Weather Fluctuations, Early-Life Conditions, and Parental Investments: Evidence from Colombia

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Abstract

There are a studies suggesting that inequalities in human capital emerge from differences in endowments. Characteristics of health and cognitive abilities determined before human capital accumulation process exemplify these endowments. The consequences of impairments in endowments can be mitigated or exacerbated through parental investment. A classic model of intra-family resource allocation predicts that worse endowments discourage parental investment due to the lower returns to investment in human capital. At the same time, poor environmental conditions *in utero* have been shown to have adverse consequences on these endowments. Weather conditions, for instance, are a potential negative influence *in utero*. Motivated by these considerations, we examine the effects of early exposure to heat waves on parental investment in human capital. We do so in the context of Colombia by using a within-municipality identification strategy. Our results indicate that *in utero* exposure to heat waves has negative effects on parental investments in child health care and schooling. Our preferred interpretation of these results is that early exposure to heat waves negatively affected individual endowments and, therefore, the returns to investment in human capital decreased. As a result, families responded by reallocating resources.

Keywords: Endowments; Temperature fluctuations; Human capital accumulation.

Resumo

Estudos recentes sugerem que as variações dessas capacidades decorrem das diferenças individuais nas dotações iniciais. Características de saúde e de habilidades cognitivas determinadas antes do processo de formação de capital humano exemplificam tais dotações. As conseqüências na formação de capital humano de deterioras nessas dotações podem ser mitigadas ou exacerbadas através do investimento dos pais. Um modelo clássico de alocação de recursos sugere que piores dotações iniciais desestimulam o investimento em devido a que o retorno do investimento em capital humano diminui. Ao mesmo tempo, tem sido documentado que pobres condições ambientais no útero trazem conseqüências adversas sobre as dotações individuais. Os eventos climáticos extremos, por exemplo, é uma potencial negativa influência das condições no útero. Motivados por essas considerações, este estudo examina o efeito da exposição no útero a temperaturas extremas de calor sobre os investimentos dos pais em capital humano no contexto da Colômbia. Usa-se uma estratégia de identificação que explora variações aleatórias na temperatura de cada município. Os resultados indicam que a exposição no útero a ondas de calor tem efeitos negativos sobre o investimento em cuidado de saúde e educação. A interpretação preferida desses resultados é que a exposição no útero a ondas de calor afetou negativamente as dotações dos indivíduos e, como conseqüência, os retornos ao investimento em capital humano diminuíram. Como um resultado, as famílias responderam realocando os recursos.

Palavras chaves: Dotações individuais; Flutuações na temperatura; Acumulação de capital humano.
Área ANPEC: Microeconomia, Métodos Quantitativos e Finanças.
Classificação JEL: I2, D1, J1.

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1. Introduction

Individual capabilities are an important determinant of human capital. Recent studies suggest that inequalities in capabilities emerge from differences in endowments. Characteristics of health and cognitive and non-cognitive abilities determined before human capital accumulation process exemplify these endowments (CUNHA; HECKMAN, 2008, 2009). The human capital consequences of impairments in endowments can be mitigated or exacerbated through parental investment. Becker and Lewis (1973)'s seminal study suggests that worse endowments discourage parental investment due to the lower returns to investment in human capital. At the same time, a literature argues that birth outcomes are closely related to these endowments. For example, it has been documented that low birth weight children are likely to have brain damage and impairments in the growth of brain structures related to learning (ABERNETHY; PALANIAPPAN; COOKE, 2002; HACK; KLEIN; TAYLOR, 1995). Along these lines, exposure to poor environmental conditions *in utero* has been shown to have adverse consequences on birth outcomes (ALMOND, 2006; BARRECA, 2010; CURRIE; ROSSIN-SLATER, 2013).

Altogether, these facts suggest that weather shocks could have long-term impacts on human capital accumulation of cohorts exposed prenatally during these periods. Episodes of high temperatures can adversely affect birth outcomes, thereby affecting endowments through changes in disease environment, agricultural activity, and maternal stress. Heat waves may favor the survival of vectors that transmit diseases such as malaria, which can harm the fetus through direct transmission from the mother and/or oxygen deprivation associated with anemia (CRIMMINS; FINCH, 2006). In addition, episodes of high temperatures can adversely affect agricultural production and, in turn, lead to inadequate nutrition due to lower food production and less variety of diets. Furthermore, a pregnant woman may be more susceptible to heat stress (STRAND; BARNETT; TONG, 2012; WELLS; COLE, 2002). And stress has been linked with increases in levels of hormones that regulate growth and development of the fetus (WADHWA et al., 1993). As a result, prenatal exposure to heat waves potentially affect parental investment in human capital through changes in individual endowments.

While there are studies that evaluate the effects of different prenatal environments on investment in human capital (ADHVARYU; NYSHADHAM, 2014; BARRECA, 2010), there has been little systematic research on the effects of early weather conditions. Understanding the effects of weather shocks is important in view of projections indicating that the annual temperature will increase in the next decades due to man-made pollution, making more frequent extreme weather episodes (IPCC, 2007). Therefore, estimates of the effects of early exposure to heat waves may be of particular interest to policy makers.

In this study, we examine the effects of early exposure to heat waves on parental investment in human capital. We do so in the context of Colombia by using a within-municipality identification strategy. Colombia is a country with a temperature that varies widely through short periods of time and has been the World's third most hit country by weather-related losses (CATARIOUS; ESPACH, 2009; GERMANWATCH, 2011). In particular, Colombia is exposed to El Niño and La Niña, which are weather events that take place, on average, every four years and cause episodes of extreme temperatures. Some projections suggest that in the coming decades, weather events will affect 8 out of 10 Colombians living in vulnerable areas (CATARIOUS; ESPACH, 2009).

Our approach for discerning the impacts of temperature from unobserved influences is based on three main components. First, we use high frequency information in order to build a weather dataset, which can be linked to microdata by using date and place of birth. Second, we use temporary temperature deviations from historical averages to limit the influence of unobservables co-varying with temperature levels. Third, we control by a full set of municipality, month, and year fixed-effects in order to account for time invariant characteristics, aggregate shocks, and seasonal factors that might be related to temperature shocks. Thus, our approach exploits random fluctuations in temperature from municipality-specific deviations in temperature after controlling for all seasonal factors and common shocks to all municipalities.

We start showing evidence of the effects of heat waves on birth outcomes. Using natality data, we find that increases in temperature are associated with poorer birth outcomes. Specifically, we find that exposure to heat waves in the first trimester of pregnancy reduces the Apgar score and increases the risk of low birth weight. Our main results focus on the effects of early temperature conditions on parental investments. Using census data, we find adverse effects on investment in child health care and schooling. In particular, an increase of one standard deviation in temperature during the first trimester of pregnancy is associated with a 1.8% reduction in the likelihood of pre-school attendance.

Our favorite interpretation of these results is that, given constant returns to child quality, worse endowments involve negative externalities on the ability of parents to invest in human capital. But we find this is not all that is going on. Rather, early exposure to temperature shocks changed the returns to child quality and families responded by reallocating resources. This interpretation is made somewhat more plausible by the results in the previous studies documenting a positive intra-family correlation between initial endowments and parental investments (ALMOND; MAZUMDER, 2013; DATAR; KILBURN; LOUGHRAN, 2010; ROSALES-RUEDA, 2014), and by our results. In particular, a possible interpretation of our findings is that early temperature shocks impair cognitive abilities and this increases the cost of child quality, which, in turn, leads to disincentives to invest in human capital.

We should recognize that there are several threats to the validity of our conclusions. First, there is evidence documenting that temperature increases result in declines in economic activity, even in non-agricultural sectors, which could reduce wages and/or employment (DELL; JONES; OLKEN, 2012). Therefore, one possibility is that our results are reflecting a persistent decline in family income which negatively affected human capital investment. Since the drop in income is caused by temperature shocks, their omission does not introduce a bias in our estimates per se, but rather affects the interpretation of the estimated relationship. Thus, in the presence of persistent falls in income, the effect of weather shocks on investment in human capital cannot be attributed only to variations in individual endowments. But if the persistent fall in income plays a key role in explaining our results, then we should see that the parental time-intensive investment should increase for children exposed to heat waves in utero as a result of lower value of time, as suggested by the findings of Miller and Urdinola (2010). In general, the use of health services in Colombia is cheap or free but requires a considerable amount of time. However, we find that parental investment in child care not only not increase, but decrease. In addition, we also do not find that early temperature conditions negatively affected maternal labor supply, which is not consistent with persistent reductions in value of time. As an exploratory analysis, we examine the relationship between early temperature conditions and parental investment including a proxy variable of shocks in local economic activity to investigate the role of persistent drop in income. All our estimates remain unaffected when we control for such proxy variable. Although we cannot completely rule out the possibility that persistent changes in income play a role, the evidence suggests that they are not the main mechanism explaining our results.

Second, it could be argued that our results reflect changes in the composition of births. For example, a possibility is that families mitigate temperature shocks by migrating and families who make these decisions have higher socio-economic status. Thus, our results may reflect the fact that less educated mothers, on average, are exposed to higher temperature and they tend to invest less in their children regardless of early weather conditions. To address this issue, we investigate if maternal characteristics, such as age or schooling, are related to early temperature conditions. We find no evidence that temperature predicts systematic changes in maternal characteristics, suggesting that there are no compositional changes in births.

Third, it could be argued that heat waves increase the rate of fetal death. If those weaker fetuses are the most likely to die, then our regressions samples would be based on a select group of “healthy” infants. Any selection bias that results from using this select group will likely lead to an underestimate of the true effect of early temperature shocks. We show that the number of births does not systematically vary with temperature shocks, suggesting that such a selection bias is not present. As an additional exercise, we investigate whether temperature shocks affect the sex ratio. This provides a way of assessing the presence of fetal selection bias in view of literature suggesting that poor conditions in utero has worse consequences on the male fetuses (ALMOND; MAZUMDER, 2011; ERIKSSON et al., 2010; KRAEMER, 2000). Hence, if there is any fetal selection bias we should observe that increases in temperature lower the sex ratio in favor of the girls. Our results show no evidence supporting a statistically significant relationship between sex ratio and temperature shocks.

Our study is related to literature that evaluates the importance of poor environmental conditions in utero on parental investment. Using the introduction of malaria eradication programs in Mexico, Venkataramani (2012) found that individuals with lower in utero exposure to malaria started school at an earlier age. Adhvaryu and Nyshadham (2014) show that an iodine supplement program during pregnancy in Tanzania increased breastfeeding duration and vaccinations among children. Almond, Edlund, and Palme (2009) study the effects of radioactive fallout caused by the Chernobyl accident in Switzerland and also provide indirect evidence that the investment in human capital decreased. Parman (2013) finds that exposure in utero to the 1918 influenza pandemic implied less investment in schooling.

Our study makes a few contributions to this literature. First, we see our study as a first attempt to show the systematic importance of early weather conditions on human capital investments. Most of previous studies have investigated the influence of unique and uncommon historical events and the validity of its conclusions to the world today may be questionable. In contrast, the Earth’s climate is expected to become hotter in the near future, which would increase the frequency of heat extreme episodes. Second, we use a broader set of parental investment measures. Most of previous studies use limited measures or rely on indirect evidence. For example, Almond, Edlund, and Palme (2009) argue that parents adopt reinforcing strategies because the effect of fetal exposure to the radioactive fallout on cognitive skills was greater in poor families. This evidence is compelling, but it turns out to be only suggestive. In contrast, we use direct measures of parental investment such as pre-school attendance and childcare. Third, we also offer interesting new evidence of potential mechanisms. In particular, we investigate whether prenatal exposure to heat waves involves changes in fertility decisions. This is important given that families with unhealthy children could change their future demand for children (SCHULTZ, 1997), which would affect investment in child quality as predicted by the quantity-quality model of fertility (BECKER; LEWIS, 1973). Therefore, if there are significant effects on fertility, this would be supportive evidence that variations in endowments involve externalities in the ability of parents to invest in human capital.

The remainder of this paper is structured as follows. The next section presents a simple framework that explains the relationship between individual endowments and parental investment. The third section describes the data used. The fourth presents the econometric model. The fifth section presents the results. The sixth section presents an overview of the results of several exercise of robustness. Finally, the seventh section concludes.

2. Framework

To illustrate how the early temperature conditions could affect parental investment in human capital, the human capabilities formation model developed by Heckman (2007) and Cunha and Heckman (2007) can be used. The model argues that early individual endowments and parental investment interact and it defines human capital formation. Parents can offset or reinforce a shock that affected the initial endowments through investment in human capital. To formalize this, we assume two periods (pre-natal and post-natal) and use the following capabilities' production function:

$$h = Ah(I)$$

where h is a measure of human capital formation, and I the parental investment during the post-natal period[4]. The term A represents a productivity factor that is directly related to the innate endowments of individuals. This implies that the investment would have a larger effect on the formation of human capital in either the most productive or the best endowed individuals, a feature that is known as "complementary dynamics". Another implication of this production function is that the initial endowments can have a direct effect, individuals with more initial skills accumulate more human capital given constant levels of investment. This second feature is known as "self-productivity". Thus, this function production has all the properties discussed in Heckman (2007).

For this study's proposals, we assume that the first-period exposure to heat waves has negative effects on the initial endowments and parents see such endowments. The optimization problem of parents consists in distributing resources on investment in human capital and the consumption of other goods. The parents are altruist and their utility increases with higher levels of h. Then, worse initial endowments as a consequence of a pre-natal shock caused by heat stress implies a reduction in the returns to investments. As a result, the optimal strategy would be to increase consumption in other assets and reduce investment in human capital. Therefore, this simple model predicts that parents would adopt reinforcement strategies if temperature shocks negatively affect initial endowments. This prediction is consistent with Becker and Tomes (1973)'s model.

3. Data

3.1. Weather Data

We use monthly temperature and precipitation data provided by Matsuura and Willmott (2012). This dataset provides estimates of climate around the world at a level of about 56x56 kilometers. These estimates are based on information collected from several nearby weather stations. The data provided geographical coordinates that identify the spatial location of weather information. Weather information is provided for each of these coordinates or nodes, constituting a monthly series for the period 1900-2010. In order to construct a municipality-by-month of weather panel over this period, we use a strategy similar to Rocha and Soares (2015). To start with, we compute the centroid for each municipality. Then, using the centroid for each of these municipalities, we located the four nearest nodes. Thus, we build monthly series of temperature and precipitation for each municipality as the weighted average of estimates related to the four nodes. We use the inverse of the distance of each municipality to each of the four nodes as weights. This information is merged with the microdata described in the next section.

[4] We assume that investment in prenatal period is irrelevant compared to the postnatal period in monetary terms. In order to maintain simplicity, we assume that the production function contains only the postnatal investment. We also assume that h is a strictly concave in I, indicating that there are diminishing marginal returns on postnatal investments.

We build our measure of temperature fluctuations for the municipality *j*, month *m* and year *t*, as follows:

$$T_{jmt} = \frac{temperature_{jmt} - \overline{temperature_{jm}}}{sd(temperature_{jm})} \quad (1)$$

This measure indicates how many standard deviations the temperature is above (or below) the historical average for a given municipality and point in time. We calculate the historical mean and standard deviation for each municipality using information from the

period 1900-2010. Our measures of prenatal exposure to temperature changes during the *q* trimester for each individual are calculated as follows:

$$\overline{T_{jq}} = \left(\sum_{\Gamma=3q-2}^{3q} T_{j\Gamma} \right) \Big/ 3$$

where Γ corresponds to the months of gestation. This calculation assumes that individuals were nine months in utero. Thus, the use of this variable would lead to a measurement error in exposure of individuals who were born prematurely. Our main response to this concern is that to the extent that this measurement error is important, it will lead to a downward bias in the effect of temperature changes. If it is so, our results showing large impacts would become even more telling. As a robustness analysis, we estimate the impact of temperature changes on birth outcomes using the sample including all infants and a subsample that excludes premature births.

Figure 1 shows the evolution of standardized temperature for the period 1995-2010. The figure shows that the temperature varies widely over time. The years with highest temperature are 1998 and 2010.It is also observed that the temperature is almost never below one standard deviation from the historical average, while periods of heat waves are more frequent. Figure 2 shows the spatial distribution of the incidence of heat waves (defined as 1.5 standard deviations above the historical average). The figure shows that the incidence of high temperatures also varies significantly across municipalities. Episodes of extreme heat occur, on average, in 10% of the Colombian municipalities. Yet, there are periods with pervasive heat waves hitting almost 80% of the municipalities and periods with no municipality experiencing a heat wave.

3.1. Natality Files

The Colombian Department of Statistics (DANE) is the source of the birth certificate microdata which are publicly available from 2009. We obtained these data for 2009 and 2010 within the 1120 municipalities in Colombia- approximately 1.4 million birth records. The data include the exact date of birth, duration of pregnancy, sex, birth weight, Apgar[5] scores and maternal characteristics such as marital status, age and education. Importantly, the information about municipality of residence is also provided. The sample is limited to births that were certified by a physician, which implies a reduction of about 2%. We also dropped the 269,642 births with either less than 37 weeks gestation or missing gestation information. The final sample consists of about 1,057,912 births. The dependent variables of interest are 5 minute Apgar score, low 5 minute Apgar score (<8), and low birth-weight (≤2,500 gr.). Using the municipality of residence of mother

[5] The Apgar test is a clinical test that is given to the newborn in which five parameters are assessed. The parameters evaluated are muscle tone, respiratory effort, heart rate, reflexes and skin color. The test provides a total score between 0 and 10, where a higher score means healthier.

and date of birth, we merge these data with our weather database. Thus, we identify prenatal exposure to temperature changes for each infant who was conceived between 2008 and 2010. Table 1 shows a statistical summary of the birth data.

The short period of study raises some concerns about the variation in the prenatal exposure to temperature. However, this has little empirical support. Indeed, there is substantial variation over time and space in that short window of time. Figure 3 shows that while in most months of 2008 the temperature is located practically in its historical average, from 2009 it is placed between 2 and 4 standard deviations above it. In fact, there are months in which temperature is placed nearly 4 standard deviations above the historical average. The figure also shows that these changes were heterogeneous across municipalities. For example, in the first months of 2010 there are municipalities where the temperature is at about 1 standard deviation above average, while in others it is at almost 4 standard deviations above. This suggests that there is substantial variation in that narrow window of time, which allows us to assess the effects of temperature shocks.

3.2.Demography and Health Surveys

To evaluate the effects of early weather conditions on investment, we use the Colombian Demography Health Survey (DHS), which is a nationally representative survey of women of childbearing age and is conducted every five years from 1986. We use the DHS of 2005 and 2010 because, with the exception of the DHS 1990, the DHS of previous years do not provide information about the municipality of residence. Without this information we are unable to identify pre-natal exposure to temperature fluctuations. Our sample consists of 31,557 children born between 1999 and 2010. This survey provides information about the exact date of birth, but the municipality of birth is not directly known. But the survey provides information on the years of residence in the current municipality. From this information, we can identify children born in the current municipality of residence. Limiting the sample to these children implies a loss of 13% in the number of observations. We also dropped 536 dead children at the time of the survey. We also eliminated to 2,860 children who are less than 6 months old. The size of our basic sample consists of 23,790 observations, but it varies across estimations because there are variables with missing values.

This survey allows us to study two types of parental investment measures: health care and development activities. As measures of health care, we use breastfeeding duration and vaccinations. To study breastfeeding, we focus on children over two years old. Most of the children in this group have completed or is not breastfeeding. This variable is subject to measurement error because it is based on retrospective information. Our identification strategy requires that this measurement error is uncorrelated with pre-natal temperature exposure. This seems plausible.

We constructed dummies indicating vaccination status for each of the following variables: hepatitis B, DPT, polio and measles. For hepatitis B, we created a dummy variable indicating whether a child received the third dose, which is expected to be received between 6 and 18 months of age. For DPT and polio, we use created dummies indicating whether a child received the second or third doses. The DPT doses are expected to be received between six and eighteen months of age, while polio doses are expected in children between 4 and 18 months of age. For measles, we create a binary variable equal to one if the child received the first dose, which is expected to be received between 12 and 15 months old. The models using the measles vaccine status as the dependent variable excludes children who are under the age of twelve months.

The variables regarding development activities are available only in the 2010 DHS. One perhaps more appropriate measure would be the time spent on these activities, as in Hsin (2012). However, DHS does not provide this information and, therefore, we are limited to examine whether parents do or not these activities. We use dummy variables for playing, walking, reading, and singing activities (see Table 2 for summary of data).

3.3.Census 2005

To investigate the potential effects of early temperature shocks on parental investment in education, we use microdata from the 2005 census. The Integrated Public Use Microdata Series (IPUMS) provides a one percent sample for 2005. Data on month, year and place of birth of individuals are provided. However, IPUMS re-classified birthplace in blocks of municipalities. For example, Ebejico, St. Jerome, and Sopetran municipalities represent a block. Thus, the 1120 Colombian municipalities are classified in about 533 blocks, indicating that on average a block contains two municipalities. Given this, we can identify only the block of birth and not the municipality. To link this information with our weather data, we build a block-by-month of weather panel over the period 1900-2005. These data were merged using the date and block of birth[6].

From census data, we use two measures of parental investment. The first is a dummy variable indicating pre-school attendance for a child between three and six years of age. The second is a dummy variable indicating whether a child between 7 and 9 years old never went to school. The reasoning for this variable is that children who never went to school receive less investment in education. We focus on this age group because in Colombia the minimum school age is six years. We do not include older children because the decision to go to school is more likely to depend on them. We also study the effects of pre-natal exposure to temperature shocks on human capital formation using IPUMS. With this in mind, we use illiteracy status and education years for children between seven and nine years of age.

From census data, we study two additional variables. The first is a dummy variable indicating whether a child between two and nine years old has a younger brother from the same mother. The second variable of interest is maternal labor force participation status for children between one and nine years old. We are interested in analyzing how fertility and labor force participation are affected by exposure during pregnancy to the temperature shocks.

4. Empirical Strategy

We regress each outcome y on a set of temperature exposure measures. Separate exposure measures for each trimester during pregnancy are included simultaneously. We use the following specification:

$$y_{ijmt} = \alpha + \sum_{q}^{3} \beta_q \overline{T_{jq}} + \gamma Z + \mu_j + \zeta_m + \lambda_t + \xi_{ijmt} \qquad (5)$$

where $\overline{T_{jq}}$ is the exposure of trimester q of gestation for the individual i, born in the municipality j in the month m in of the year t. Z is a vector of control variables including maternal and child characteristics. Z also includes precipitation and precipitation squared. In our analysis of parental investments, we also include a vector of municipality specific time trends. The inclusion of these trends is possible in the analysis of parental investments because we have children who were born within a period longer than two years. The terms μ are municipality fixed effects. The month and year fixed effects are ζ, and λ, respectively. The term of random error is ξ.

The validity of any estimate of the impact of pre-natal exposure to temperature fluctuations based on (5) relies crucially on the assumption that its estimate will produce unbiased estimates of β_q. For this, we require the following identification assumption:

[6] To facilitate the presentation, we use the terms municipality blocks and municipalities interchangeably.

$$Cov(\overline{T_{jq}}, \xi_{ijmt} \mid Z, \mu_j, \zeta_m, \lambda_t) = 0 \forall q = 1, 2, 3$$

In other words, including municipality, year and month fixed effects, the impact of fetal exposure is identified from municipality-specific deviations in temperature after controlling for all seasonal factors and common shocks to all municipalities. This variation is assumed to be random and therefore should not be correlated with omitted determinants of birth outcomes or parental investments. Furthermore, the inclusion of specific time trends in the investment models control for long-term differences in weather and socio-economic factors across municipalities correlated with parental investment and human capital. Given these conditions, we are able to identify the causal impact of early temperature shocks.

Despite random variation in temperature argued above, there are challenges to our identification strategy. First, poor conditions in utero due to heat waves may increase the rate of fetal death, as hypothesized by Lam and Miron (1996). Empirically this is problematic because we only observe birth outcomes for those born alive. If those weaker fetuses are the most likely to die, then would arise a selection bias. This bias may also arise if surviving fetuses are those from mothers with better economic status. A second potential problem is that changes in temperature may affect the probability of conception. If the least fertile or healthy mothers are less likely to conceive during heat wave episodes, then exposure to temperature would be correlated with unobserved factors. A third potential source of bias is that parents can respond to temperature shocks migrating. As a result, we would assign incorrectly fetal exposure to temperature changes for these infants. In the presence of these sources of bias, our estimates may underestimate the true effect of temperature shocks on birth outcomes.

We do not have a perfect remedy for these potential threats, but we can investigate its relevance. In particular, we investigate as total births responds to changes in temperature. Insignificant estimates would suggest that fetal selection bias caused by fetal death is not present. We also investigate other sources of bias by running placebo regressions. Favorable results in these tests do not allow us to rule out the possibility that our estimates are plagued by these sources of bias. Thus, we conservatively interpret our estimates as lower bounds of the true effect of pre-natal exposure to temperature shocks. All specifications use robust standard errors clustered at municipality level.

5. Results

5.1. Results from Natality Data

Table 4 presents the results for Apgar score, low Apgar score, and low birth-weight. Each column is from a separate regression. These results include controls related child and mother characteristics mentioned above. At the bottom of the table, we present a measure of goodness of fit and the total number of observations.

Column (1) indicates that exposure during the first trimester to an increase of one standard deviation in temperature reduces the Apgar score at around 0.008 points. This result is significant at the 1% level. In magnitude, the estimated effect is small relative to the mean of the Apgar score (0.08%≈100*0.008/9.6). Exposure during the other trimesters has no statistically significant effects.

The results in column (2) indicate that an increase of one standard deviation in temperature in the first trimester implies a statistically significant increase of 0.10 percentage points in the likelihood of low Apgar score. This impact is large in magnitude (10%≈100*0.00102/0.001), indicating the presence of disproportionate effects across Apgar score distribution. Again, there are no significant effects for the second and third trimester.

Column (3) shows no detectable effects on the risk of low birth weight in the third and second trimester. However, increases in temperature during the first trimester significantly increase the likelihood of low birth weight. In magnitude, one additional standard deviation in temperature implies in an increase of 2% in the risk of low birth weight.

5.2.Results from DHS and Census Data

Table 5 shows the results for child health care. Columns (1)-(4) presents the results for vaccines, while column (5) for breastfeeding duration. The goodness of fit and number of observations are presented at the bottom of table. Robust standard errors are clustered at municipality level.

We found a statistically significant reduction of exposure in the second trimester in the probability of hepatitis B vaccine (Column (1)). The point estimate is -0.019 with a standard error of 0.0067. Given the mean rate of 75%, this implies that one standard deviation above mean in temperature lead to a 2.5% reduction in the likelihood of hepatitis B vaccine. The columns (3) and (4) show that exposure during the first trimester is associated with a reduction in the probability of polio and measles vaccines. Specifically, an increase of one standard deviation implies a reduction of 0.8 and 1.04 percentage points in the probability of these vaccines, respectively. Relative to mean rates, these coefficients imply a reduction of 0.85 and 1.1%.

Table 6 presents the results for parental investment in stimulating activities and schooling. Column (1) shows the results for playing activities and significant exposure effects are observed in the first and third trimester. Children who were exposed to one standard deviation higher in temperature during the first trimester have a reduction of 1.3 percentage points in the likelihood of playing activities. The corresponding reduction for the third trimester is 0.8 percentage points. These effects are significant at the 1 and 10% level, respectively. The results in column (2) show that only exposure in the third trimester affects walking activities. The reduction in the likelihood of walking activities of exposure to increases of one standard deviation in temperature in the last trimester is 1.7 percentage points. This effect represents about 2% of the mean rate. For reading activities, the effects of the first and third trimester are negative but not statistically significant. There are no effects for singing activities.

Column (5) presents the results for likelihood of preschool attendance. As can be seen, fetal exposure to temperature conditions has significant negative effects in all the trimesters. The estimated parameters are precisely estimated. In magnitude, exposure in the third trimester has the greatest effect. The reduction in the probability of attending pre-school for infants who were exposed in the third trimester to one standard deviation higher in temperature is 4.8 percentage points. Given the mean rate of 61%, this implies that exposure reduces the likelihood of attending pre-school at 7.8%. The same exposure during the first and second trimester leads to reductions of 1.8 and 1.4%, respectively.

The most striking finding is the increased probability of never school attendance when a child is exposed during the first trimester. The point estimate is 0.0368 with a p-value of 0.001. This coefficient implies that a child exposed to one standard deviation higher in temperature increases the likelihood of never school attendance by 27%. We also find that those with similar exposure in the second trimester have to 10% of increase (significant at 5%).

5.3.Investigating Reasons for Differential Investments

We now present evidence of reasons why early temperature shocks affect parental investment. We started investigating whether there are persistent economic shocks influencing our results. Persistent reductions in economic activity would have two potential effects on parental investments. On the one hand, lower labor participation may imply falls in family income. This would negatively affect the financial ability of parents to invest. In this way, pre-school attendance could be adversely affected. On the other hand, lower labor force participation could increase parental investment in time-intensive inputs. Miller and Urdinola (2010) show that when the cost of time is low, mothers tend to invest more in child health care. Therefore, persistent declines in the opportunity cost of time could positively affect vaccines and stimulation activities. However, our results suggest that there are other most important mechanisms since investment in these inputs tend to be lower for children who were prenatally exposed to higher temperatures.

To empirically investigate these possibilities, we run all the above specifications but now included as a control variable shocks in the GDP in the year immediately after birth[7]. The results of this exercise are presented in Table 7. Each line in the table represents a separate regression. Columns (1) to (3) represent the effects of exposure from first to third trimester. Column (4) has the coefficient of early GDP shocks. There is virtually no change in the coefficients with pre-natal exposure to temperature changes. In fact, the coefficients increase slightly in many cases. Early GDP shocks, in turn, do not appear to be statistically significant in most of the time. This does not necessarily mean that temperature shocks do not affect economic activity. Rather, it means that the effects of temperature on economic activity are not persistent. In any case, controlling for GDP shocks does not change our results. This suggests that changes in value of time are not the main link between temperature shocks and parental investment.

We now explore how the labor force participation of mothers responds to early temperature conditions. The maternal labor force participation could be affected not only by changes in value of time, but also by the initial endowments of their children. A mother could reduce their labor supply to take care of unhealthy children. Conversely, unhealthy children could increase financing requirements, which would lead to an increase in labor force participation. Panel A of Table 8 presents regressions in which the dependent variable is a binary variable equal to one if the mother participates in the labor market. The results indicate that there are no significant effects. Thus, this suggests that changes in labor force participation are unlikely to play an important role.

It has been well documented that children growing up in larger families receive less investment in human capital due to decreased per capita income (BECKER; LEWIS, 1973). The theoretical model of Becker and Tomes (1976) suggests that families can change their fertility decisions in response to variations in endowments. The predictions of this model are ambiguous. On the one hand, less healthy children increase the cost of child quantity. That is, if prenatal exposure to high temperature reduces life expectancy, then, it would increase the number of births that a family requires to achieve a given number of surviving children. Then, early temperature shocks would increase the shadow price of child quantity, which lead to a reduction in fertility. On the other hand, unhealthy children mean lower returns of parental investment, which would increase the shadow price of child quality. Under the quantity-quality tradeoff in this model, this would lead to an increase in fertility. In addition, the lower life expectancy of unhealthy children may increase replacement fertility, given constant prices of child quantity and quality (DOEPKE, 2005).

In Panel B of Table 8 we investigated if early temperature conditions affect fertility. For this, we use the subsample of children between two and nine years old and estimate a model where the dependent variable is a dummy indicating if a child has at least one sibling from the same mother. The intuition is that a child who does not have a younger brother implies that the mother does not increase fertility. The results suggest that exposure in the third trimester reduced the likelihood of having an additional child. The point estimate is

[7] Given that in Colombia there are no official estimates for GDP at the municipal level, we use as a proxy for GDP municipal revenues.

-0.011, being significant at the 1% level. Relative to the mean, this implies a marginal effect of -2.5%. These results suggest that pre-natal exposure to temperature shocks leads to reductions in fertility. Thus, this indicates that children exposed pre-natally to high temperature are benefited by the reduction in family size. However, this also suggests that there is another mechanism annihilating the benefit of reduced fertility.

6. Robustness of Findings

We perform a number of robustness tests designed to assess the validity of our identification strategy[8]. First, we evaluate whether the estimates of the effect of early temperature conditions on birth outcomes are affected when premature infants are included in the sample. We had excluded this group because infants born prematurely are more likely to have adverse birth outcomes. Furthermore, using the sample of infants with normal length of gestation, we can more accurately assign temperature exposure. All estimates are broadly similar to those of the baseline, but the effect on the risk of low birth weight is estimated less precisely. The second exercise investigates the role of the fetal selection bias. As we mentioned before, whether the heat waves lead to more miscarriages in weak fetuses, then our estimates may underestimate the true effect of early temperature conditions. As a practical matter, we estimate the relationship between temperature conditions and the births. If such bias is present, then, we should observe a negative relationship between the births and temperature conditions. We found no significant effect on the number of births. We also investigate whether sex ratio is affected by temperature conditions. If there is any fetal death bias, then we should expect that temperature shocks lower the sex ratio in favor of the girls, as predicted by literature suggesting that poor conditions in utero have worse consequences for the male fetuses (ALMOND; MAZUMDER, 2011; ERIKSSON et al., 2010; KRAEMER, 2000). We found no significant effects on the sex ratio. Finally, we investigated whether there are changes in the composition of births due to, for example, selective timing of conception or migration. For this, we estimate the relationship between temperature conditions and maternal characteristics. To the extent that our estimates do not reflect the compositional changes in births due to strategic maternal behavior, prenatal exposure to temperature shocks should not predict maternal characteristic changes. We found no significant effects, suggesting no changes in the composition of births.

7. Conclusion

Analyzing the relationship between early temperature conditions, endowments, and parental investments has been the main subject of this study. We found that in utero exposure to heat waves has adverse consequences on the initial endowments. The most important timing is the first trimester, since we found greater effects. We also show that early exposure to heat waves decreases parental investment in child health care and schooling. We believe that variations in endowments due to fluctuations in temperature could have negatively affected returns to the quality of children. As a result, parents responded by adopting reinforcement strategies. However, other mechanisms may play some role. For example, we found that early temperature conditions affect fertility decisions, suggesting the possibility that variations in endowments involve externalities in the parents' ability to invest in human capital. Furthermore, although our evidence does not suggest that there are persistent changes in income explaining our results, we cannot completely rule out this possibility.

Our findings provide evidence suggesting that parents respond to changes in initial endowments. This has implications for studies evaluating the fetal programming hypothesis, which states that chronic diseases

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[8]Given space constraints, we do not present the results for these robustness exercises, but they are available upon author request. The complete code that allows replicating all our results from the authors.

in the final stages of life stem from the uterus. For example, an influential work by Almond (2006) found that individual exposed prenatally to pandemic influenza were more likely to report physical illnesses, besides lower educational attainment and wages. However, in the presence of parental response to variations in endowments, as our results suggest, parents could enlarge the initial disadvantages by investing less in human capital. Therefore, part of the effects found in Almond (2006) may reflect the lower parental investment in health care during childhood. As a result, these studies may overestimate the role of fetal programming.

At this point, we should point out that there are various caveats. First, our estimates represent the effect of the reduced form of prenatal exposure to temperature shocks. Given the multidimensional concept of capabilities, our estimates do not allow us to disentangle what type of initial endowment has more or less influence on parental investment. This could be important in view that parental response to a cognitive shock could be different from a health shock, as hypothesized by Yi et al (2014). Our methodology provides only suggestive evidence of the combined effect of these channels. Second, it is not clear the external validity of our results for countries with different climatic characteristics. For example, the effects of temperature increases on the initial endowments may be different for countries with very low temperatures. In fact, there is evidence based on correlations suggesting that increases in temperature are beneficial to the fetus in these countries. Thus, setting aside the issue of generalizability, the fact that weather shocks will become increasingly common implies that understanding the short and long term consequences of temperature variations is an important question *per se*. Therefore, our study is at least a clarion call for future research in this area.

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Figure 1. Z-scores of Temperature by Month over the period 1995-2010

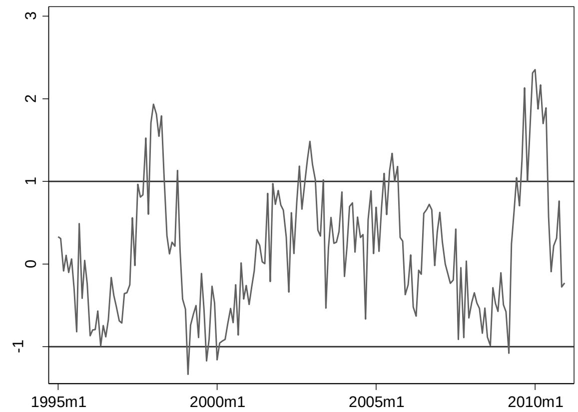

Figure 2. Distribution of the Heat Shocks by Municipality over the period 1995-2010

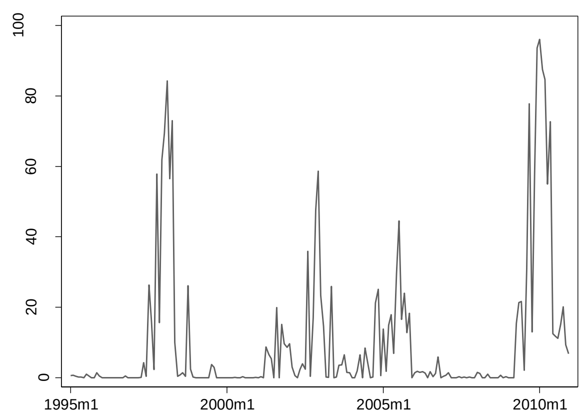

Figure 3. Z-scores of Temperature by Month over the period 2008-2010

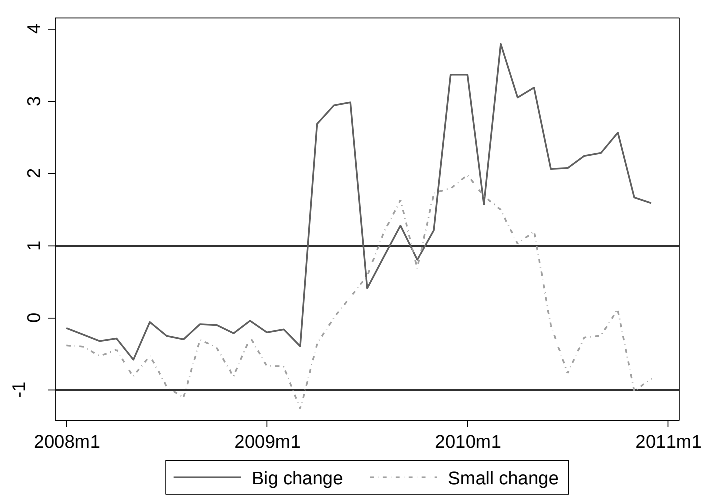

Table 1. Summary Statistics for Natality Data, 2009-2010

	N	Mean	Standard Deviation	Min	Max
Birth outcomes:					
5 Minute APGAR Score	1,045,357	9.63	0.67	1	10
Low 5 Minute APGAR (<8)	1,045,357	0.01	0.11	0	1
Low Birth Weight (≤2,500 gr)	1,056,410	0.03	0.17	0	1
Child characteristics					
Singleton	1,057,912	0.99	0.12	0	1
Male	1,057,912	0.51	0.50	0	1
Mother characteristics:					
Urban residence	1,041,285	0.80	0.40	0	1
Age <20	1,057,912	0.23	0.42	0	1
Age 20-24	1,057,912	0.29	0.46	0	1
Age 25-29	1,057,912	0.23	0.42	0	1
Age 30-34	1,057,912	0.15	0.35	0	1
Age 35-44	1,057,912	0.09	0.29	0	1
Age 45 +	1,057,912	0.00	0.04	0	1
Married	1,057,912	0.18	0.38	0	1
Low education (<12 years of schooling)	1,057,912	0.80	0.40	0	1

Source: Research results.

Table 2. Summary Statistics for Demography and Health Surveys Data, 2005 and 2010

	N	Mean	Standard Deviation	Min	Max
Parental measures:					
Hepatitis B	22,898	0.75	0.43	0	1
DPT	22,838	0.94	0.23	0	1
Polio	23,213	0.94	0.24	0	1
Measles	20,687	0.92	0.26	0	1
Breastfeeding duration (in months)	12,149	12.95	9.30	0	54
Playing	13,277	0.91	0.28	0	1
Walking	13,277	0.80	0.40	0	1
Reading	13,277	0.50	0.50	0	1
Singing	13,277	0.76	0.43	0	1
Child characteristics:					
Age (in months)	23,790	31.61	15.59	6	59
Male	23,790	0.51	0.50	0	1
First born	23,790	0.38	0.49	0	1
Singleton	23,790	0.98	0.12	0	1
Urban residence	23,790	0.71	0.45	0	1
Mother characteristics:					
Household head	23,790	0.31	0.46	0	1
Age <20	23,790	0.13	0.34	0	1
Age 20-24	23,790	0.29	0.45	0	1
Age 25-29	23,790	0.25	0.43	0	1
Age 30-34	23,790	0.18	0.38	0	1
Age 35-44	23,790	0.15	0.36	0	1
Age 45 +	23,790	0.01	0.07	0	1
Married	23,790	0.22	0.41	0	1
Low education (<12 years of schooling)	23,790	0.84	0.37	0	1

Source: Research results.

Table 3. Summary Statistics for Census Sample 2005

	N[1]	Mean	Standard Deviation	Min	Max
Parental measures:					
Preschool attendance	2,763,980	0.61	0.49	0	1
Never went to school	2,085,049	0.11	0.32	0	1
Illiteracy	2,088,887	0.11	0.31	0	1
Years of schooling	2,085,049	1.96	1.18	0	5
Child characteristics:					
Age (in years)	6,207,297	5.05	2.58	1	9
Male	6,207,297	0.51	0.50	0	1
First born	6,207,297	0.40	0.49	0	1
Urban residence	6,207,297	0.72	0.45	0	1
Mother characteristics:					
White	6,207,297	0.84	0.36	0	1
Household head	6,207,297	0.15	0.36	0	1
Age <20	6,207,297	0.17	0.38	0	1
Age 20-24	6,207,297	0.28	0.45	0	1
Age 25-29	6,207,297	0.24	0.43	0	1
Age 30-34	6,207,297	0.17	0.38	0	1
Age 35-44	6,207,297	0.13	0.34	0	1
Age 45 +	6,207,297	0.01	0.08	0	1
Married	6,174,405	0.30	0.46	0	1
Low education (<12 years of schooling)	6,207,297	0.85	0.35	0	1
Employed	6,141,604	0.34	0.47	0	1
Number of children	5,236,366	2.93	1.80	1	16

Source: Research results. Notes: (1) represents the expanded sample using factor provided by the IPUMS.

Table 4. Estimated Impact of Temperature Changes on Birth Outcomes

	5 Minute APGAR Score	Low 5 Minute APGAR (<8)	Low Birth Weight (≤2,500 gr)
	(1)	(2)	(3)
Prenatal exposure during:			
1st trimester	-0.00873	0.00103	0.000631
	[0.00324]***	[0.000258]***	[0.000346]*
2st trimester	0.00308	-0.0000950	-0.000169
	[0.00272]	[0.000235]	[0.000254]
3st trimester	-0.000443	-0.0000560	0.000402
	[0.00294]	[0.000237]	[0.000310]
Number of observations	1,028,828	1,028,828	1,039,502

Source: Research results.
Notes: Robust standard errors (in brackets) are clustered at municipality level. Regressions include sex, and singleton status of newborn, and age, married, low and missing education dummies of mother. Year, month and municipality fixed effects are also included. Urban dummy is also included. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Estimated Impact of Temperature Changes on Parental Investments in Health Care

	Vaccinations				Nutrition
	Hepatitis B (1)	DPT (2)	Polio (3)	Measles (4)	Breastfeeding duration (5)
Prenatal exposure during:					
1st trimester	-0.00587	-0.00994	-0.00806	-0.0104	-0.0125
	[0.00903]	[0.00632]	[0.00379]**	[0.00412]**	[0.207]
2st trimester	-0.0190	-0.00374	0.00212	0.00218	0.388
	[0.00674]***	[0.00389]	[0.00296]	[0.00902]	[0.296]
3st trimester	0.00864	0.00010	-0.00136	-0.00819	-0.0509
	[0.00754]	[0.00565]	[0.00443]	[0.00618]	[0.234]
Number of observations	22,777	22,715	23,090	20576	12,085

Source: Research results.

Notes: Robust standard errors (in brackets) are clustered at municipality level. Regressions include sex, and singleton status of child, and age, married, low and missing education dummies of mother. Year, month and municipality fixed effects are also included. Urban dummy is also included. *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Estimated Impact of Temperature Changes on Parental Investments in Stimulant activities and Schooling

	Stimulation activities				Schooling	
	Playing (1)	Walking (2)	Reading (3)	Singing (4)	Preschool attendance (5)	Never went to school (6)
Prenatal exposure during:						
1st trimester	-0.0135	-0.0146	-0.00808	0.00627	-0.0119	0.0368
	[0.00653]**	[0.00912]	[0.00879]	[0.00811]	[0.00298]***	[0.00325]***
2st trimester	0.00582	0.00273	0.00422	-0.0055	-0.00907	0.0112
	[0.00520]	[0.0101]	[0.0123]	[0.00887]	[0.00324]***	[0.00496]**
3st trimester	-0.00897	-0.0178	-0.00156	0.00633	-0.0485	-0.000166
	[0.00523]*	[0.00872]**	[0.00876]	[0.00778]	[0.00537]***	[0.00486]
Number of observations	13,206	13,206	13,206	13,206	272,522	202,181

Source: Research results.

Notes: Robust standard errors (in brackets) are clustered at municipality level. Regressions include sex, and singleton status of child, and age, married, low and missing education dummies of mother. Year, month and municipality fixed effects are also included. Urban dummy is also included. All estimations use sample weights. *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Estimated Impact of Temperature Changes on Parental Investments Controlling by Early GDP shocks

	Prenatal exposure during:			Early	N
	1st trimester	2st trimester	3st trimester	GDP shocks	
	(1)	(2)	(3)	(4)	(5)
Vaccinations:					
Hepatitis B	-0.00597	-0.0182	0.00891	-0.0165	21,290
	[0.00912]	[0.00677]***	[0.00750]	[0.0122]	
DPT	-0.0100	-0.00236	0.000129	-0.00923	21,238
	[0.00632]	[0.00358]	[0.00567]	[0.00540]*	
Polio	-0.00879	0.00153	-0.00203	0.00308	21,588
	[0.00396]**	[0.00314]	[0.00466]	[0.00562]	
Measles	-0.0108	0.00311	-0.00834	0.00496	19,477
	[0.00412]**	[0.00928]	[0.00627]	[0.00761]	
Nutrition:					
Breastfeeding duration	-0.0248	0.405	-0.0676	-0.792	11,426
	[0.210]	[0.298]	[0.238]	[0.332]**	
Stimulation activities:					
Playing	-0.0154	0.00938	-0.00967	-0.0029	12,139
	[0.00707]**	[0.00526]*	[0.00549]*	[0.0124]	
Walking	-0.0149	0.00657	-0.0205	0.00389	12,139
	[0.00922]	[0.00994]	[0.00869]**	[0.0203]	
Reading	-0.00569	0.00345	-0.00184	-0.0192	12,139
	[0.00920]	[0.0135]	[0.00902]	[0.0210]	
Singing	0.0055	-0.00402	0.00616	-0.00832	12,139
	[0.00969]	[0.00940]	[0.00841]	[0.0170]	
Schooling:					
Preschool attendance	-0.0127	-0.00887	-0.0487	0.00241	263,760
	[0.00295]***	[0.00327]***	[0.00552]***	[0.00435]	
Never went to school	0.039	0.0119	0.00122	0.0021	182,777
	[0.00303]***	[0.00496]**	[0.00514]	[0.00284]	

Source: Research results.
Notes: Robust standard errors (in brackets) are clustered at municipality (or block) level. All child and maternal controls and year, month and municipality fixed effects are included. Urban dummy is also included. *** p<0.01, ** p<0.05, * p<0.1

Table 8. Estimated Impact of Temperature Changes on Maternal Labor Supply and Family Size

	(1)
Panel A: Dependent variable is maternal labor force participation	
Prenatal exposure during:	
1st trimester	0.000812
	[0.00287]
2st trimester	0.00458
	[0.00344]
3st trimester	-0.0016
	[0.00190]
Number of observations	606,500
Panel B: Dependent variable is additional children	
Prenatal exposure during:	
1st trimester	-0.00185
	[0.00219]
2st trimester	0.00378
	[0.00233]
3st trimester	-0.0113
	[0.00282]***
Number of observations	542,856

Source: Research results. Notes: Robust standard errors (in brackets) are clustered at municipality (or block) level. All child and maternal controls and year, month and municipality fixed effects are included. Urban dummy is also included. *** p<0.01, ** p<0.05, * p<0.1.