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Child health outcomes in sub-Saharan Africa: A comparison of changes in climate and socio-economic factors

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ABSTRACT

We compare changes in low birth weight and child malnutrition in 13 African countries under projected climate change versus socio-economic development scenarios. Climate scenarios are created by linking surface temperature gradients with declines in seasonal rainfall sea along with warming values of 1 °C and 2 °C. Socio-economic scenarios are developed by assigning regionally specific changes in access to household electricity and mother's education. Using these scenarios, in combination with established models of children's health, we investigate and compare the changes in predicted health outcomes. We find that the negative effects of warming and drying on child stunting could be mitigated by positive development trends associated with increasing mothers' educational status and household access to electricity. We find less potential for these trends to mitigate how warming and drying trends impact birth weights. In short, under warming and drying, the risk of more malnourished children is greater than the risk of more children with low birth weights, but increases in child malnutrition could be averted in regions that increase access to educational resources and basic infrastructure.

1. Introduction

Many in the scientific community are actively trying to determine the impact of a warming and drying planet on individual health and wellbeing (Brooks et al., 2005; Burke et al., 2015; McMichael, 2013). However, the evidence suggests that climate change has already begun to impact people in dramatic and measurable ways (Funk and Brown, 2009; McMichael, 2013; Morton, 2007). Increases in extreme weather events like droughts and floods, as well as wildfires, have all been linked to climate change (Allen et al., 2010; Flannigan et al., 2009). These events are likely to cause long lasting damage, including economic struggles, loss of life, and chronic impacts on overall health and development (Asseng et al., 2015; Brown and Funk, 2008; Dellink et al., 2017; Jones and Thornton, 2003; Moore and Diaz, 2015; Parry et al., 2004). There is also increasing evidence of negative health impacts associated with warming and drying trends among some of the very youngest people – newly born infants and very young children (Grace et al., 2015; McMichael, 2013). The relationship between warming, drying, and child health is especially pronounced in sub-Saharan Africa (SSA) – a region with a history of chronic food insecurity, poor health outcomes and, more recently, increased temperatures and decreased rainfall (Funk et al., 2008b).

Warming temperatures, decreasing rainfall and increasing variability in rainfall and temperature are associated with low birth weights and child stunting (a measure of malnutrition), both of which are related to chronic health issues in SSA (Funk and Brown, 2009; Funk et al., 2008b; Grace et al., 2012, 2015; Verdin et al., 2005). Prior research suggests that low birth weights and stunted growth result from combined exposure to poverty along with both extremes and variability in temperature and rainfall (Balk et al., 2005; Grace et al., 2012, 2015). The relationship between child health and weather stems from the combined influences of in utero heat stress along with undernutrition from crop and livestock loss related to rainfall shortages and inconsistent seasonal patterns. Chronic seasonal crop and livestock loss is a serious concern in SSA as subsistence and small-scale farming dominate the food systems of most SSA countries (Jones and Thornton, 2003; Morton, 2007). Overall the evidence suggests that if SSA gets warmer and dryer, the region may see increases both in the number of babies born with low birth weight and in the number of children suffering from chronic malnutrition (Balk et al., 2005; Grace et al., 2012, 2015).

On the other hand, it is possible that the increases in low birth weights and child malnutrition induced by warming, drying, and climatic variability might be mitigated by positive socio-economic development trends. Increased access to basic infrastructure could provide

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relief from heat and water stress and weather instability. More educational opportunities can broaden labor force participation beyond subsistence agriculture. However, the mitigating impacts of development trends across and within SSA countries have been mixed: not all areas are improving and areas that are getting better are not doing so at the same rate. Places that experience extreme weather events and increased variability along with decreased access to infrastructure and education are at increased risk of poor health outcomes. *If positive development trends continue, will they compensate for the negative health outcomes induced by warming and drying and within-season variation? If development trends reverse and people lose access to infrastructure and educational resources, how might this exacerbate low birth weights and child malnutrition in areas that are becoming warmer and dryer? How will these effects vary across urban and rural populations? Will populations dependent primarily on crop production for their livelihoods fare the same as those dependent on livestock?*

The goal of this paper is to begin to answer these questions by using empirical models to generate combined climate and development scenarios. We use these scenarios to explore the relative effects of socio-economic development and climate trends on household-level child health outcomes. Using household survey data from 13 SSA countries we examine spatially explicit child health outcomes under varying degrees of warming, drying, and socio-economic development. Specifically, we examine how joint changes in the mother's education and access to electricity influence birth weights and child stunting. We examine these changes under warming and drying scenarios, and we compare results across countries and livelihood zones. By examining changes in predicted values under various scenarios we quantify the differential impacts of investment in climate change mitigation versus factors associated with development. We note that our goal of using a scenario-based approach, consistent with the historical use of scenarios, is to establish a sense of the range of our outcome variables and the related uncertainty in human response (Bradfield et al., 2005; Moss et al., 2010). A scenario approach allows for an investigation of the potential impacts of *changes* in certain factors that already have an established link to the outcomes under study (Moss et al., 2010). We *do not intend to predict future outcomes*, but instead wish to provide a perspective on the relative influence of probable future changes in development versus climate factors as they impact children's health.

The next section of the paper (Section 2) summarizes prior research on the relationships among climate, weather, development, and health outcomes and then outlines our scenario analysis approach. Sections 3 and 4 present the data, methods, and results. The following section (Section 5) summarizes and concludes and the two supporting appendices provide more detailed information regarding our precipitation scenarios and empirical results.

2. Background

2.1. Climate, weather, development, and health outcomes

We focus on the ways that climate and development scenarios influence health outcomes in some of the poorest and most climatically sensitive places on the planet. Specifically, we investigate how birth weight and child stunting vary as a response to different scenarios across thirteen of the poorest sub-Saharan African countries. These outcomes are selected for two reasons: (1) prior research has already established a link between low birth weight, stunting occurrence, and climate related stress in selected African countries (Grace et al., 2012, 2015); and (2) Low birth weights and stunted growth can lead to impaired health and productivity in adulthood (Alderman et al., 2002; Hoddinott et al., 2008; Jamison, 1986). As an example, children who were born low birth weight or who experience stunting are less likely to attend school and achieve the income earning levels of their peers (Alderman et al., 2006; Black et al., 2008). The developmental challenges faced by low birth weight babies and undernourished children are considered a leading cause of intergenerational poverty transmission (Grantham-McGregor et al., 2007). Given the multi-generational effects of low birth weight and stunting, reducing the rates of these mostly preventable conditions is vital to the long-term economic development of poor countries.

2.1.1. Socio-economic factors and child health

Because there is already an expansive and detailed literature addressing the correlates or causes of these conditions in sub-Saharan Africa, we can select a suite of independent variables with known relationships to birth weight and child stunting. For example, more educated mothers, relative to their country-norms, who are in the middle of their childbearing years, and space their children around three years apart are less likely to have low birth weight or stunted children (Grace et al., 2015).

Increased education is linked to positive maternal and child health outcomes for a variety of reasons. Among the theorized links is the increased understanding of nutrition (Glewwe, 1999; Engle et al., 1999; Barrera, 1990), increased household income, or strengthened maternal bargaining power that may accompany higher education (Frost et al., 2005), as well as the possibility that more time spent in a formal educational setting contributes to a greater maternal understanding of public institutions related to health and aid procurement (Joshi, 1994). Given the varying levels of development within the countries under study in this investigation, the role of and access to education may be somewhat relative within country. In other words, secondary education may be attainable to most urban dwellers in Kenya but much less attainable to those urban dwellers in Mali.

Increased access to public infrastructure, specifically electricity, is also found to benefit the most malnourished children, although this effect varies from urban to rural areas (Bassole, 2007). Electricity may serve as a proxy measure of household income. Electricity could also serve as a way for people to reduce their risk of heat stress through fan/air conditioner use and ownership or provide greater access to information if it is used to power televisions (see, Fay et al., 2005).

2.1.2. Warming, drying and child health

The relationship between climate change and low birth weight and stunting is both direct, likely because of heat stress and dehydration, and indirect, likely connected through food production failures.

The research linking birth weights with climate focuses on developed-world births (Cooperstock and Wolfe, 1986; Keller and Nugent, 1983; Rayco-Solon et al., 2005). Of the investigations focused on low-income communities, Rousham and Gracey (1998) found a connection between very low birth weight babies (those weighing less than 1500 g) and the wet season, but did not find a connection among larger low birth weight infants. In studies focused on African infants, agricultural production and food insecurity seems to primarily explain incidence of low birth weight (Grace et al., 2015; Rayco-Solon et al., 2005). Without consideration of food and agricultural production, ambient temperature has been linked to LBW as pregnant women are theorized to face increased emotional and physical strain due to high ambient temperatures (Prentice, 1989; Wells and Cole, 2002). However, Strand et al. (2011) suggest that because low temperatures may also have a negative impact on birth weight outcomes, extreme temperatures may be at the root of the link between temperature and birth weight. LBW is also associated with preterm birth, which may also result from extreme weather (Basu et al., 2010; Rousham and Gracey, 1998; Wang et al., 2013).

With regard to child malnutrition, prior evidence suggests that agricultural production and food insecurity are among the main mechanisms linking climate and child health. Children who are at the highest risk of increased rates of chronic malnutrition induced by warming and drying tend to be those dependent on regional and rain-fed dependent agricultural food production to meet caloric requirements (Brown et al., 2014, 2015; Shively et al., 2015). Because poor