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# The effect of ambient temperature shocks during conception and early pregnancy on later life outcomes

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ABSTRACT

A large body of research has recently shown that early life or in utero shocks, especially climatic shocks, may affect long-run human capital outcomes. Most of these effects are assumed to be biological – including poor nutrition during critical windows of fetal development, or through increased maternal stress. However, in addition to these biological effects, climatic conditions at the time of conception may also cause changes in parental behavior, not only affecting the mix of parents who conceive, but also the characteristics of the children once born. This paper explores whether increases in ambient temperature at the time of conception, while in utero, or after birth affect educational and health outcomes as adults. Using Census and Demographic and Health Survey data from sub-Saharan Africa, we show that individuals conceived during high temperatures have higher educational attainment and literacy. In addition, we find evidence of temperature effects at other times in utero, especially during the first trimester. We then explore the biological and behavioral mechanisms through which this effect may occur, including heat-induced changes in sexual behavior, differences in parental characteristics, and intensified fetal selection. We conclude that fetal selection is the most likely mechanism driving our result.



## 1. Introduction

Human capital is a fundamental component of labor productivity and income. For this reason, over the past several decades scholars and policy makers alike have emphasized the importance of education and health in reducing poverty in the developing world. A large number of studies explore the potential for early life environmental or nutritional shocks, especially in early childhood or in utero, to affect health, cognitive ability, educational attainment and other human capital outcomes.[2] While this literature has well established the link between early life shocks and infant or child outcomes, a large but relatively smaller body of work looks at the long-run effects of these shocks. For example, Barker et al. (1990) famously argued that adverse nutritional shocks in utero affect the metabolic characteristics of the fetus which may lead to health

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[1] Research was completed before author began employment at AT&T.

[2] While this literature is much too voluminous to summarize here, please see Almond and Currie (2011), Almond and Mazumder (2011), Bleakley (2007), Chen and Zhou (2007), Cutler et al. (2010), Deschênes et al. (2009), Gluckman et al. (2008), Maccini and Yang (2009), and Nikolov (2012) for recent examples.

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problems later in life. But in practice, testing this hypothesis is difficult due to a range of competing factors, such as differential investment in less healthy children, fetal loss and natural selection, or behavior aimed at mitigating the effect of shocks.[3]

Recently, a considerable amount of attention has been placed on quantifying the effect of climate shocks on human capital outcomes given the interest in determining the "damage function" of climate change (Dell et al., 2014). This question is especially relevant given that most models of climate change not only predict an increased likelihood of extreme weather events, but also a disproportionate effect on the developing world – the area least able to mitigate the adverse effects of these shocks. Several studies have explored the effects of weather variables – such as rainfall, temperature, windstorms, and snowstorms – on a large number of dependent variables, including health outcomes. But most of these studies focus on the contemporaneous effects of temperature on health, and not on its long-run effect. For example, there is a small but growing literature examining the effect of current temperature on mortality, cardiovascular conditions, or respiratory problems (Barreca (2012), Burgess et al. (2017), Curriero et al. (2002), and Deschênes and Greenstone (2011)). Only two studies examine the effect of temperature shocks in utero on short-run health outcomes: Deschênes et al. (2009) who find that temperature spikes during the third trimester lower birth weight in the US, and Kudamatsu et al. (2012) who find that temperature in utero increases infant mortality in malarious and drought-prone areas of sub-Saharan Africa. And no studies link temperature in utero or after birth to any long-run human capital outcome.[4]

Another gap in the literature is the fact that the reduced form effect of temperature at the time of conception on long-run outcomes is likely to be very different than at other times in utero. For example, temperature changes may have heterogeneous effects on sexual behavior by socioeconomic status, affecting the mix of couples which select into pregnancy. Fetal loss also frequently occurs soon after conception.[5] Therefore, the effect of natural selection may be more pronounced at this time than later in pregnancy when a negative shock may be more likely to scar the fetus than cull it. Finally, since women do not know they are pregnant at the time of conception, they may react differently to shocks compared with when the pregnancy is known.[6] As a result, the reduced-form effect of temperature on children conceived during temperature spikes is a mix of biological effects, behavioral effects from parents, and selection effects which are not present at other times in utero. To our knowledge, there are no studies investigating the link between temperature at conception and outcomes.

We fill these gaps by testing whether temperature spikes at conception, in utero, and immediately after birth causally affect long-run human capital outcomes. In particular, this paper estimates the monthly effect of temperature shocks from 6 months before conception to 3 months after birth on educational attainment, literacy, and disability as adults in sub-Saharan Africa. We also test whether there is an effect on child mortality. Our methodology relies on using region-month of birth fixed effects to control for permanent geographic or seasonal characteristics which may affect these outcomes directly, allowing us to identify the effects using only the random variation in temperature. To do so, we merge gridded monthly weather data with the region, month, and year of birth of individuals found in Census records. Our Census data come from the six sub-Saharan African nations in the Integrated Public Use Microdata Series (IPUMS) International data repository for which detailed information on the timing of birth exists. These countries are Burkina Faso, Cameroon, Guinea, Malawi, Rwanda and Uganda. The gridded weather data are from Willmott and Matsuura (2012).

We find that larger temperature deviations around the time of conception and during early pregnancy are positively associated with better educational human capital outcomes later in life. For example, a one standard deviation shock in average monthly temperature nine months before birth increases years of schooling by 0.024 years, which corresponds to a 0.46% increase from the mean. Similarly, the probability of being literate increases by 0.37%. We find no statistically significant effect on disability status or infant mortality. In addition, we find that the effects of temperature 8 months before birth are 40–60% larger than the effects at conception, suggesting that the effects of temperature shocks are particularly important during very early pregnancy as well. We also sometimes find somewhat smaller effects in the third trimester as well. The effect of heat immediately after birth is similar to the magnitude and direction of the effect at conception for years of schooling and literacy, but again we do not find any effect of temperature shocks after birth for disability or infant mortality.

Given the reduced form nature of our results, it is important to keep in mind the limitations of our findings. If parents are engaged in compensatory investments in the human capital of the affected cohorts after birth, our results will be underestimated. In addition, temperature in utero may cause both scarring and culling of the fetus, leaving the overall effect the net of these two channels. Either way, our paper provides additional evidence and raises important questions for the literature on the fetal origins hypothesis.

We then tease out the unique mix of biological, behavioral, and selection effects by testing a series of potential mechanisms which may be driving these correlations. These channels include differential coital frequency by socioeconomic status

[3] See Almond and Currie (2011) for an extensive discussion of these issues.

[4] In fact, the only study to our knowledge which links any early-life climate variable with long-run outcomes is Maccini and Yang (2009) who find a positive effect of rainfall in the year of birth on self-reported adult health status, height, wealth, and educational attainment, but only for women. They find no effect for men.

[5] Boklage (1990) finds that 73% of natural single conceptions have no real chance of surviving 6 weeks of gestation, with most wastage occurring before detection. Wilcox et al. (1988) find that 22% of all pregnancies fail to implant, and Wilcox et al. (1999) find that of those which implant, 25% fail to survive an additional 2 weeks. 50 to 70% never become an established pregnancy while over 75 percent of conceptions do not lead to birth (Wilcox et al., 1988).

[6] Liu et al. (2014) note that over half of all conceptions terminate before the mother knows she is pregnant.