# The Nitrogen Legacy: Long-Term Effects of Water Pollution on Human Capital

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The Green Revolution, starting in the mid-1960s, was a watershed moment in Indian agriculture. Along with a rapid increase in agricultural productivity, it also led to a dramatic rise in the consumption of synthetic nitrogenous fertilizers such as nitrogen-phosphate-potassium (NPK). The five-fold rise in the use of NPK fertilizers per hectare of cultivated land since the mid-1960s resulted in profound changes to the nitrogen cycle and exacted a toll on India's waters — runoff of excess nitrogen from fields increased concentrations of nitrate and nitrite in the rivers to harmful levels (Fields, 2004). Despite ecological evidence of too much nitrogen on the environment such as algal blooms, much less is known about its toll on humans. Prior work has shown adverse health effects on children such as a rise in infant mortality due to agrichemical pollution in India ( Brainerd and Menon, 2014). In this paper we provide new evidence of the legacy effects of nitrogen pollution and contribute to a growing literature on the persistent effects of early-life exposure on later life health outcomes (Currie and Vogl, 2013).

We combine data from multiple sources to conduct our analysis. We compile a rich dataset of water pollution measurements along rivers in India collected by the Central Water Commission as well as the Central Pollution Control Board. The dataset includes 50,000 observations from 1000 monitoring stations along 145 rivers between the years 1970-2016. Since the pollution measures are not consistently recorded over the entire sample time frame, we also use a novel spatial statistical network model for stream data to interpolate and fill in missing observations across monitor-year pairs (Peterson and Hoef, 2010). We focus on cumulative exposure to nitrates and nitrites when the concentrations exceed the EPA recommended threshold of 10 mg/l from the year of birth to age 3. Prior work has shown that the first 1000 days of a child's life are the most critical for early childhood development. We trace the birth-year histories of all adult women in the most recent 2015 Demographic and Health Survey for India ranging from 1966 to 1999, a period when the full effect of the Green Revolution was already in force. We then compare later-life health outcomes among cohorts with more and less pollution exposure after accounting for a rich set of controls like birth-year, birth-month, district fixed effects, state-trends as well as temperature and precipitation at the time of birth, and individual characteristics that are salient to the Indian context such as religion and caste.

To estimate the long-run health impacts of childhood pollution exposure, we require exogenous measures of pollution since pollution can be correlated with other factors that can affect health. Our research design, therefore, exploits the direction of river flow and the upstream-downstream geographic relationship used in past literature (Do et al. 2018; Garg et al. 2016) to estimate a pollution-health dose-response function. Since pollution can only flow downstream, pollution

upstream is orthogonal to downstream health. In our analysis, we measure how health downstream is impacted by cumulative exposure to upstream nitrate-nitrite pollution

Preliminary findings show that women exposed to nitrate-nitrite pollution in their earliest years of life are shorter on average by 2 cm. They are also 2% more likely to experience a stillbirth in adulthood than women of similar circumstances who were not exposed to such pollution. Early-life exposure to nitrate-nitrite pollution also lowers later-life labor productivity and depresses adult wages decreasing overall welfare.

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