Journal of Development Economics 107 (2014) 49–64

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Seasonal effects of water quality: The hidden costs of the Green Revolution to infant and child health in India☆

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ARTICLE INFO

Article history:
Received 15 October 2012
Received in revised form 8 November 2013
Accepted 13 November 2013

JEL classification:
O12
I15
Q53
Q56

Keywords:
Fertilizer agrichemicals
Water pollutants
Child health
Infant mortality
India

ABSTRACT

This paper examines the impact of fertilizer agrichemicals in water on infant and child health using water quality data combined with data on child health outcomes from the Demographic and Health Surveys of India. Because fertilizers are applied at specific times in the growing season, the concentrations of agrichemicals in water vary seasonally and by cropped area as some Indian states plant predominantly summer crops while others plant winter crops. Our identification strategy exploits the differing timing of the planting seasons across states and differing seasonal prenatal exposure to agrichemicals to identify the impact of agrichemical contamination on various measures of child health. The results indicate that children exposed to higher concentrations of agrichemicals during their first month experience worse health outcomes on a variety of measures; these effects are largest among the most vulnerable groups, particularly the children of uneducated poor women living in rural India.

1. Introduction

The Green Revolution in India transformed the country from one heavily reliant on imported grains and prone to famine to a country largely able to feed itself and successful in achieving its goal of food security. Yields of the country's main crops, wheat and rice, increased dramatically and farmers prospered from the use of Green Revolution technologies including high-yield variety seeds, irrigation, pesticides and nitrogenous fertilizer. The growth in agricultural production improved the well-being of millions of Indians by reducing the incidence of hunger and raising the living standard of the rural poor, but it also exacted a toll on the country's environment. In particular, the heavy use of fertilizers to increase yields led to high levels of toxicity and contamination of surface and ground water in India.

This paper examines the impact of fertilizer agrichemicals in water on infant and child health in India. We study agro-contaminants in water as it is considered to be a reliable measure of human exposure, and use data on water quality from monitoring stations run by India's Central Pollution Control Board (CPCB) combined with data on the health outcomes of infants and children from the 1992–93, 1998–99, and 2005–06 Demographic and Health Surveys (DHS) of India. We focus on fertilizers because they have relatively clear application times, unlike pesticides which may be used (based on need) throughout the crop cycle.[2] Because fertilizers are applied early in the growing season and residues may subsequently seep into water through soil run-off, the concentrations of agrichemicals in water vary seasonally; water contamination also varies regionally by cropped area in India because states in

☆ Thanks to Andrew Foster, Dilip Mookherjee, and John Strauss for comments on research design. Thanks to Linda Bui, Sonia Bhalotra, Rema Hanna and seminar participants at Brandeis, the IGC-ISI Conference in New Delhi, India, Williams College, the Fletcher School for Law and Diplomacy at Tufts University, IGC Growth Week 2012, NEUDC 2012, ISI Economic Growth and Development Conference 2012, CSAE Oxford 2013, PAA 2013, IGC-ISI South Asia Growth Conference 2013 and Brown. We are grateful to Rema Hanna and Michael Greenstone for sharing their subset of Central Pollution Control Board's (CPCB) data on water pollution measures. We extend our gratitude to many people at CPCB especially J.S. Kamyotra, D.D. Basu, and Rajendra Bhardwaj for facilitating access to and for answering numerous questions on the water data. Thanks to Kelly Hodgson at the UNEP GEMS/Water Program for help with the India data and to two anonymous referees whose comments have improved the paper. Menon thanks the International Growth Center's India Central Program for financial support. Yubing Cui, Carol Hughes-Hallett Ramos, Tarini Nalwa, Udit Patwardhan, and Ari Pipe-Mazo provided excellent research assistance. The usual disclaimer applies.

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[2] Furthermore, unlike fertilizer, pesticide use in India has remained relatively stable across the years we analyze. Moreover, note that our measure of fertilizer includes the agrichemicals that comprise pesticides.

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http://dx.doi.org/10.1016/j.jdeveco.2013.11.004

northern India plant predominantly winter crops while southern Indian states plant mainly summer crops. Our identification strategy exploits the increase in fertilizer use over time in India, the differing timing of the crop planting seasons across India's states, and the differing seasonal prenatal exposure of infants and children to identify the impact of fertilizer agrichemical contaminants in water on various measures of child health.

Our analysis of the effects of agrichemicals provides several noteworthy results. We find that the presence of fertilizer chemicals in water in the month of conception significantly increases the likelihood of infant mortality, particularly neo-natal mortality. The presence of toxins in water in the first month is also significantly associated with reduced height-for-age and weight-for-age z scores for children below five years of age. These effects are most pronounced among vulnerable populations, in particular the children of uneducated poor women living in rural India.

Evaluating the link between water agrichemical contamination and child health in India is important for several reasons. First, in rural India, women form 55–60% of the agricultural labor force and are often at the forefront of farming activities. This suggests that they are directly exposed to chemical applications that are made to the soil to improve productivity; their children are exposed both in utero and after birth to these toxins and at these young ages are highly vulnerable to environmental insults. This exposure may contribute to the relatively poor indicators of child health in India: Indian children have one of the highest rates of stunting and wasting among all developing countries. These rates are higher than predicted given the level of per capita income and infant mortality rates in the country.[3] Second, since water is motile, high levels of chemical contaminants in water have the potential to affect individuals outside of farming communities. Third, evidence from biomedical studies indicates that seasonal exposure to water toxins can affect health outcomes not only in the current population but also in subsequent generations. For example, illnesses such as coronary heart disease — which have been shown to be more likely in adults who as babies were of low-birth weight — are inheritable and may be bequeathed to subsequent generations. Such transmission occurs even without any additional exposure to the chemical contaminants that caused the health problems in the preceding generation. The importance of fetal health is emphasized in Behrman and Rosenzweig's (2004) study which demonstrates that fetal nutrition as measured by birth-weight is a significant determinant of adult earnings. With a few exceptions, the impact of water pollution on all of these dimensions of health in developing countries has largely been neglected in the economics literature, as we discuss below.

The paper is structured as follows. The next section provides a brief overview of the economics, public health and biomedical literature on pollution and child health outcomes in developed and developing countries. The section that follows describes the implementation and impact of the Green Revolution in India, the features of the planting and growing seasons of rice and wheat which we exploit in the paper, and water quality and its regulation in India. We then describe our methodology and data and present our results. Robustness checks are presented thereafter, followed by an analysis of heterogeneity in the impact of water pollution on various subgroups of the population. The paper concludes with a discussion of implications for policy.

2. Previous literature

This research fits into several strands of literature in economics. An active area of current research examines the impact of air pollution and other contaminants on infant mortality and child health in developed countries. Many of these studies focus on the United States and use the discontinuity in air pollution created by plausibly exogenous events such as the Clean Air Act, economic recession which reduces industrial activity and emissions, and the introduction of electronic tolls on highways which reduced idling time and car exhaust for identification. These studies document a statistically significant and quantitatively large effect of reduced air pollution on infant and child health (Chay and Greenstone, 2003; Currie and Walker, 2011; Sanders and Stoecker, 2011).[4] Other papers analyzing the impact of negative health shocks on infants in utero, such as exposure to the 1918 influenza epidemic and radiation fallout from the 1986 Chernobyl disaster (Almond, 2006; Almond et al., 2009), further confirm the vulnerability of infants to prenatal exposure to contaminants and underscore the long-lasting effects such exposure can have, extending well into adulthood.[5]

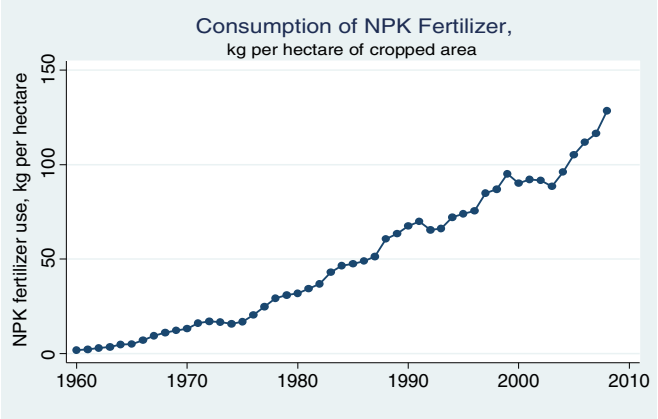

Fig. 1. Trend in consumption of NPK fertilizer in India.
Source: Statistical abstract of India. Various years.

Relatively few studies have examined the impact of pollution on health in developing countries, and these have primarily considered the effects of air pollution on child and adult health (for example, Arceo-Gomez et al., 2012; Jayachandran, 2009; Pitt et al., 2006). The work most closely related to ours is Greenstone and Hanna (2011) which assesses the impact of air and water quality regulations on infant mortality across Indian cities for the years 1986–2005. Using air and water pollution data from India's CPCB combined with data on air and water quality regulations, they find that air quality regulations significantly reduced air pollution, which in turn led to a statistically insignificant reduction in infant mortality. However, the water pollution regulations have been ineffective at reducing measures of surface water pollution. As these authors discussed, the implementation of the water quality policies appears to be weak and underfunded in India; the paper does not investigate the effect of fertilizer agrichemicals in water.

A second strand of literature examines the contributions of public health measures (e.g., reduced exposure to lead; enhanced water quality) to improvements in population health. Studies in this area include that of Cutler and Miller (2005), which demonstrates that access to clean water through filtration and chlorination was associated with large reductions in infant and child mortality between 1900 and 1936 in the United States. Similarly, the privatization of local water companies in Argentina in the 1990s was associated with increased access to clean water and significant reductions in child mortality (Galiani et al., 2005). Other recent papers, including those of Zhang (2012) and Ebenstein (2012), document the health impacts of improved water quality in China.

[3] See Deaton and Drèze (2009) for a discussion of the relatively low anthropometric indicators for Indian children.

[4] See Almond and Currie (2010) for a comprehensive review of this literature.

[5] Currie and Vogl (2012) provide a detailed survey of the literature on the impact of early-life health shocks on adult outcomes in developing countries. Recent papers in this line of research include Maccini and Yang (2009) and McEniry and Palloni (2010).