	9.33 (26.3)	30.5 (34.2)
Birth year 2002	79.5** (34.4)	92.7** (37.2)	−0.61 (19.0)	11.5 (24.2)	−8.95 (19.0)	−8.42 (19.3)	−47.0** (19.6)	−5.48 (22.4)	−40.0 (28.0)	−4.01 (34.3)
Birth year 2003	20.0 (35.3)	37.1 (38.4)	−0.61 (18.7)	10.5 (25.0)	0.48 (18.3)	2.03 (19.6)	−38.7** (19.4)	−14.5 (22.9)	−30.7 (26.0)	14.4 (34.0)
Birth year 2004	23.4 (35.1)	67.2* (37.8)	−20.6 (20.2)	−4.15 (25.1)	−8.37 (19.8)	−0.66 (20.2)	−32.6* (19.7)	−6.51 (22.2)	−20.1 (27.5)	11.5 (34.5)
Birth year 2005	−40.5 (35.1)	−24.5 (40.6)	−60.1*** (21.4)	−33.4 (26.1)	−19.7 (19.8)	−17.7 (20.8)	−32.6* (19.7)	−6.30 (23.6)	−16.3 (27.1)	24.1 (32.8)
Birth year 2006	9.75 (37.9)	46.1 (41.7)	−20.6 (22.1)	−10.7 (25.9)	−8.37 (21.6)	4.92 (21.7)	−27.0 (21.1)	20.1 (24.3)	−20.0 (30.6)	31.5 (34.7)
Birth year 2007	−30.2 (43.3)	−10.6 (48.3)	−20.6 (23.9)	−0.40 (27.8)	−14.5 (20.3)	−15.8 (21.5)	−58.7*** (22.4)	−21.7 (23.4)	−35.5 (32.7)	0.79 (37.0)
Birth year 2008	−40.5 (43.3)	−7.96 (44.2)	−50.6* (28.0)	−31.8 (28.4)	−8.37 (24.1)	−0.13 (26.2)	−48.2* (25.3)	17.9 (24.4)	29.5 (34.9)	75.7* (39.7)
Constant	2640.8*** (30.4)	1985.5*** (92.4)	3001.1*** (17.5)	2382.1*** (55.8)	3301.0*** (17.1)	2683.9*** (46.1)	3649.2*** (18.0)	2954.3*** (50.7)	3920.4*** (24.7)	3129.1*** (63.2)

Standard errors in parentheses;

* p<0.1,

** p<0.05,

*** p<0.01;

[a] indicate that the effects are different between the quantiles at p<0.1

[b] indicate that the effects are different between the quantiles at $p<0.05$

[c] indicate that the effects are different between the quantiles at $p<0.01$, respectively.

Table A3

Quantile Regression Coefficients of the Birth Weight Production Function – 1,854-3,600 Meter Range

	Quantiles									
	0.1	0.1	0.25	0.25	0.5	0.5	0.75	0.75	0.9	0.9
Altitude	−7.45*** (2.33)	−12.9* (7.23)	−9.74*** (1.75)	−6.37* (3.87)	−12.5*** (1.92)	−5.57 (3.67)	−11.9*** (2.00)	−9.27** (4.05)	−13.9*** (2.65)	−7.50 (5.09)
Acute illnesses		−48.4 (30.3)		−29.6 (18.2)		−30.6* (16.8)		−18.5 (20.8)		17.2 (24.4)
Chronic illnesses		−4.59 (65.6)		44.5 (48.4)		−25.5 (27.6)		−58.0 (40.6)		−27.3 (50.4)
Conception difficulty		−240.9** (93.6)		−124.2** (63.1)		−112.3*** (42.5)		−53.1 (55.6)		−110.6** (46.3)
Live births		−6.03[a] (8.41)		3.67 [a] (5.87)		10.4** [a] (5.26)		18.4*** [a] (5.25)		22.8*** [a] (7.04)
Miscarriages/ stillbirths		−3.96 (26.9)		8.39 (14.0)		3.22 (9.95)		17.4 (15.2)		7.10 (17.6)
Physical shocks		−78.9 (88.1)		−3.27 (60.1)		−16.0 (37.6)		−11.9 (66.0)		−31.7 (65.0)
SES		10.8 (15.2)		10.2 (9.70)		12.6 (9.00)		23.5** (11.6)		24.1* (12.8)
Maternal age		48.6*** (16.5)		41.8*** (10.9)		37.0*** (9.36)		34.4*** (9.90)		28.2** (12.4)
Maternal age squared		−0.87*** (0.30)		−0.67*** (0.21)		−0.56*** (0.17)		−0.48*** (0.18)		−0.34 (0.22)
Male		52.3** [b] (23.9)		66.9*** [b] (14.7)		93.2*** [b] (14.6)		110.6*** [b] (17.2)		145.9*** [b] (19.9)
African ancestry		59.8 (61.6)		−24.1 (66.2)		−36.7 (54.0)		−40.9 (58.9)		−53.7 (103.4)
Native ancestry		−82.5* (48.4)		−83.4*** (31.7)		−29.8 (32.0)		−46.3 (37.2)		−57.7 (46.1)
European Latin ancestry		−26.1 (31.9)		−22.9 (22.5)		2.99 (20.2)		1.55 (22.3)		−9.05 (27.2)
European non-Latin ancestry		−35.0 (232.7)		37.5 (84.2)		−38.0 (77.1)		−15.6 (94.1)		−130.9 (128.3)
Other ancestry		−26.7 (173.2)		−92.3 (160.5)		−155.1 (134.7)		−209.8 (178.3)		−245.9 (281.0)
No university affiliation		35.2 (91.2)		7.77 (48.3)		30.9 (45.4)		107.4** (52.1)		119.3* (66.6)

	Quantiles									
	0.1	**0.1**	**0.25**	**0.25**	**0.5**	**0.5**	**0.75**	**0.75**	**0.9**	**0.9**
Maternity hospital		−81.7 (56.9)		−22.4 (37.9)		2.53 (35.1)		−0.97 (35.4)		−10.1 (49.9)
Other institution		−9.02 (65.6)		13.6 (44.0)		40.7 (28.1)		−33.4 (44.4)		−41.2 (51.0)
Private institution		−58.5 (48.2)		−55.8* (33.4)		−75.5*** (28.3)		−125.6*** (35.8)		−107.2** (47.6)
State/Province institution		−119.6** (55.2)		−41.1 (35.3)		10.1 (35.5)		−13.5 (37.5)		24.5 (47.0)
Local public institution		−127.7 (120.2)		66.3 (63.9)		108.8* (57.9)		49.3 (66.7)		131.2* (78.2)
Colombia	−224.5*** (32.1)	−276.1*** (89.2)	−191.2*** (25.8)	−155.7*** (42.6)	−213.0*** (26.7)	−147.2*** (40.3)	−197.0*** (29.6)	−116.5** (50.2)	−208.9*** (36.0)	−126.2** (52.2)
Ecuador	−113.0*** (29.6)	−177.6** (72.7)	−116.3*** (24.2)	−104.7*** (39.8)	−190.6*** (25.8)	−141.5*** (37.9)	−219.3*** (25.5)	−164.6*** (42.9)	−251.9*** (32.6)	−185.8*** (52.8)
Birth year 1983	280.0 (210.7)	261.0 (191.4)	131.0 (90.0)	46.7 (103.4)	51.8 (92.5)	71.0 (84.4)	−20.0 (134.4)	54.5 (109.2)	−80.0 (133.5)	−112.2 (121.3)
Birth year 1984	30.0 (206.7)	73.0 (176.9)	−10.00 (92.8)	−44.0 (101.5)	10.00 (83.9)	20.7 (82.3)	92.0 (143.3)	96.9 (120.3)	−0.0000001 (129.3)	41.8 (121.4)
Birth year 1985	100.0 (193.5)	114.5 (164.3)	83.8 (68.7)	−17.9 (76.1)	61.8 (93.3)	30.5 (80.8)	22.0 (117.6)	27.7 (113.6)	30.0 (151.4)	−20.5 (117.8)
Birth year 1986	170.0 (163.8)	88.7 (141.7)	30.0 (81.9)	−28.4 (87.2)	50.0 (82.0)	69.0 (75.4)	100.0 (129.8)	99.4 (126.6)	−10.0 (131.1)	17.7 (110.3)
Birth year 1987	230.0 (160.6)	204.3 (148.3)	83.8 (90.9)	36.7 (87.0)	141.8* (74.6)	126.0* (71.6)	2.00 (109.0)	59.5 (108.5)	−40.0 (127.2)	−51.2 (107.8)
Birth year 1988	80.0 (166.4)	60.7 (143.4)	−50.0 (73.2)	−75.9 (87.3)	−18.2 (84.5)	5.59 (72.1)	−178.0* (103.5)	−71.2 (100.2)	−170.0 (176.1)	−33.2 (130.7)
Birth year 1989	−30.0 (207.9)	−51.9 (175.0)	−90.0 (96.6)	−95.7 (103.9)	−18.2 (79.7)	15.7 (76.9)	−158.0 (112.7)	−62.4 (127.6)	−150.0 (135.3)	−138.2 (112.2)
Birth year 1990	80.0 (267.3)	29.1 (238.4)	40.0 (80.3)	−5.46 (83.2)	11.8 (76.9)	35.1 (71.3)	−98.0 (114.0)	2.44 (110.3)	−70.0 (131.1)	−75.3 (127.1)
Birth year 1991	80.0 (253.5)	12.4 (239.8)	90.0 (89.7)	41.3 (95.7)	21.8 (92.7)	18.8 (90.1)	−8.00 (149.0)	25.6 (111.1)	−100.0 (119.9)	−43.1 (118.8)
Birth year 1992	170.0 (267.8)	167.5 (244.7)	0.0000009 (112.4)	17.3 (105.6)	−8.19 (87.4)	16.8 (77.0)	−78.0 (120.4)	−51.7 (125.5)	−100.0 (154.1)	−54.8 (148.3)
Birth year 1993	90.0 (175.5)	62.7 (149.8)	−60.0 (128.2)	−74.4 (128.4)	−38.2 (116.3)	29.2 (118.0)	−228.0* (135.8)	−85.2 (126.5)	−220.0 (176.9)	−49.8 (158.8)
Birth year 1994	−70.0 (459.8)	−114.2 (460.6)	−210.0 (136.0)	−269.8 (166.0)	−128.2 (157.4)	0.35 (137.9)	−178.0 (147.4)	−59.1 (132.7)	30.0 (260.1)	115.8 (218.4)

	Quantiles									
	0.1	0.1	0.25	0.25	0.5	0.5	0.75	0.75	0.9	0.9
Birth year 1995	−70.0 (194.9)	−84.6 (186.7)	−80.0 (86.8)	−130.7 (98.9)	−118.2 (102.9)	−91.5 (94.5)	−88.0 (120.1)	−22.9 (122.1)	−220.0 (151.5)	−122.7 (152.1)
Birth year 1996	−40.0 (223.8)	−23.8 (200.2)	−10.0 (80.3)	−13.1 (88.7)	−38.2 (78.5)	19.5 (80.9)	−78.0 (104.2)	24.5 (105.6)	−112.5 (142.2)	−27.9 (125.8)
Birth year 1997	−190.0 (202.1)	−138.0 (190.7)	−60.0 (116.6)	−65.9 (124.1)	−6.19 (83.0)	56.5 (75.9)	−108.0 (125.6)	−15.6 (116.4)	−160.0 (151.9)	−76.7 (114.3)
Birth year 1998	50.0 (211.3)	−31.5 (188.1)	50.0 (126.4)	52.4 (113.5)	41.8 (70.8)	106.9 (75.7)	−78.0 (112.2)	21.4 (109.7)	−170.0 (145.5)	−55.6 (120.2)
Birth year 1999	90.0 (191.8)	70.1 (164.3)	30.0 (94.0)	48.2 (91.2)	−6.19 (77.4)	64.5 (72.9)	−28.0 (125.0)	40.7 (136.4)	20.0 (165.9)	96.1 (124.9)
Birth year 2000	100.0 (203.4)	45.5 (177.9)	20.0 (77.1)	−85.0 (78.5)	−8.19 (84.8)	11.7 (84.4)	−85.9 (118.9)	5.95 (129.4)	−12.5 (135.4)	13.2 (110.6)
Birth year 2001	60.0 (163.8)	51.6 (147.6)	33.3 (66.3)	−26.2 (74.8)	28.8 (67.4)	115.9* (69.6)	−38.0 (92.3)	56.8 (93.8)	−78.2 (120.5)	−60.3 (105.3)
Birth year 2002	80.0 (154.7)	77.7 (134.3)	33.3 (72.8)	−19.9 (74.3)	41.8 (63.7)	108.7* (65.5)	−29.0 (92.3)	71.6 (94.6)	−42.2 (119.8)	−29.3 (99.6)
Birth year 2003	220.0 (153.6)	182.7 (137.0)	53.8 (64.9)	28.1 (70.6)	80.1 (65.4)	129.7** (63.9)	−25.4 (90.1)	55.0 (92.1)	−12.5 (117.3)	−14.7 (101.7)
Birth year 2004	150.0 (152.4)	129.8 (135.7)	57.2 (65.5)	16.3 (71.3)	76.8 (66.4)	135.0** (63.9)	0.000013 (88.0)	71.0 (93.1)	−24.2 (117.3)	6.95 (97.0)
Birth year 2005	180.0 (153.0)	105.9 (136.7)	40.9 (62.3)	3.39 (72.8)	93.8 (63.0)	132.5** (63.6)	−25.4 (88.9)	38.2 (93.0)	−20.0 (117.5)	−33.9 (96.4)
Birth year 2006	130.0 (157.1)	83.2 (136.0)	40.0 (64.4)	24.2 (69.2)	73.8 (65.6)	111.6* (62.7)	−78.0 (88.3)	23.3 (94.9)	−112.2 (118.6)	−69.9 (98.6)
Birth year 2007	80.0 (158.8)	38.1 (142.4)	20.0 (65.8)	−14.1 (73.1)	12.9 (63.2)	102.9 (66.2)	−98.0 (89.8)	−27.9 (93.9)	−112.5 (117.0)	−59.0 (104.8)
Birth year 2008	90.0 (163.3)	39.2 (145.9)	20.0 (67.2)	−41.5 (78.9)	13.8 (70.8)	111.8* (67.3)	−73.6 (88.3)	36.6 (99.9)	−92.5 (116.7)	−55.1 (102.0)
Constant	2738.0*** (177.8)	2478.8*** (394.4)	3160.5*** (83.5)	2559.7*** (214.1)	3537.7*** (89.8)	2680.7*** (202.1)	3906.6*** (112.4)	3161.2*** (226.7)	4270.0*** (144.0)	3474.6*** (278.4)

Standard errors in parentheses;

* $p < 0.1$,

** $p < 0.05$,

*** $p < 0.01$;

[a] indicate that the effects within each model (adjusted and unadjusted) are different between the quantiles at p<0.1

[b] indicate that the effects within each model (adjusted and unadjusted) are different between the quantiles at p <0.05, respectively.

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Instituto Brazileiro de Geografia e Estatistica I (IBGE). Tabela 3 - Mulheres de 15 anos ou mais de idade, responsáveis pelos domicílios, total e sua respectiva distribuição percentual and Tabela 17 - Proporção de pessoas de 10 anos ou mais de idade, responsáveis pelos domicílios, por classes de anos de estudo, segundo o sexo e os grupos de idade - 1991/2000. 2000b. http://www.ibge.gov.br/english/estatistica/populacao/perfildamulher/default.shtm

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Table 1

Description of Study Variables

Variable	Description	Mean (SD)	
		5-1,280 meter altitude sample	**1,854-3,600 meter altitude sample**
Birth weight	Infant's birth weight in grams	3235.09 (568.84)	3096.01 (489.08)
Gestational age	Infant's gestational age in weeks	39.06 (2.78)	39.04 (2.6)
Altitude	Altitude at hospital of birth (in 100 meter unites)	3.34 (3.11)	28.49 (5.71)
Acute illnesses	Indicator (0,1) for maternal acute illnesses	0.32 (0.47)	0.30 (0.46)
Chronic illnesses	Indicator (0,1) for maternal chronic illnesses	0.12 (0.33)	0.05 (0.21)
Conception difficulty	Indicator (0,1) for difficulty in conception	0.08 (0.27)	0.03 (0.17)
Live births	Number of live births	1.50 (2.00)	1.28 (1.92)
Miscarriages/stillbirths	Number of miscarriages/stillbirths	0.25 (0.72)	0.19 (0.66)
Physical shocks	Indicator (0,1) for exposure to physical shocks in first trimester	0.03 (0.16)	0.02 (0.14)
SES	Socioeconomic status index	0.00 (1.03)	0.00 (1.13)
Maternal age	Maternal age in years	25.49 (6.54)	25.60 (6.39)
Maternal age squared	Maternal age in years squared	692.7 (358.63)	696.14 (353.2)
Male	Indicator (0,1) for a male infant	0.54 (0.50)	0.54 (0.5)
African ancestry	Indicator (0,1) for infant's African ancestry	0.19 (0.39)	0.02 (0.13)
Native ancestry	Indicator (0,1) for infant's Native ancestry	0.75 (0.43)	0.86 (0.34)
European Latin ancestry	Indicator (0,1) for infant's European Latin ancestry	0.45 (0.50)	0.40 (0.49)
European non-Latin ancestry	Indicator (0,1) for infant's European non-Latin ancestry	0.10 (0.31)	0.01 (0.08)
Other ancestry	Indicator (0,1) for infant's other ancestry	0.01 (0.09)	0.003 (0.05)
No university affiliation	Indicator (0,1) for birth at an institution not affiliated with a university	0.36 (0.48)	0.05 (0.22)
Maternity hospital	Indicator (0,1) for a birth at a maternity hospital	0.21 (0.41)	0.28 (0.45)
Other institution	Indicator (0,1) for a birth at an “other-type” healthcare institution	0.01 (0.11)	0.16 (0.37)
Private institution	Indicator (0,1) for a birth at a privately owned healthcare institution	0.03 (0.18)	0.32 (0.47)
State/Province institution	Indicator (0,1) for a birth at province/state	0.43 (0.49)	0.10 (0.30)

Variable	Description	Mean (SD)	
		5-1,280 meter altitude sample	**1,854-3,600 meter altitude sample**
	owned healthcare institution		
Local public institution	Indicator (0,1) for a birth at a local publicly owned healthcare institution	0.20 (0.40)	0.13 (0.33)
Brazil	Indicator (0,1) for a birth in Brazil	0.38 (0.49)	
Chile	Indicator (0,1) for a birth in Chile	0.25 (0.43)	
Colombia	Indicator (0,1) for a birth in Colombia	0.01 (0.12)	0.29 (0.45)
Ecuador	Indicator (0,1) for a birth in Ecuador		0.32 (0.47)
Birth year 1983	Indicator (0,1) for birth year of 1983	0.02 (0.14)	0.01 (0.11)
Birth year 1984	Indicator (0,1) for birth year of 1984	0.02 (0.13)	0.01 (0.12)
Birth year 1985	Indicator (0,1) for birth year of 1985	0.02 (0.13)	0.01 (0.12)
Birth year 1986	Indicator (0,1) for birth year of 1986	0.02 (0.14)	0.02 (0.14)
Birth year 1987	Indicator (0,1) for birth year of 1987	0.01 (0.12)	0.02 (0.13)
Birth year 1988	Indicator (0,1) for birth year of 1988	0.02 (0.13)	0.02 (0.13)
Birth year 1989	Indicator (0,1) for birth year of 1989	0.02 (0.13)	0.01 (0.12)
Birth year 1990	Indicator (0,1) for birth year of 1990	0.02 (0.13)	0.02 (0.12)
Birth year 1991	Indicator (0,1) for birth year of 1991	0.03 (0.16)	0.01 (0.10)
Birth year 1992	Indicator (0,1) for birth year of 1992	0.03 (0.18)	0.01 (0.09)
Birth year 1993	Indicator (0,1) for birth year of 1993	0.04 (0.19)	0.01 (0.07)
Birth year 1994	Indicator (0,1) for birth year of 1994	0.04 (0.19)	0.004 (0.07)
Birth year 1995	Indicator (0,1) for birth year of 1995	0.04 (0.19)	0.01 (0.10)
Birth year 1996	Indicator (0,1) for birth year of 1996	0.04 (0.19)	0.02 (0.13)
Birth year 1997	Indicator (0,1) for birth year of 1997	0.03 (0.18)	0.01 (0.12)
Birth year 1998	Indicator (0,1) for birth year of 1998	0.04 (0.19)	0.01 (0.12)
Birth year 1999	Indicator (0,1) for birth year of 1999	0.04 (0.21)	0.02 (0.12)
Birth year 2000	Indicator (0,1) for birth year of 2000	0.07 (0.25)	0.02 (0.13)
Birth year 2001	Indicator (0,1) for birth year of 2001	0.07 (0.26)	0.05 (0.22)

Variable	Description	Mean (SD)	
		5-1,280 meter altitude sample	**1,854-3,600 meter altitude sample**
Birth year 2002	Indicator (0,1) for birth year of 2002	0.07 (0.26)	0.08 (0.27)
Birth year 2003	Indicator (0,1) for birth year of 2003	0.07 (0.25)	0.10 (0.31)
Birth year 2004	Indicator (0,1) for birth year of 2004	0.07 (0.25)	0.13 (0.34)
Birth year 2005	Indicator (0,1) for birth year of 2005	0.06 (0.25)	0.14 (0.35)
Birth year 2006	Indicator (0,1) for birth year of 2006	0.04 (0.19)	0.09 (0.29)
Birth year 2007	Indicator (0,1) for birth year of 2007	0.04 (0.19)	0.09 (0.28)
Birth year 2008	Indicator (0,1) for birth year of 2008	0.02 (0.15)	0.06 (0.23)

Note: Standard deviations (SD) of study variables are in parentheses. The reference country for the 5-1280 meter sample is Argentina. The reference country for the 1854-3600 meter sample is Bolivia. The reference type of institution of birth is general hospital. The reference ownership of institution of birth is nationally owned healthcare institutions. The reference birth year is 1982.

Table 2

OLS Regression Coefficients of the Birth Weight Production Function in the 5-1,280 Meter Range

	Birth weight		Gestational age	
Altitude	−11.6*** (3.64)	−8.59*** (2.90)	−0.060***a (0.011)	−0.044***a (0.011)
Acute illnesses		−28.6*** (6.80)		−0.15*** (0.036)
Chronic illnesses		−55.1*** (12.0)		−0.29*** (0.065)
Conception difficulty		−15.9* (8.18)		0.014 (0.050)
Live births		15.9*** (1.81)		−0.030*** (0.0096)
Miscarriages/ stillbirths		−18.3*** (3.76)		−0.10*** (0.019)
Physical shocks		−26.6* (15.4)		−0.16** (0.062)
SES		12.4** (5.17)		0.015 (0.017)
Maternal age		41.7*** (2.79)		0.17*** (0.014)
Maternal age squared		−0.67*** (0.048)		−0.0031*** (0.00024)
Male		106.3*** (5.79)		−0.084*** (0.025)
African ancestry		−58.4*** (16.2)		−0.11 (0.078)
Native ancestry		17.9* (10.1)		0.090* (0.046)
European Latin ancestry		11.5 (10.2)		0.12*** (0.044)
European non-Latin ancestry		21.7** (9.32)		−0.029 (0.036)
Other ancestry		−3.90 (24.0)		0.16 (0.12)
No university affiliation		20.1 (17.6)		0.0037 (0.071)
Maternity hospital		37.3** (16.5)		0.056 (0.080)
Other institution		−51.5* (28.6)		−0.24 (0.18)
Private institution		−27.2 (22.0)		−0.22 (0.15)
State/ Province institution		−48.8* (26.0)		−0.30** (0.13)
Local public institution		−52.4* (29.0)		−0.33** (0.13)
Brazil	−99.5*** (22.6)	−78.0*** (25.0)	0.087 (0.076)	0.049 (0.096)

	Birth weight		Gestational age	
Chile	146.2*** (17.3)	101.4*** (31.4)	0.22*** (0.079)	−0.14 (0.14)
Colombia	−142.7 (89.1)	−128.9 (80.0)	−0.61 (0.61)	−0.71 (0.54)
Birth year 1983	−39.9 (29.6)	−34.3 (29.3)	−0.10 (0.13)	−0.085 (0.13)
Birth year 1984	−34.3 (31.3)	−28.7 (28.0)	−0.23* (0.13)	−0.20 (0.13)
Birth year 1985	−53.1* (27.5)	−50.5* (26.5)	−0.32*** (0.067)	−0.33*** (0.063)
Birth year 1986	−24.1 (34.9)	−20.0 (36.0)	−0.15* (0.086)	−0.17** (0.085)
Birth year 1987	−59.1** (28.3)	−55.6* (28.1)	−0.35*** (0.084)	−0.39*** (0.087)
Birth year 1988	−49.4* (26.0)	−51.8** (23.8)	−0.37*** (0.071)	−0.41*** (0.064)
Birth year 1989	−79.0** (34.4)	−82.6** (32.4)	−0.43*** (0.13)	−0.47*** (0.13)
Birth year 1990	−40.8 (40.8)	−44.2 (37.5)	−0.21* (0.11)	−0.28*** (0.10)
Birth year 1991	−11.6 (33.0)	−11.1 (28.1)	−0.23** (0.11)	−0.28** (0.11)
Birth year 1992	−14.1 (42.5)	−22.3 (35.2)	−0.24** (0.12)	−0.28** (0.11)
Birth year 1993	−11.8 (43.5)	−9.04 (34.8)	−0.44*** (0.13)	−0.47*** (0.13)
Birth year 1994	−23.4 (42.0)	−8.58 (34.7)	−0.43*** (0.14)	−0.41*** (0.14)
Birth year 1995	−24.0 (40.3)	−3.76 (32.1)	−0.43*** (0.15)	−0.36** (0.15)
Birth year 1996	−31.8 (39.7)	−9.56 (33.4)	−0.55*** (0.14)	−0.48*** (0.14)
Birth year 1997	−22.1 (38.4)	0.36 (29.4)	−0.45*** (0.097)	−0.37*** (0.094)
Birth year 1998	−31.0 (41.2)	−8.06 (33.6)	−0.44*** (0.096)	−0.38*** (0.096)
Birth year 1999	−16.9 (41.5)	9.43 (32.9)	−0.43*** (0.12)	−0.35*** (0.13)
Birth year 2000	−16.5 (39.6)	4.15 (31.4)	−0.41*** (0.12)	−0.29** (0.12)
Birth year 2001	−6.33 (38.7)	18.9 (32.0)	−0.37*** (0.11)	−0.24** (0.12)
Birth year 2002	−19.7 (38.9)	8.14 (32.1)	−0.41*** (0.11)	−0.27** (0.12)
Birth year 2003	−28.4 (40.5)	−2.61 (33.7)	−0.45*** (0.11)	−0.33*** (0.11)
Birth year 2004	−32.0 (41.4)	−3.11 (33.6)	−0.54*** (0.13)	−0.42*** (0.13)

	Birth weight		Gestational age	
Birth year 2005	−48.8 (42.2)	−22.1 (34.4)	−0.80*** (0.15)	−0.66*** (0.16)
Birth year 2006	−24.3 (42.9)	9.82 (38.3)	−0.59*** (0.13)	−0.47*** (0.14)
Birth year 2007	−46.9 (45.2)	−21.2 (37.5)	−0.81*** (0.14)	−0.70*** (0.14)
Birth year 2008	−40.3 (43.4)	−0.83 (36.8)	−0.74*** (0.16)	−0.62*** (0.17)
Constant	3305.0*** (38.0)	2632.1*** (54.5)	39.6*** (0.093)	37.7*** (0.23)

Standard errors in parentheses

* $p < 0.1$,

** $p < 0.05$,

*** $p < 0.01$

[a] indicates that the two coefficients are significantly different at p <0.05.

Table 3

OLS Regression Coefficients of the Birth Weight Production Function in the 1,854-3,600 Meter Range

	Birth Weight		Gestational Age	
Altitude	−11.0*** (1.31)	−6.88** (3.03)	−0.0057 (0.0046)	−0.011 (0.011)
Acute illnesses		−30.6* (17.3)		−0.15 (0.11)
Chronic illnesses		−20.4 (30.0)		0.078 (0.19)
Conception difficulty		−129.3** (46.9)		−0.41 (0.37)
Live births		7.21** (3.05)		−0.064*** (0.022)
Miscarriages/stillbirths		−0.50 (9.82)		−0.054 (0.051)
Physical shocks		−6.78 (24.7)		−0.015 (0.23)
SES		12.6 (8.55)		−0.036 (0.041)
Maternal age		39.8*** (6.72)		0.17*** (0.046)
Maternal age squared		−0.60*** (0.11)		−0.0030*** (0.00078)
Male		95.3*** (14.9)		−0.074 (0.046)
African ancestry		7.73 (31.6)		0.20 (0.14)
Native ancestry		−45.7*** (14.0)		0.028 (0.14)
European Latin ancestry		−3.12 (11.3)		0.092 (0.063)
European non-Latin ancestry		−32.5 (86.1)		−1.05 (1.12)
Other ancestry		−66.9 (117.9)		−0.28 (0.24)
No university affiliation		27.8 (50.5)		0.12 (0.25)
Maternity hospital		−17.0 (24.2)		−0.44*** (0.13)
Other institution		4.69 (25.0)		−0.072 (0.11)
Private institution		−71.1*** (20.1)		−0.13 (0.12)
State/Province institution		−35.8 (35.7)		0.25* (0.13)
Local public institution		57.2 (37.7)		−0.47** (0.18)
Colombia	−221.2*** (30.4)	−168.8*** (25.7)	−0.25*** (0.074)	−0.44*** (0.078)
Ecuador	−173.1*** (21.9)	−145.7*** (30.8)	0.23* (0.12)	−0.15 (0.16)

	Birth Weight		Gestational Age	
Birth year 1983	73.2* (35.9)	54.7 (39.3)	−0.48 (0.66)	−0.47 (0.63)
Birth year 1984	30.3 (30.9)	37.4 (31.7)	−0.62 (0.60)	−0.61 (0.59)
Birth year 1985	63.3*** (3.27)	27.7 (16.2)	0.053 (0.28)	−0.030 (0.30)
Birth year 1986	64.6** (25.8)	49.3 (38.2)	0.22*** (0.063)	0.21** (0.095)
Birth year 1987	66.6*** (17.8)	72.6** (26.0)	−0.68 (0.50)	−0.65 (0.51)
Birth year 1988	−54.5 (69.2)	−24.5 (50.9)	−0.23 (0.16)	−0.12 (0.11)
Birth year 1989	−88.9 (57.3)	−71.9 (51.6)	−1.11*** (0.11)	−1.14*** (0.16)
Birth year 1990	4.08 (13.1)	0.20 (27.4)	−0.69*** (0.059)	−0.70*** (0.080)
Birth year 1991	29.4 (70.7)	20.2 (78.3)	−0.14* (0.083)	−0.15 (0.093)
Birth year 1992	−11.5 (9.36)	−11.9 (12.0)	−0.65*** (0.12)	−0.68*** (0.15)
Birth year 1993	−45.1 (65.8)	−13.7 (47.6)	−0.20** (0.074)	−0.19*** (0.065)
Birth year 1994	−172.8** (65.8)	−133.5*** (46.2)	−0.58*** (0.074)	−0.55*** (0.063)
Birth year 1995	−89.0 (65.8)	−58.7 (45.8)	−0.44*** (0.074)	−0.39*** (0.060)
Birth year 1996	−53.5 (101.3)	−24.1 (87.2)	−0.54*** (0.17)	−0.48*** (0.14)
Birth year 1997	−79.7 (144.3)	−41.9 (126.5)	−0.94*** (0.12)	−0.82*** (0.076)
Birth year 1998	7.61 (70.5)	30.1 (40.8)	−0.33** (0.15)	−0.26 (0.20)
Birth year 1999	20.2 (106.3)	66.8 (82.1)	−0.42** (0.17)	−0.30** (0.13)
Birth year 2000	−16.5 (52.2)	−2.68 (42.9)	−0.61*** (0.085)	−0.51*** (0.12)
Birth year 2001	4.27 (59.1)	35.1 (32.6)	−0.83*** (0.12)	−0.61*** (0.20)
Birth year 2002	15.1 (76.6)	51.2 (50.7)	−0.53*** (0.11)	−0.34*** (0.092)
Birth year 2003	67.4 (77.1)	94.3* (52.1)	−0.61*** (0.12)	−0.50*** (0.12)
Birth year 2004	48.7 (71.4)	73.2 (45.8)	−0.90*** (0.14)	−0.87*** (0.14)
Birth year 2005	53.0 (74.5)	65.6 (56.0)	−0.72*** (0.096)	−0.68*** (0.13)
Birth year 2006	29.3 (81.3)	51.9 (61.4)	−0.77*** (0.13)	−0.80*** (0.11)

	Birth Weight		Gestational Age	
Birth year 2007	−11.9 (86.3)	30.6 (66.7)	−0.77*** (0.12)	−0.77*** (0.10)
Birth year 2008	−7.27 (87.6)	37.4 (67.6)	−1.10*** (0.22)	−1.10*** (0.19)
Constant	3505.8*** (96.5)	2757.0*** (131.3)	39.9*** (0.14)	38.3*** (0.76)

Standard errors in parentheses

* $p < 0.1$,

** $p < 0.05$,

*** $p < 0.01$

Table 4

Marginal Effects of Altitude on Infant Health within the 5-1,280 Meter Range

Infant health Measure	Mean Effect	Quantile Effect				
		0.1	0.25	0.5	0.75	0.9
Birth Weight						
Unadjusted	-11.6^{***} (3.64)	$-16.6^{***\,b}$ (1.85)	$-10.1^{***\,b}$ (1.10)	$-9.45^{***\,b}$ (0.84)	$-9.47^{***\,b}$ (0.99)	$-8.33^{***\,b}$ (1.21)
Adjusted	-8.59^{***} (2.90)	$-9.60^{***\,a}$ (2.02)	$-5.91^{***\,a}$ (1.22)	$-7.49^{***\,a}$ (1.05)	$-8.58^{***\,a}$ (1.17)	$-7.39^{***\,a}$ (1.53)
Gestational Age						
Unadjusted	-0.06^{***} (0.011)	$-0.12^{***\,b}$ (0.012)	$-0.051^{***\,b}$ (0.006)	$-0.045^{***\,b}$ (0.0041)	$-0.048^{***\,b}$ (0.004)	$-0.043^{***\,b}$ (0.005)
Adjusted	-0.044^{***} (0.011)	$-0.078^{***\,b}$ (0.014)	$-0.038^{***\,b}$ (0.006)	$-0.033^{***\,b}$ (0.004)	$-0.037^{***\,b}$ (0.004)	$-0.033^{***\,b}$ (0.0052)

Note: This table presents the marginal effects of altitude on the study birth outcomes in OLS and quantile regression. The adjusted effects are from the full specification that includes all model inputs, and the unadjusted effects are from the nested specification that only includes time and country fixed effects. The standard errors are in parentheses.

[*] indicate significance at p<0.1,

[**] indicate significance at p<0.05

[***] indicate significance at p<0.01, respectively.

[a] indicate that the effects are different across the quantiles at p<0.05

[b] indicate that the effects are different across the quantiles at p < 0.01, respectively.

Table 5

Marginal Effects of Altitude on Infant Health within the 1,854-3,600 Meter Range

Infant health Measure	Mean Effect	Quantile Effect				
		0.1	0.25	0.5	0.75	0.9
Birth Weight						
Unadjusted	−11.0*** (1.31)	−7.45*** (2.33)	−9.74*** (1.75)	−12.5*** (1.92)	−11.9*** (2.00)	−13.9*** (2.65)
Adjusted	−6.88** (3.03)	−12.9* (7.23)	−6.37* (3.87)	−5.57 (3.67)	−9.27** (4.05)	−7.50 (5.09)
Gestational Age						
Unadjusted	−0.0057 (0.0046)	−0.0082 (0.021)	−0.006 (0.0094)	−0.0082 (0.0069)	−0.016** (0.0074)	−0.016 (0.010)
Adjusted	−0.011 (0.011)	−0.04 (0.051)	0.019 (0.023)	−0.00017 (0.013)	−0.019 (0.014)	−0.035 (0.023)

Note: This table presents the marginal effects of altitude on the study birth outcomes in OLS and quantile regression. The adjusted effects are from the full specification that includes all model inputs, and the unadjusted effects are from the nested specification that only includes time and country fixed effects. The standard errors are in parentheses.

* indicate significance at $p<0.1$,

** indicate significance at $p<0.05$

*** indicate significance at $p<0.01$, respectively.