Seasonal Effects of Water Quality on Infant and Child Health in India

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Abstract: This paper examines the impact of fertilizer agrichemicals in water on infant and child health using data on water quality combined with data on the health outcomes of infants and children from the 1992-93, 1998-99, and 2005-06 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 regions 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 (infant mortality, neo-natal mortality, height-for-age z scores and weight-for-age z-scores). Disaggregated runs reveal that effects are largest amongst the most vulnerable groups - children of uneducated poor women living in rural India.

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I. 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.[1] 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 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

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

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 modestly associated with reduced birth weight and the probability of the child being male, and 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, particularly 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 percent 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 toxins. 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.[2] Second, since water is motile, high levels of chemical contaminants in water have the potential to affect individuals outside of farming communities. Thus, elevation in pollutant levels in water that occur in crop-sowing months in rural areas may negatively impact women and children outside of rural agriculture. 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

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

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 nutrition as measured by birth weight is also emphasized in Behrman and Rosenzweig (2004) which demonstrates that weight at birth is a significant factor in determining levels of adult earnings and adult height. 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 main results. Robustness checks are presented thereafter and the paper concludes with a discussion of implications for policy.

II. 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. 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).[3] 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, Edlund and Palme 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.

Relatively few studies have examined the impact of pollution on health in developing countries, and these have primarily considered the effects of indoor air pollution on child and adult health (for example, 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 1986-2007. 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 discuss, the implementation of the water quality policies appears to be weak and underfunded in India. In this paper Greenstone and Hanna (2011) evaluate the effect of three consistently measured water pollutants – faecal coliform, biochemical oxygen demand, and dissolved oxygen. Their study does not consider the implications 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 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

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

associated with increased access to clean water and significant reductions in child mortality (Galiani *et al*. 2005). Other recent papers document the health impacts of improved water quality in China, such as Zhang (2012) and Ebenstein (2012).

Biomedical studies in the developed world document the relationship between chemicals in water and risks to adult and infant health relatively well. Winchester *et al*. (2009) shows that in the United States (US), there is a significant correlation between seasons of high agrichemical content in water and total birth defects. Garry *et al*. (2002) finds that in Minnesota, pesticide applicators had high rates of specific birth defects, and that the risk was most pronounced for infants conceived in the crop-sowing spring months of April to June. Public health studies of poor water quality in developing countries include Heeren *et al*. (2003) and Restropo *et al*. (1990). Heeren *et al*. (2003) reports a positive correlation between agricultural chemical exposure and birth defects in South Africa, whereas Restropo *et al*. (1990) analyzes the prevalence of abortions, prematurity, and stillbirths among female workers and wives of male workers employed in the floriculture industry of Colombia where pesticide use is widespread. Given resource constraints and high contamination levels, it is likely that the damaging impacts of agrichemicals in water are more pronounced and widespread in other poor countries such as India.[4] An evaluation of this topic using the lens of economics is thus highly relevant.

III. The Green Revolution, Agriculture, and Water Quality in India

At independence in 1947, agriculture in India was characterized by labor-intensive subsistence farming methods that resulted in low yields and continued vulnerability to inadequate food supplies. The country had suffered a devastating famine – the Bengal famine of 1943 – in which an estimated two to four million people died and which has been discussed before in the economics literature (Sen 1977).

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[4] Indeed we find state and year-level evidence that the incidence of miscarriages, stillbirths, and abortions is positively associated with levels of nitrogen in water; the incidence of having a prematurely born child is positively associated with levels of nitrogen and phosphate. These results are not reported in the paper but are available on request.

Indian leaders considered food security to be of paramount importance after independence and implemented programs to achieve this goal including promotion of modern farming techniques broadly referred to as the “Green Revolution.” These techniques were implemented across many developing countries including India beginning in the mid-1960s. Green Revolution methods primarily entailed (i) increased area under farming; (ii) increased use of irrigation; (iii) double-cropping, that is planting two crops rather than one annually; (iv) adoption of high-yield variety (HYV) seeds; and (v) significantly increased use of inorganic fertilizers and pesticides.

HYV seeds can increase crop yields by two to four times those of indigenous seeds, but they require more fertilizer and water than do indigenous seeds. Besides high yields, these seeds also have a shorter growing cycle than traditional seeds and thus in some areas crops may be planted twice (double cropped). The main HYV seeds used in India were wheat (K68) and rice (IR8, or “Miracle Rice”). The diffusion of HYV seeds proceeded rapidly in India, particularly for wheat; for example the share of acreage under wheat sown with HYV seeds increased from 4.1 percent in the first year of the program (1966-67) to 30.0 percent only two years later. Over the same period, consumption of nitrogenous fertilizer increased from 658,700 metric tons to 1,196,700 metric tons, and consumption of phosphatic and potassic fertilizer increased in similar proportions (Chakravarti 1973).

Production of the country’s main crops, wheat and rice, increased dramatically after the Green Revolution. Over a span of thirty years from 1960 to 1990, wheat production increased by more than five times (from 10 million tons to 55 million tons) and there was a greater than two-fold increase in rice production (from 32 million tons to 74 million tons).[5] India became a net exporter of rice and wheat in 1978 (Chand 2001) and famine has not reappeared in the country since independence. At the same time, consumption of synthetic nitrogen-based fertilizers such as Urea and Nitrogen-Phosphate-Potassium

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[5] Directorate of Economics and Statistics, Dept. of Agriculture and Cooperation, Ministry of Agriculture, India.

(NPK) fertilizers rose almost nine-fold in India from the early 1960s to 2003-2004.[6] Figure 1 illustrates the rapid increase in use of NPK fertilizers per hectare under cultivation between 1960 and 2008. These fertilizers are heavily subsidized by the Government of India and recent research suggests that the large subsidies are directly responsible for the overuse of nitrogen based fertilizers in many regions.[7]

The liberal use of agrochemicals has worked in tandem with rapid industrial growth in recent times to lead to high levels of water pollution in India. Water quality is monitored by India's CPCB which was established in 1974 as part of the Water Act of 1974. This legislation represented India's first effort to reduce water pollution and focused primarily on reducing industrial water pollution and extending sewage treatment facilities rather than reducing the prevalence of agrochemicals. As discussed in Greenstone and Hanna (2011), the water quality regulations have had a negligible impact to date mainly because of faulty implementation.

Although a cross-country comparison of water quality may in general be inappropriate given differing regulations and circumstances, it serves to paint a picture of water contamination in India relative to other countries. As noted in Greenstone and Hanna (2011), water pollution concentrations in India are higher than in other countries such as China and the United States. Focusing specifically on nitrogen (the primary composite of fertilizers such as NPK) measured in milligrams per liter (mg/l), Figure 2 shows that the average nitrogen level in Indian water bodies is significantly higher than in the U.S. and China over a comparable time period. India's dominance in nitrogen consumption is evident even in relation to Pakistan, a neighboring country that shares many agricultural and socio-economic practices.

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[6] Tewatia, R.K., and T.K. Chanda (2005). "Fertilizer Use by Crop," in Fertilizer Use by Crop in India. Rome: Food and Agriculture Organization of the United Nations. Chapter 4.

[7] Chattopadhay, G.N., B.C. Roy, and R. Tirado (2009). Subsidising Food Crisis. Bangalore: Greenpeace India. See Bardhan and Mookherjee (2011) for an analysis of one of the subsidized farm input programs implemented in West Bengal from 1982-1995, which included provision of HYV seeds, pesticides, and fertilizers.

Moreover, the concentration of agrochemicals in water is likely to be higher in months in which crops are sown. In the Netherlands, atrazine concentration peaks in June, the month when the herbicide of which it is a component is widely applied for weed control purposes (Carr and Neary 2008). In the United States, Winchester *et al*. (2009) demonstrate that nitrate concentration in surface water is at its peak level in the spring months of April to June when crops are sown. The same pattern is evident in our water quality data for India. This is seen in Figures 3 and 4 which portray monthly data on levels of nitrogen and phosphate concentration in water by type of agricultural region. The bulk of wheat production in India occurs in the northern states of Uttar Pradesh, Punjab, Haryana, Bihar, Madhya Pradesh and Gujarat. Wheat is a *rabi* (winter) crop sown beginning in November through to April and harvested from late spring onwards. As illustrated in Figure 3, nitrogen concentrations peak in April and May in the wheat-producing states but not in the non-wheat-producing states, as expected. The bulk of rice production in India occurs in the southern states of Andhra Pradesh, Tamil Nadu and Kerala and in the eastern states of Orissa, West Bengal and Assam; rice is a *kharif* (summer) crop and is mainly sown in June-August and reaped in autumn. Figure 4 shows that phosphate concentrations peak in September in the rice-producing states but not in the non-rice-producing states.[8] It is these differences in soil endowments across the country making some regions more suitable for rice production and others for wheat production, and differences in the timing of crop cycles for these two main crops which allow us to identify the impact of water agro-toxins on infant and child health.

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[8] We present a graph for phosphate concentration for rice since nitrogen is very soluble in water (Tonn 2004) and the cultivation of rice involves two stages – sowing and transplantation – both of which are water-intensive. Since phosphates are relatively less soluble in water, a distinct peak in its concentration is evident in rice-producing states compared to other states (no clear pattern is discernible when we look at relative nitrogen concentrations in rice states). Further, the sowing season for rice is less clear-cut as compared to wheat. There could be several rice harvests in a year, particularly in southern India where soil and climate are more amenable. We focus on the *kharif* crop for rice as this is the larger harvest. This also contributes to the lack of discernible patterns in nitrogen concentration for rice since the *kharif* season coincides with the arrival of the annual monsoons in India. As noted in Ebenstein *et al*. (2011), rainfall may dilute the presence of agrichemicals by supplying quantities of clean water.

In the following section, we describe the econometric framework which is used to evaluate the causal association between fertilizer agro-contaminants and child health in India.

IV. Identification Methodology

The main question is whether live births resulting from conceptions during months of the year when fertilizer agrichemicals in water are at their highest levels (the early cropping season in wheat and rice producing regions) face greater risk of negative health outcomes such as infant mortality, low birth-weight and low levels of attainment on height-for-age and weight-for-age z scores as of age five. In its simplest form, this may be answered by estimating the following empirical specification:

$$H_{ijt} = \beta_0 + \beta_1 F_{jtm_c} + \beta_2 P_{jtm_c} + \beta_3 X_{ijt}^{c} + \beta_4 X_{ijt}^{w} + \beta_5 X_{ijt}^{h} + \beta_6 X_{ijt}^{HH} + \beta_7 X_{jt}$$

$$+\beta_8 M_c + \beta_9 T_c + \beta_{10} S_j + \beta_{11}(M_c \, x \, S_j) + \beta_{12}(T_c \, x \, S_j) + \varepsilon_{ijt} \qquad (1)$$

where H_{ijt} denotes a health outcome for child *i* in state *j* in year *t*, F_{jtm_c} denotes the average of a dummy that measures presence of fertilizer agrichemicals in water in the state and year in m_c, the month of conception, and P_{jtm_c} measures the presence of other water pollutants that originate from industrial activity and human presence in the state and year in m_c. X_{ijt}^{c} are child-specific indicators (order of birth, gender, whether nursed after birth, whether delivered by caesarian-section), X_{ijt}^{w} are woman (mother)-specific indicators (measures of maternal risk factors such as tobacco use and work characteristics and mother's demographic characteristics including age, education, and general health), X_{ijt}^{h} are husband (father)-specific indicators (age, education, and type of work), X_{ijt}^{HH} are household-specific indicators (rural/urban indicator, age and gender of household head, household religion and caste, indicator for access to electricity and ownership of assets such as refrigerators, televisions, and motorcycles as well as information on sources of drinking water), and X_{jt} are state-specific indicators (per capita net state domestic product, annual rainfall, territorial location in India). In order to control for month and year-specific time trends and regional level heterogeneity, equation (1) includes month of conception dummies (M_c), year of conception dummies (T_c), region dummies (S_j), and interactions of month of conception and region dummies and year of conception and region dummies. ε_{ijt} is the standard idiosyncratic error term. The coefficient of interest is β_1: the impact of fertilizer agrichemicals in the month of conception on child health outcomes.

We use state-year-month information on the presence of agrichemicals in water to measure *in utero* exposure to fertilizer toxins (F_{jtm_c}). For a variety of reasons it is likely that this variable is measured with error. First, there could be measurement errors in the early days of water monitoring when technology was relatively primitive and not all agrichemicals were evaluated (1979-1987). Second, the number of monitoring stations has increased significantly over time (188 in 1979-1987 to 870 as of 2005). Thus early measures of water quality are less likely to accurately portray ground realities at an all-India level. Third, unlike measures of general water pollutants which are collected directly, we construct an indicator for presence of fertilizer agrichemicals in water based on the chemical composition of fertilizers (described below).[9] We allow for errors in its measurement since it is a constructed variable. Finally, lacking information on village or district of residence of women and their children in the DHS data, we match demographic data to the water data on the basis of state of residence. The use of state-level information is a proxy for the level of toxins women and children are exposed to in their environment; the use of this proxy may result in additional errors in measurement.

For these reasons, we use instrumental variables to correct for measurement error in order to isolate the exogenous component of agrichemicals and obtain an unbiased estimate of β_1 in equation (1). The identifying instruments that we use are interactions of crop area (area planted in the state with *kharif* rice normalized by total state area; area planted in the state with *rabi* wheat normalized by total state area) and crop sowing months (indicator for months of the year when *kharif* rice and *rabi* wheat are

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[9] For this reason, we assume that there is measurement error in agrichemicals but not in general water pollutants – faecal coliform, biochemical oxygen demand, and dissolved oxygen.

sown in different states of India). Since planting seasons across India's regions do not coincide for the main crops of rice and wheat, this is a source of variation that may be exploited to establish causal links between water agro-contaminants and child health. Our two stage least squares model is of the standard form where the first stage (written as a function of the identifying instruments only) is:

$$F_{jtm_c} = \gamma_0 + \gamma_1\,(R_j\ x\ M^R) + \ \gamma_2(W_j\ x\ M^W) +_{\vartheta_{ij}} \qquad (2)$$

R_j and W_j denote normalized crop area for rice and wheat, respectively. M^R and M^W are indicators for months of the year when rice and wheat crops are sown, respectively. The interaction terms in equation (2) are the identifying instruments; however as discussed in Table 6 below, the first stage in the empirical specifications also includes a full set of (non-identifying) exogenous regressors. The second stage is similar to equation (1) except that F_{jtm_c} is replaced by $\widehat{F_{jtm_c}}$, its orthogonal component from (2).

In this two stage specification, the identifying assumption required for the effects to be interpreted as causal is that the instruments satisfy the exclusion restriction (correlated with the presence of agrichemicals in water but, conditional on agrichemicals, uncorrelated with child health outcomes), and there are no omitted variables that are both correlated with health outcomes and seasonal levels of water pollution. We present tests of instrument validity below.

V. Data

Water Data

The water quality data are from the Central Pollution Control Board (CPCB) of India, which, as of 2005, monitors inland water quality at 870 stations under two programs: the Global Environment Monitoring System (GEMS) and Monitoring of Indian National Aquatic Resources (MINARS). The monitoring network covers all rivers and their tributaries, and other sources of water such as creeks, wells, tanks, lakes, ponds, and canals. Although CPCB has collected water data from 1978 onwards, they maintain electronic records only from 2005. Computable water quality information on CPCB measures was compiled from two other sources – UNEP GEMS/Water program that computerized CPCB records from 1978 to 2005 for a subset of monitoring stations, and Greenstone and Hanna (2011) that uses electronic water quality data from 1986 to 2005 for a subset of monitoring station (489 stations in 424 cities). Remaining gaps were filled by using information from annual water quality statistics publications obtained from CPCB (we assumed that the annual average level is the same as the missing monthly value for the corresponding state and year) to create our complete monthly-level water quality data which spans 1978-2005. We end at 2005 since that year coincides with the last round of DHS data.

CPCB collects detailed water quality statistics on a number of measures. These include information on microbiology (faecal coliform, total coliform), nutrients (ammonia, nitrates, nitrites, nitrogen kjeldahl, phosphates), organic matter (biochemical oxygen demand), major ions (calcium, chloride, fluoride, magnesium, potassium, sodium, sulphates), metals (arsenic, boron, cadmium, lead mercury, zinc) and physical/chemical characteristics of water (alkalinity, dissolved oxygen, hardness, pH, turbidity, temperature). As general controls for water pollution, we include measures of faecal coliform, biochemical oxygen demand (BOD) and dissolved oxygen in all models. Higher levels of faecal coliform and BOD (the main source of which is industrial pollutants) are associated with more pollution; higher levels of dissolved oxygen are associated with less pollution. Figure 5 reports the trend in the average levels of these measures in our sample. Declines in the log value of faecal coliform and increases in dissolved oxygen suggest some improvement in these water quality measures over time. However, the more than one and half times increase in the level of BOD in the 2000-2005 time period compared to earlier years indicates that industrial pollutants have contributed to a serious contamination of water in India in recent times.

In addition to general controls for water pollution, we require a measure of the presence of fertilizer agrichemicals in water. Since there is no measure for the presence of fertilizers in the water data, we create a commensurate variable using information on the main chemical components of fertilizers in India. This is accomplished by constructing a dummy variable that indicates the presence in water of any of the main fertilizer constituents.[10] Figure 6 shows the trend in the average presence of fertilizer chemicals in water. It is apparent that agrichemical levels have fallen over time – periods that were closest to the Green Revolution in India were characterized by higher levels of use as compared to more recent years. The plateauing in fertilizer use between 2000 and 2005 is also evident in Figure 1, and explanations include the fact that pricing policies now seek to correct incentives to overuse fertilizer. Soil-exhaustion is also widely understood, and farmers are now more likely to use optimum levels of fertilizers. There were also additional efforts in the late 1990s to increase the efficiency of irrigation; it is possible that as a consequence, less ground and surface water was exposed to soil run-off and leaching from fertilizer agrichemicals.[11] Table 1 reports average water pollutant and fertilizer agrichemical levels in the first month and first trimester, demarcated by the years for which we have demographic data from India – 1992, 1998, and 2005. These estimates indicate that there has been some improvement in dissolved oxygen and some deterioration in terms of BOD (as noted in Figure 5). Estimates in Table 1 are also consistent with the trend for fertilizer agro-contaminants in Figure 6. Next, we discuss our demographic data for India.

Demographic Data

Child health outcomes, maternal, paternal and household characteristics are available from three rounds of the Indian National Family Health Survey (NFHS). These are the DHS for India and in

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[10] Information on the components of fertilizers is available from India's Department of Fertilizer under the Ministry of Chemicals and Fertilizers (http://fert.nic.in/aboutfert/aboutfertilizers.asp). More specifically, the components (in decreasing order) are nitrogen, nitrates, nitrites, phosphates, potassium, ammonia, iron, sulphates, sodium, magnesium, fluoride, calcium, and chlorides.

[11] See Foster and Sekhri (2008) for groundwater effects. Further, although fertilizer use has declined, the median year of birth of children in our DHS data is 1991, a time when fertilizer use was still relatively high.

addition to the maternal risk factors and demographic characteristics that are asked of all women between the ages of 15-49, these data contain detailed reproductive histories on year and month of delivery of every child born, gender of the child, and information on birth-weight and height-for-age and weight-for-age z scores for children less than age five. Table 2 presents summary statistics of child-specific, woman-specific, husband-specific, household-specific and state-specific characteristics in our sample, differentiated by rounds of the DHS.[12] In general, there are decreasing trends evident in terms of order of birth and complications in delivery. Across the DHS rounds, women are older and more literate.[13] Self-employment probabilities for women improve over time as does woman's general health measured by body mass index (BMI).

Husband-specific characteristics in Table 2 show similar trends. Husband's age increases over time as does literacy (measured by a declining proportion of those with no education). Further, household-specific measures reveal that up to three quarters of our sample is rural, there is declining male headship, about 80 percent of households are Hindu, and between 22 – 30 percent belong to the disadvantaged caste group in India (Scheduled Caste/Scheduled Tribes). General infrastructure measures and proxies for wealth also show improvements over time. Access to electricity has increased by about 15 percent from 1992 to 2005, and there have been increases in ownership of consumer durables such as refrigerators, televisions, and motorcycles. Piped water (a relatively safe source) is the

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[12] Information on per-capita net state domestic product was obtained from the Economic Organization and Public Policy Program (EOPP) database from the London School of Economics. Data on rainfall, malaria cases, tuberculosis (TB) deaths, external deaths, and live births were obtained from various years of the Vital Statistics of India. Data on air temperature, average distance from sea and average elevation were obtained from India Agriculture and Climate Data Set (Dinar *et al*. 1998), rice and wheat cropped area and information on crop sowing months were obtained from the Statistical Abstract of India and Area and Production of Principal Crops in India, various years. Wheat and rice yields were obtained from the Directorate of Economics and Statistics, Department of Agriculture, various years.

[13] For literacy and the dummy for woman's work in farming, fishing, hunting, or logging, the means for 1998 appear skewed in comparison to 1992 and 2005. This is because we have a relatively large number of missing observations in the monthly water quality data leading to imperfect matches between the demographic data and the water information on the basis of state, year, and month in 1998.

origin of drinking water for only about a third of the sample over time. State-specific measures reveal that per capita state income has increased by about 32 percent over the period of analysis – a substantial increase that may, in part, reflect the 1991 liberalization that India underwent and the subsequent rise in the pace of economic growth. Finally, although there is evidence of an increase in the number of malaria cases, TB deaths, number of live births, rice and wheat yields, and rice and wheat cropped areas over the years we examine, average air and water temperature have remained relatively constant.

Table 2 describes the exogenous determinants of child health. For purposes of estimation, these measures are merged with the water quality data on the basis of each child's state of residence and year and month of conception. Year and month of conception are determined retrospectively using information on year and month of birth of the child, assuming a nine month gestation cycle.[14] The resulting data set has child health outcomes matched with general water pollution measures in the month of conception, agrichemical presence in the month of conception and other characteristics described in Table 2. We focus on first trimester impacts since there is evidence that exposure at this juncture in fetal development is most critical. In particular, Manassaram *et al*. (2006) notes that nitrates and nitrites may travel through the placenta to affect the fetus in the first trimester. The separation of blood circulation between mother and fetus is achieved only from the beginning of the second trimester of pregnancy (fourth month) when the placental membrane becomes adequately developed. We begin by considering the effect of exposure to reproductive toxins in the month of conception; later we report results that consider the effect of first trimester averages of the presence of fertilizer agrichemicals in water on infant mortality, neo-natal mortality, and post-natal mortality.

We turn next to a description of the child outcomes we study. These are reported in Table 3 and include infant mortality (child was born alive but died at or less than eleven months of age), neo-natal

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[14] Alternative specifications using a 10 month gestation cycle (40 weeks) did not result in appreciably different results.

mortality (child was born alive but died in the first month of life), and post-natal mortality (child was born alive but died between the first and eleventh month of life). *In utero* exposure to toxins is believed to have the strongest impact on neo-natal mortality; post-natal mortality is more likely to result from diseases (diarrhea), poor nutrition, child living circumstances/environment or accidents. Further, recent studies have noted that male fetuses are more susceptible to environmental insults (Garry *et al*. 2002, Sanders and Stoecker 2011) and have low immune responses and weak resistance to infection (Drevenstedt *et al*. 2008). To see whether this pattern holds in our data, we measure impacts of agrichemicals in water on child gender. Birth-weight, a widely used measure of immediate and long-run health for children, is also analyzed along with standardized evaluators of stunting (height-for-age z score for children less than five years) and being under-weight (weight-for-age z scores for children less than five years).[15] Summary statistics for these outcomes are presented in Table 3.

Estimates in Table 3 reveal that although infant mortality has declined in our sample, most of this has come from declines in post-natal mortality. The proportion of male children has remained somewhat stable, whereas birth-weight has shown marginal improvements over time. The height-for-age z score shows that the average Indian child was stunted (the threshold for stunting is less than 2 standard deviations from the mean) in 1992, but there has been a gradual improvement in this measure from then on. Similarly, the average Indian child scored well below conventionally accepted threshold levels for adequate nutrition in terms of the weight-for-age measure in 1992. Again, there has been improvement in this measure, especially from 1992 to 1998.

We conclude this section by describing the estimates in Tables 4 – 5. Table 4 shows pairwise correlation coefficients between the presence of fertilizer agrichemicals in the month of conception and the outcomes examined. These coefficients indicate that fertilizer chemicals are significantly positively

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[15] Deaton and Dreze (2009) note that for Indian children, weight-for-age z scores are better suited measures of being under-weight (as opposed to weight-for-height).

correlated with infant mortality (both neo-natal and post-natal) and low birth-weight (using the conventionally accepted threshold of 2500 grams), and significantly negatively correlated with gender being male and height-for-age and weight-for-age z scores. Other tests not reported in the paper show that birth weight is positively correlated with post-birth health measures on height and weight. That is, low birth-weight children in India are likely to continue to score poorly on the post-birth health indicators as of age five. This is in contrast to literature from the developed world which suggests that after-birth interventions may be able to ameliorate some of the long term negative health implications of low birth-weight (Almond and Currie 2010). Finally, estimates in Table 5 reveal that it is not just agrichemicals in the first month that are important. Aggregate trimester averages of fertilizer toxins also exert harmful consequences on all outcomes considered.

VI. Results

Ordinary Least Squares

We begin the discussion of results by reporting ordinary least squares (OLS) models that do not correct for measurement error in the endogenous variable, fertilizer agrichemicals. This corresponds to the empirical specification in equation (1) and the OLS results are reported in Appendix Tables 1 and 2. As is well known, classical measurement error leads to attenuation bias (Greene 1993). This is consistent with the size of the coefficients on the agrichemicals variable in these tables which are mostly biased towards zero and measured imprecisely. Not correcting for measurement error also leads to counter-intuitive results as in Appendix Table 2 where fertilizers are found to increase birth-weight and height-for-age and weight-for-age z scores. We turn next to our preferred specification, the two stage least squares (TSLS) instrumental variables model.

Two Stage Least Squares

Results from the first stage in equation (2) are reported in Table 6. The three columns of Table 6 report results in which the indicator of the presence of fertilizer agrichemicals in the first month is averaged at the state, year, and month level.[16] The rice instrument is significant whereas the wheat instrument is measured imprecisely in the first column. The rice instrument has a positive effect on the endogenous variable consistent with our hypothesis that agrichemical levels peak in these states during the application months. The second column adds child, woman, husband, and state-specific characteristics to those in the first column of Table 6 and explains about 10 percent of the variation in fertilizer presence.[17] The coefficient on the wheat instrument is now as expected and, along with the rice, instrument indicates that average fertilizer presence is higher in rice and wheat cropped areas during sowing months.

Given the nature of these data, it is likely that the effects of the rice and wheat instruments are contaminated with time and state-level heterogeneity. A way to control for this is to include month and year of conception dummies, region dummies, and interactions of month of conception and region dummies and year of conception and region dummies. This also controls for omitted variables at these levels whose exclusion may bias results. The third column of Table 6 shows results with the inclusion of these additional controls. The wheat instrument is as before and along with the rice instrument and other included variables now explains about 24 percent of the variation in agrichemical presence (the rice instrument has the correct sign but is measured imprecisely). The F-statistic on the identifying instruments in the third column of Table 6 is above 10, the rule-of-thumb threshold value for sufficient strength. This is consistent with the corresponding *p*-value which strongly rejects the null hypothesis

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[16] Without this averaging, the dependent variable in the first stage is non-linear. Angrist and Krueger (2001) show that a two-stage model where the first stage is estimated using non-linear techniques is suspect since the model is essentially identified from the non-linearity.

[17] There is a large decline in the number of observations between column 1 and columns 2 and 3 of Table 6 since column 1 does not include women and child characteristics which are missing for some variables.

that the identifying instruments are jointly insignificant. The results in Table 6 indicate that the wheat instrument in particular is a significant determinant of the seasonal presence of fertilizer agrichemicals in water. Effects for the rice instrument are not as strong in the last column of Table 6; however, we include it in the first stage since rice is as important a crop as wheat in India (production of rice exceeds production of wheat in India).

Our main results from the second stage of the TSLS model are presented in Tables 7 and 8. Before we discuss these results we note that in order to implement a linear instrumental variables model, non-linear outcomes (infant mortality, neo-natal mortality, post-natal mortality, and male gender) are averaged to the state, year and month levels. Linear TSLS is the preferred econometric method since it has the advantage of reporting tests of instrument validity. As noted above, the TSLS models include separate controls for general measures of water quality – faecal coliform, BOD, and dissolved oxygen. This is necessary to ensure that their absence does not bias the effect of the agrichemical variable.[18]

Table 7 reports the instrumental variables results for the impact of average fertilizer presence in water in the month of conception on outcomes that are most susceptible in the first trimester. We begin by noting that a test of over-identifying restrictions robust to the presence of weak instruments (Anderson-Rubin Wald test) cannot be rejected at the 5 percent level in all models of Table 7. The first column reports that fertilizer agrichemicals have a strong positive impact on infant mortality. Estimates indicate that a unit increase in the average measure of such agro-toxins increases average infant mortality by 0.03 units. This means that for a 10 percent increase in the average level of agrichemicals in water average infant mortality increases by 3.52 percent. The second column of Table 7 shows that

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[18] We should note that exclusion of the general water pollutant variables can result in bias through omitted variables even if there is little overlap between these measures of water quality and agrichemicals. The main source of faecal coliform and BOD is human presence and industrial pollutants (which are composed of a mostly non-overlapping set of different chemicals such as arsenic and mercury), respectively. Thus agrichemicals from fertilizer have little feedback effects on BOD and vice versa. However, fertilizer levels may be correlated with dissolved oxygen as in Ebenstein *et al*. 2011.

most of this effect comes from the adverse consequences on neo-natal mortality. The coefficient in this column indicates that for a 10 percent increase in the average level of fertilizer in water average neo-natal mortality increases by 6.56 percent. Fertilizer effect on male children has the expected sign but is measured without significance in the last column of Table 7. Finally, other measures of water pollution (faecal coliform, BOD, and dissolved oxygen) are mostly insignificant except for the first column where BOD is likely picking up the beneficial impact of increased income from economic activity, and the last column where faecal coliform has the expected impact on child gender.

Table 8 reports the instrumental variables results for the impact of average fertilizer presence in water in the month of conception on other child health outcomes. Again, a test of over-identifying restrictions robust to the presence of weak instruments cannot be rejected in all models. As expected, agrichemicals have negative influences on birth weight and height-for-age and weight-for-age z scores.[19] In particular, the coefficient in the first column of Table 8 indicates that for a unit increase in average fertilizer presence in water birth-weight declines by 0.34 kilograms, although this is not significantly different from zero. Focusing on the weight-for-age z score which is considered to be a comprehensive measure of child health in India (Deaton and Dreze 2009), estimates indicate that for a 10 percent increase in the level of agrichemical toxins in water, weight-for-age z scores as of age five decline by about 0.26 standard deviations. This is a significant but not overly large effect. Even though the magnitude is not large, it is striking that exposure in the first month has such long-lasting negative effects on child health. Other general water pollution measures in Table 8 are mostly insignificant.

The remaining two tables in the results section consider different specifications of the main TSLS results in Tables 7 and 8. Table 9 reports disaggregated runs for neo-natal mortality for the following sub-samples: uneducated versus educated women, rural versus urban areas, and poor versus

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[19] Birth-weight is less likely to be recorded in rural areas where women may deliver at home. This may contribute to the relatively few observations for this variable in Table 8.

rich households. It is apparent that the negative consequence of fertilizer toxins is evident only among uneducated women; although educated women may also be exposed to agrichemical toxins perhaps through drinking water, these results indicate that they are able to engage in behaviors that counter-act some of the negative *in utero* consequences of exposure to tainted water (educated women may be more aware of the benefits of filtration and chlorination). Next, in keeping with increased exposure from agriculture, the harmful impact of agrichemicals on neo-natal mortality is most evident in rural areas. Finally, using proxy measures of wealth to differentiate between poor and rich households, estimates in Table 9 reveal that it is the poor who are particularly susceptible to the detrimental impacts of agro-contaminants. These results underscore that the negative health implications of fertilizer agrichemicals are strongest among the most disadvantaged – children of uneducated poor women living in rural India.

Finally, Table 10 reports the child health impacts of average first trimester exposure to agrichemicals in water (average of exposure in the first, second, and third months). The aim is to investigate whether exposure beyond the month of conception has added effects on infant and child well-being. We focus only on measures that are most impacted in the first trimester, infant mortality and its components. It is clear from the results in Table 10 that there is little added effect on infant mortality from exposure in the second and third months. The magnitude of the agrichemical variable on infant mortality and neo-natal mortality is only slightly different than the corresponding value in Table 7.[20] Results continue to remain insignificant for post-natal mortality in Table 10. We conduct robustness checks for these results in the following section.

VII. Robustness Checks

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[20] Although estimates in Table 10 are slightly different in magnitude than the corresponding estimates in Table 7, we cannot reject that month of conception and first trimester impacts are statistically equivalent. These tests are available on request.

The checks conducted in this section ascertain the robustness of the identifying instruments and demonstrate that they have no indirect effects on child health measures through correlation with omitted variables. Table 11 presents first stage tests that check for correlation of the identifying instruments with the number of accidental deaths, access to prenatal or antenatal care provided by a doctor, number of living births and income. To be clear, these variables are used (separately) as dependent variables in place of the fertilizer agrichemical variable in the first stage equation (2). Accidental deaths[21] is used to provide a falsification test: the identifying instruments should not have any effects on deaths not linked to fertilizer agrichemicals. The other outcomes act as proxies for investments in infant health. As evident from Table 11, the rice and wheat instruments have no statistical impact on any of the outcomes considered. The F-statistics and the corresponding *p*-values in the table confirm this conclusion.

Next, for the identifying instruments to have indirect effects on child health through correlation with omitted variables, such variables would have to vary seasonally and by agricultural region in the same way that fertilizer concentrations vary seasonally and across regions. Weather-related natural phenomena such as average rainfall, water temperature, air temperature, as well as the incidence of diseases such as malaria and TB may satisfy these conditions, and we verify the validity of our instruments with respect to these variables (note that average rainfall and water temperature are already included in the second stage). In particular, air temperature may have independent effects on child health measures such as infant mortality conditional on rice and wheat instruments (for example, the likelihood of infant mortality may rise when temperatures are unseasonably warm as noted in Burgess *et al*. 2011). The incidence of disease may also vary seasonally and by regions and have direct effects on child health through influencing mother’s health in the year of conception. To account for the effects of air temperature and the incidence of disease, these variables are directly included in the second stage.

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[21] Defined as deaths from bites/stings, accidental burns, falls, drowning, accidental poisoning, transport and other accidents, suicides and homicides.

Furthermore, if a "hungry season" immediately precedes crop sowing cycles as is usually the case in agriculture, the timing of food shortages may independently impact mother's health net of the identifying instruments. We include retrospective information on wheat and rice yields (tons/hectare) in the second stage to adjust for such effects. Average distance from the sea and average elevation are also included in the second stage to control for market integration which may determine how widely food shortages are experienced at the state level.[22] Finally, if women's labor increases during sowing cycles, this may also invalidate the exclusion restriction. Given lack of information on hours worked in the DHS data, we include a full set of indicators on the types of work undertaken by women to control for these effects (note that many of these variables are already included in the above specifications). These results are reported in Table 12.

It is evident that the inclusion of air temperature, log number of malaria cases and TB deaths, log wheat and rice yields, and controls for woman's work do not change the main results in Table 7 (we lose a few observations because of missing malaria and TB data). The magnitude on fertilizer agrichemicals in response to the inclusion of the weather variable is larger in its impact on infant mortality in Table 12 as compared to Table 7 and still significant. In terms of neo-natal mortality, agrichemical effects are also comparable and still measured with precision. Inclusion of malaria cases and TB deaths in the second stage significantly increases the magnitude of the effect of agrichemical toxins in the month of conception on infant mortality and neo-natal mortality. Further, conditional on the incidence of malaria and TB in the year of conception, water toxins are now found to have a significant effect on post-natal mortality. Hence, inclusion of disease in the second stage serves to strengthen the effect of agro-toxins

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[22] Note that we already control for consumption of food items in the models above. As a further test, we included consumption (indicator for consumption of different food items) as the dependent variable in the first stage to determine whether the identifying instruments had any explanatory power. We cannot reject the null that the identifying instruments are zero, that is, they have no power in explaining variations in consumption patterns.

on child health suggesting that its absence led to a conservative bias in the estimates reported in Table 7. The impact of agrichemicals remains evident even with controls for food quantities (rice and wheat yields) and the types of work women engage in. The tests in Table 12 corroborate the results reported above by demonstrating that the instruments are randomly assigned.[23]

VIII. Conclusion and Implications for Policy

This analysis aims to broaden our understanding of the health effects of fertilizer use in India on a section of the population that is particularly vulnerable to environmental abuses – infants and children below the age of five. Although economists have recognized the importance of water quality in reducing mortality (Cutler *et al*. 2006), to the best of our knowledge, no rigorous evaluation of the health impacts of fertilizer agrichemicals in water that is attentive to the seasonal aspect of agriculture has been conducted using data from a less developed country like India. We seek to rectify this omission.

Using data on water pollution from monitoring stations run by India's Central Pollution Control Board combined with data on the health outcomes of infants and children from the 1992-93, 1998-99, and 2005-06 Demographic and Health Surveys of India, our identification strategy exploits the increase in fertilizer use over time in India, the differing timing of the planting seasons across India's states, and the differing seasonal prenatal exposure of infants and children to agrichemicals to identify the impact of water contamination on various measures of child health. We correct for possible measurement error in agrichemicals using measures of major rice and wheat producing areas in India interacted with indicators of the planting seasons of these crops as identifying instruments. First stage results reveal that wheat in particular is associated with elevated levels of agro-contaminants in water. This is consistent with the fact that the Green Revolution in India began in the wheat growing regions of the north.

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[23] Other checks that were implemented included interacting agrichemicals with sources of drinking water and interacting agrichemicals with the rural dummy. The results were not significantly different from zero. We also checked to see whether gains from access to fertilizer disproportionately affected the rich or middle income – again, there was no evidence that this was the case.

Our TSLS analysis of the effects of agrichemicals on different measures of child health provides notable results. We find that a 10 percent increase in the average level of fertilizer chemicals in water in the month of conception increases the likelihood of infant mortality by about 4 percent. Our results indicate that neo-natal mortality is particularly susceptible to agro-contaminants in water as a 10 percent increase in water toxins from fertilizers is associated significantly with about a 7 percent increase in mortality within the first month. These are relatively large effects but in-keeping with the findings in Chay and Greenstone (2003), Cutler and Miller (2005), and Galiani *et al*. (2005).[24] Disaggregated runs reveal that the harmful consequences are most evident for vulnerable populations – children of rural uneducated poor Indian women. We employ alternate specifications to establish the robustness of results that are at most risk in early pregnancy: infant mortality, neo-natal and post-natal mortality.

The findings of this research highlight the tension between greater use of fertilizer to increase yields and the negative child health effects that result from such use. In order to guarantee greater security in child health, it may be necessary to focus on generating only reasonable yield amounts by curtailing the use of synthetic chemical additives. Strategies that assist in circumventing the harmful effects of water toxins while still ensuring a sufficient level of output include increasing reliance on organic fertilizers (compost, manure), and adoption of alternative farming techniques that improve soil productivity without the application of inorganic supplements (crop-rotation). Implementation of programs that seek to raise consciousness and bolster the nutrition of mothers who are most exposed may also counteract some of the negative impacts. Finally, early health intervention programs that provide nutrient supplements to low-birth weight babies may be an ameliorative proposition. These strategies are likely to be costly for cash-strapped developing countries such as India. However, their

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[24] In particular, Cutler and Miller (2005) argue that the adoption of clean water technologies such as filtration and chlorination was responsible for up to 75 percent of infant mortality reduction in early twentieth century America. Galiani *et al*. (2005) conclude that privatization of water supply in low-income areas of Argentina reduced the mortality of children under age 5 by 26 percent.

adoption may prove vital to slowing the unintended health consequences of the widespread use of inorganic fertilizers in Indian agriculture. We study the effects of fertilizer agrichemicals in water on infant and child health to draw awareness to this subject, and to contribute to an area of economic research which has previously not been examined in detail in the context of a low-income country.

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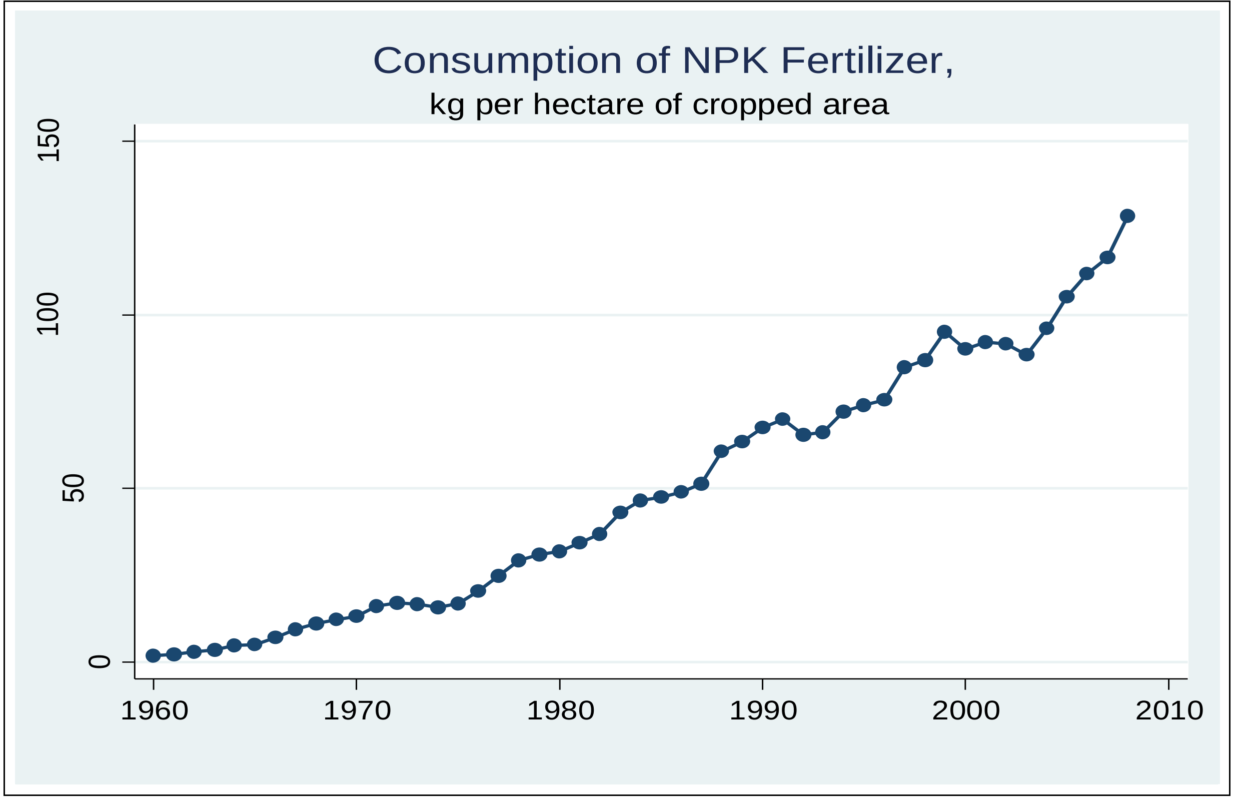
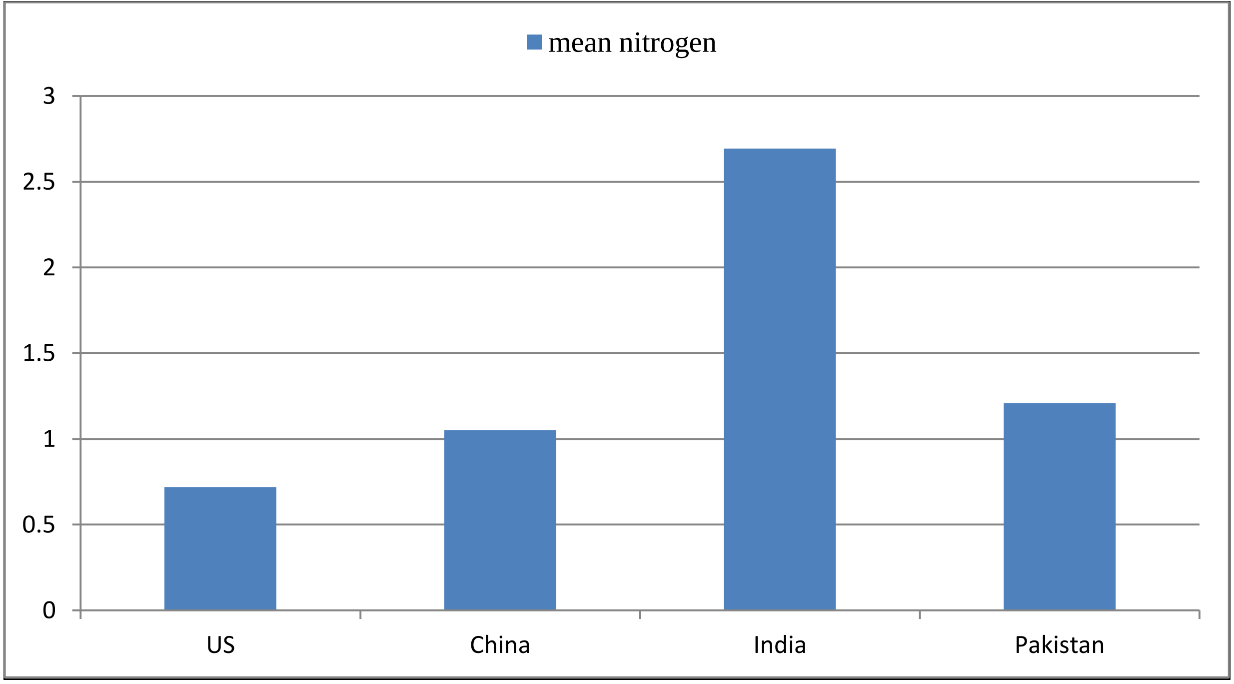
Figure 1: Trend in consumption of NPK fertilizer in India.



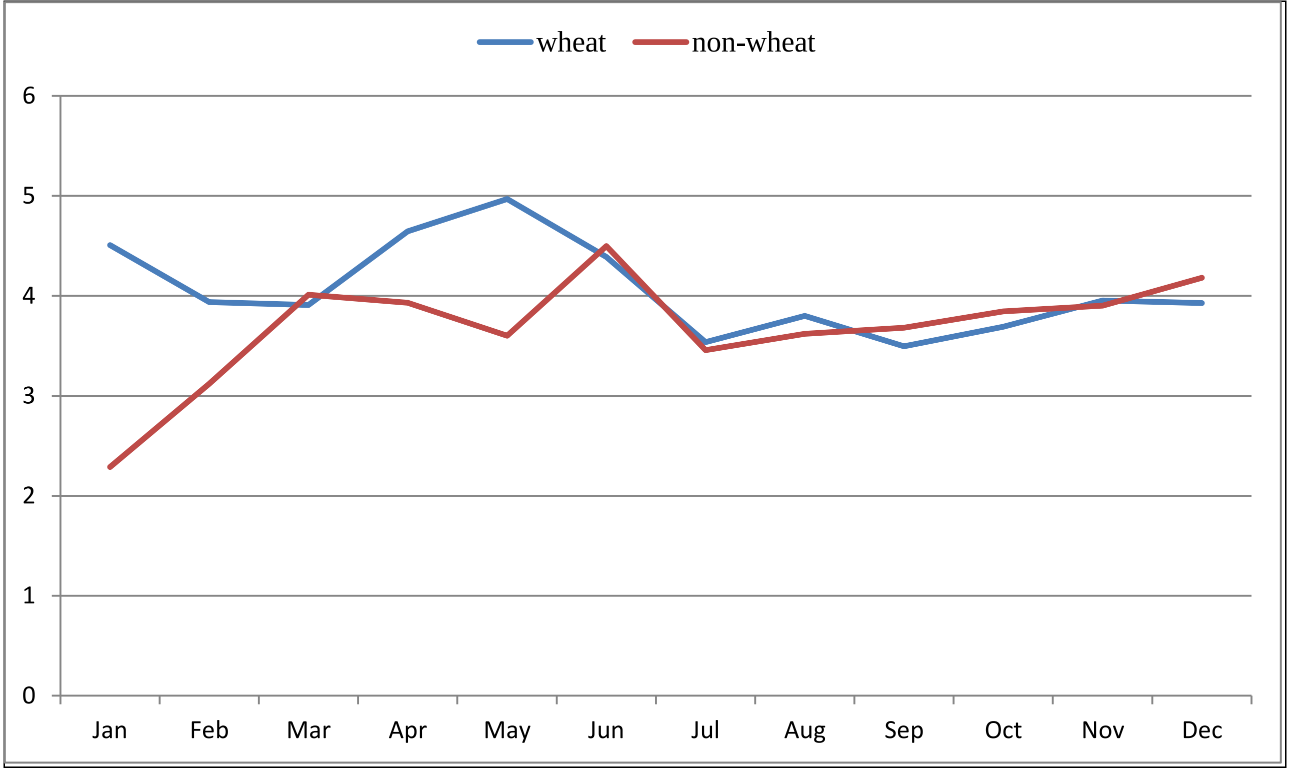
Source: Statistical abstract of India. Various years.

Figure 2: Cross-country comparison of the consumption of nitrogen from 1980-1996.



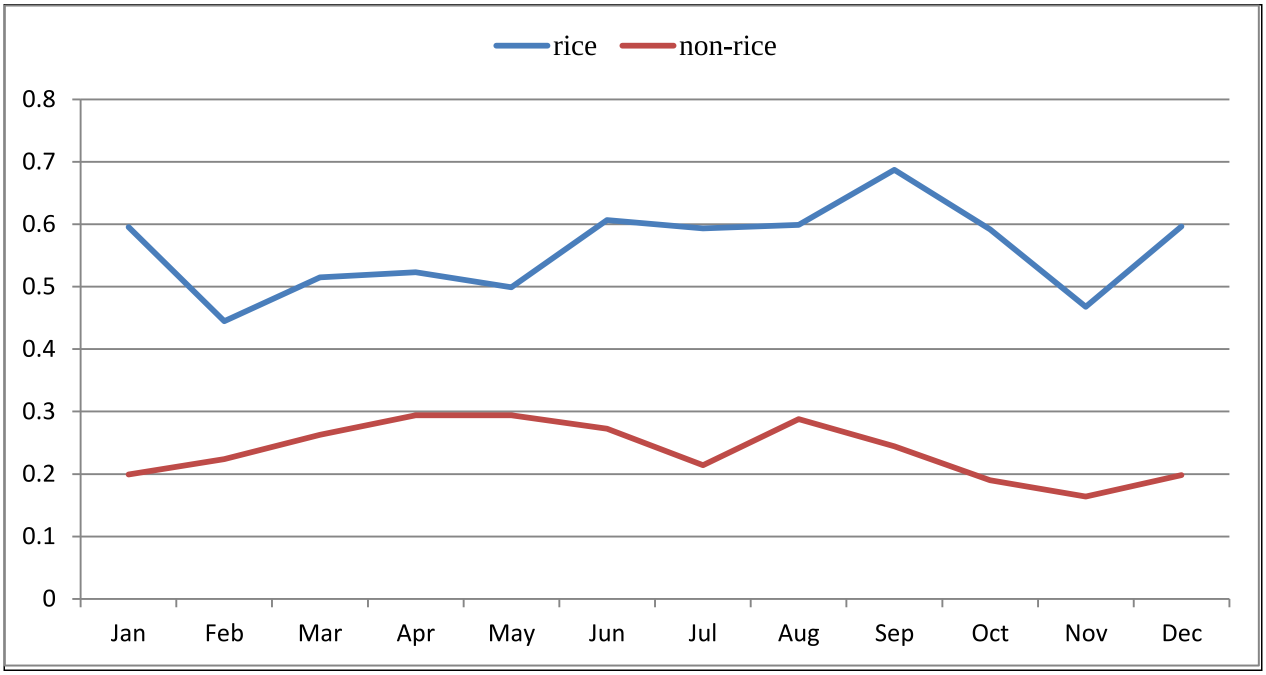
Source: GEMStat global water quality database. Nitrogen is measured as the sum of nitrates (mg/l) and nitrites (mg/l). Available at: http://gemstat.org/queryrgn.aspx. Accessed on October 24, 2011.

Figure 3: Mean nitrogen concentration in water by month from 1978-2005 for wheat.



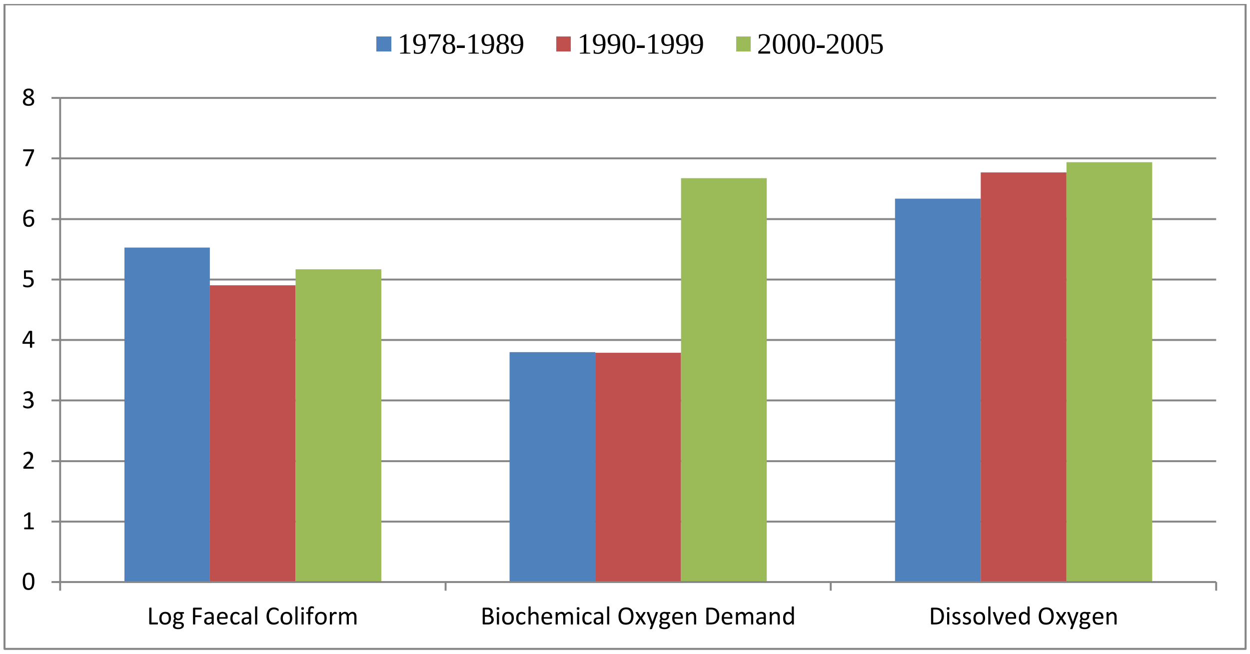
Notes: Authors' calculations. Wheat states include Punjab, Haryana, Gujarat, Bihar, Madhya Pradesh and Uttar Pradesh. Nitrogen is measured as nitrogen kjeldahl (mg/l).

Figure 4: Mean phosphate concentration in water by month from 1978-2005 for rice.



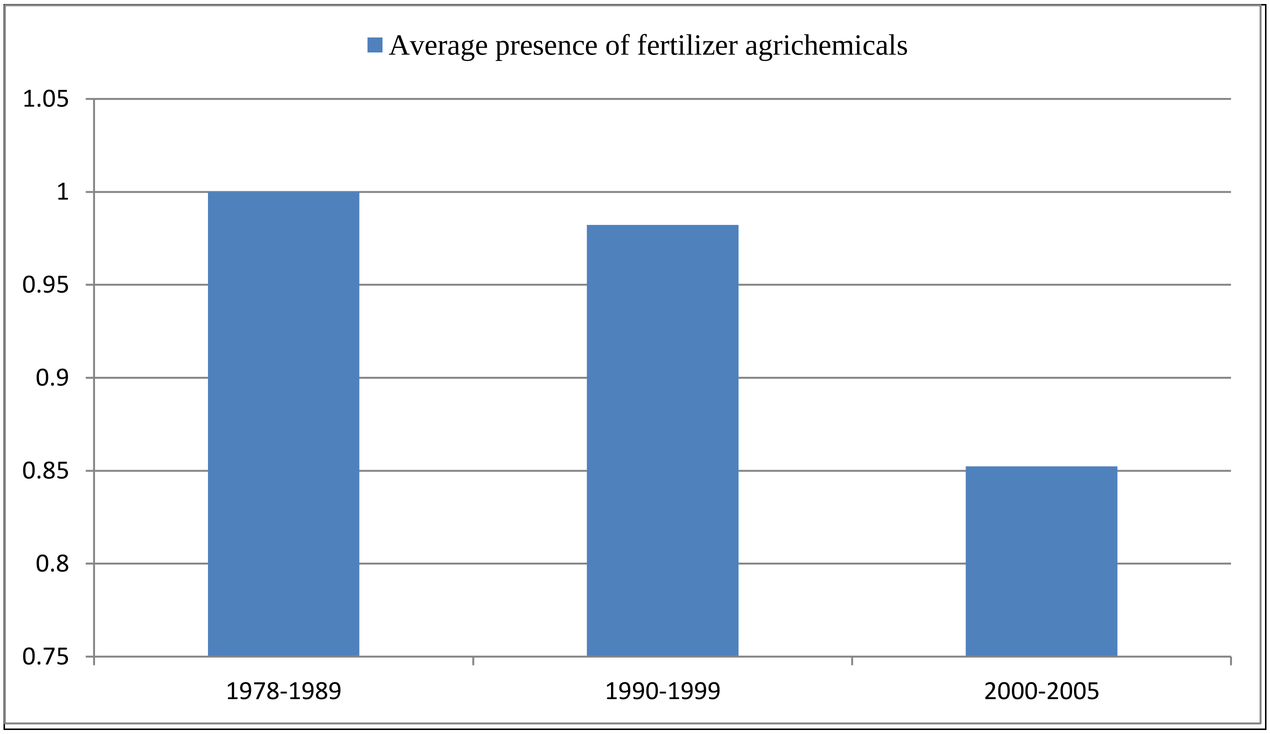
Notes: Authors' calculations. Rice states include Assam, Andhra Pradesh, Tamil Nadu, Kerala, Orissa and West Bengal. Phosphate is measured in mg/l.

Figure 5: Trend in general water pollution measures over time.



Notes: Author's calculations. Figure shows mean level over all available states for each of the three time spans considered. Faecal coliform is measured in most probable number (MPN) per 100 milliliters (ml), biochemical oxygen demand is measured in milligrams (mg) per liter (l), and dissolved oxygen is measured in mg/l.

Figure 6: Trend in presence of fertilizer agrichemicals in water over time.



Notes: Author's calculations. Table reports mean of the dummy for the presence of fertilizer agrichemicals in water over all available states for each of the three time spans considered.

Table 1: Means and standard deviations of general water pollutants and presence of fertilizer agrichemicals by year.

Pollutant/Chemical	1992	1998	2005
General water pollutants			
Log of faecal coliform	-2.301	-2.301	-2.302
in month of conception	(0.025)	(0.018)	(0.013)
	N=78723	N=118905	N=159848
Log of the first trimester	-4.373	-4.407	-4.407
average of faecal coliform	(0.723)	(0.651)	(0.578)
	N=76852	N=115752	N=156984
Log of biochemical oxygen	-4.345	-4.340	-4.326
demand in month of conception	(0.223)	(0.226)	(0.269)
	N=88739	N=135565	N=175358
Log of the first trimester average	-3.315	-3.300	-3.270
of biochemical oxygen demand	(0.560)	(0.555)	(0.606)
	N=88242	N=134579	N=174319
Log of dissolved oxygen in	-4.141	-4.125	-4.107
month of conception	(0.104)	(0.096)	(0.088)
	N=88709	N=136097	N=176107
Log of the first trimester average	-0.530	-0.482	-0.432
of dissolved oxygen	(0.272)	(0.242)	(0.211)
	N=88258	N=135750	N=175806
Log of water temperature in	3.272	3.257	3.239
month of conception	(0.369)	(0.349)	(0.393)
	N=88337	N=135625	N=173350
Log of the first trimester average	0.988	0.971	0.957
of water temperature	(0.137)	(0.158)	(0.203)
	N=87914	N=134990	N=170158
Fertilizer agrichemicals			
Dummy for presence of fertilizer	1.000	0.997	0.962
chemicals in month of conception	(0.000)	(0.053)	(0.192)
	N=89347	N=136689	N=176564
Average of dummy for presence	1.000	0.997	0.962
of fertilizer in the first trimester	(0.000)	(0.047)	(0.170)
	N=89347	N=136689	N=176564

Notes: Weighted to national level with weights provided by the DHS. Standard deviations reported in parentheses. Faecal coliform is measured in MPN/100 ml units, biochemical oxygen demand is measured in mg/l units, dissolved oxygen is measured in mg/l units, and water temperature is measured in degrees Celsius. "N" denotes number of observations.

Table 2: Means and standard deviations of exogenous characteristics by year.

Variables	1992	1998	2005
Child-specific			
Order of birth	3.133	2.967	2.753
	(2.055)	(1.939)	(1.805)
Dummy for child was nursed	0.946	0.613	0.949
	(0.227)	(0.487)	(0.220)
Dummy for child was delivered by caesarian section	0.204 (0.403)	0.165 (0.372)	0.081 (0.273)
Dummy for child was large at birth	0.143 (350)	0.142 (0.349)	0.234 (0.423)
Dummy for child was average at birth	0.644 (0.479)	0.613 (0.487)	0.555 (0.497)
Dummy for child was born prematurely (not on time)	0.032 (0.177)		
Woman-specific			
Woman's age	29.654	31.684	33.917
	(6.609)	(7.021)	(7.453)
Number of years since first marriage	13.410 (6.680)	15.107 (7.238)	17.000 (7.728)
Dummy for woman is literate	0.277	0.142	0.357
	(0.448)	(0.349)	(0.479)
Dummy for woman is currently working	0.350 (0.477)	0.418 (0.493)	0.426 (0.494)
Dummy for woman works in farming, fishing, hunt. or logging	0.229 (0.420)	0.648 (0.477)	0.113 (0.317)
Dummy for woman is self-employed	0.087 (0.282)	0.117 (0.322)	0.140 (0.347)
Dummy for woman works at home	0.153 (0.360)	0.163 (0.369)	0.175 (0.380)
Woman's body mass index		19.922	20.465
		(3.469)	(3.898)
Dummy for woman consumes fruits daily or weekly		0.279 (0.449)	0.323 (0.467)
Dummy for woman consumes green vegetables daily or weekly		0.961 (0.195)	0.975 (0.157)
Dummy for woman consumes eggs daily or weekly		0.248 (0.432)	0.286 (0.452)
Dummy for woman consumes chicken/meat/fish daily or weekly		0.283 (0.450)	0.200 (0.400)
Dummy for woman smokes		0.023	0.029
		(0.150)	(0.168)

Table 2: Means and standard deviations of exogenous characteristics by year continued.

Dummy for woman has had a miscarriage, abortion, or stillbirth	0.192	0.175	0.194
	(0.394)	(0.380)	(0.396)
Number of living children woman has	3.468	3.629	3.623
	(1.758)	(1.794)	(1.775)
Total children ever born	4.162	4.291	4.248
	(2.194)	(2.209)	(2.201)
Number of children five years and under	1.648	1.263	0.975
	(1.334)	(1.270)	(1.121)
Dummy for woman suffers from TB		0.008	0.006
		(0.088)	(0.076)
Dummy for had prenatal care or antenatal check-up with doctor	0.150	0.089	0.104
	(0.357)	(0.285)	(0.306)
Dummy for was given tetanus injection before birth of child	0.609	0.745	0.834
	(0.488)	(0.436)	(0.372)
Number of times given tetanus injection before birth of child	1.395	1.632	1.832
	(1.235)	(1.095)	(0.972)
Dummy for delivered at home	0.742	0.671	0.618
	(0.438)	(0.470)	(0.486)
Dummy for delivered in public sector hospital	0.146	0.317	0.373
	(0.353)	(0.465)	(0.484)
Dummy for delivered in private sector hospital	0.112	0.002	0.006
	(0.316)	(0.048)	0.076)
Dummy for goes to the cinema at least once a month	0.125	0.079	0.033
	(0.331)	(0.270)	(0.179)
Husband-specific			
Husband's age	35.615	37.942	39.677
	(7.814)	(9.080)	(9.157)
Dummy for husband has no education	0.388	0.334	0.339
	(0.487)	(0.472)	(0.473)
Dummy for husband has some or all primary school	0.261	0.207	0.176
	(0.439)	(0.405)	(0.380)
Dummy for husband has some secondary school	0.241	0.211	0.383
	(0.428)	(0.408)	(0.486)
Dummy for husband has comp. secondary school or higher	0.109	0.248	0.094
	(0.312)	(0.432)	(0.292)
Dummy for husband works outside the home	0.979	0.975	0.982
	(0.142)	(0.155)	(0.135)
Dummy for husband works in farming, fishing, hunt., or logging	0.436	0.538	0.502
	(0.496)	(0.499)	(0.500)
Household-specific			
Rural household	0.766	0.770	0.729
	(0.423)	(0.421)	(0.444)
Age of household head	43.218	43.661	43.627
	(13.736)	(12.957)	(11.943)
Dummy for household has a male head	0.942	0.930	0.877
	(0.233)	(0.256)	(0.329)

Table 2: Means and standard deviations of exogenous characteristics by year continued.

Variables	1992	1998	2005
Dummy for household religion is Hinduism	0.810	0.812	0.807
	(0.393)	(0.391)	(0.395)
Dummy for household religion is Islam	0.153	0.148	0.153
	(0.360)	(0.355)	(0.360)
Dummy for household belongs to Scheduled Caste/Scheduled Tribe	0.216	0.289	0.297
	(0.411)	(0.453)	(0.457)
Dummy for household has electricity	0.460	0.545	0.612
	(0.498)	(0.498)	(0.487)
Dummy for household owns a car	0.009	0.011	0.018
	(0.092)	(0.105)	(0.132)
Dummy for household owns a bicycle	0.437	0.504	0.574
	(0.496)	(0.500)	(0.495)
Dummy for household owns a refrigerator	0.044	0.070	0.113
	(0.205)	(0.256)	(0.316)
Dummy for household owns a radio or transistor	0.359	0.341	0.290
	(0.480)	(0.474)	(0.454)
Dummy for household owns a television	0.169	0.292	0.399
	(0.374)	(0.455)	(0.490)
Dummy for household owns a motorcycle	0.072	0.096	0.154
	(0.258)	(0.295)	(0.361)
Source of drinking water: piped water	0.286	0.322	0.339
	(0.452)	(0.467)	(0.473)
Source of drinking water: ground water	0.282	0.445	0.507
	(0.450)	(0.497)	(0.500)
Source of drinking water: well water	0.381	0.204	0.123
	(0.486)	(0.403)	(0.329)
Source of drinking water: surface water	0.034	0.023	0.021
	(0.182)	(0.149)	(0.143)
Source of drinking water: rain-water, tanker truck, other	0.016	0.006	0.010
	(0.124)	(0.078)	(0.098)
Dummy for toilet facility is a flush toilet	0.166	0.179	0.315
	(0.373)	(0.383)	(0.465)
Dummy for toilet facility is a pit toilet/latrine	0.071	0.106	0.037
	(0.256)	(0.308)	(0.189)
State-specific			
Per capita net state domestic product (base 1980-1981)	1773.566	2006.442	2333.283
	(633.757)	(868.841)	(1190.500)
Rainfall in millimeters	93.322	96.188	95.060
	(123.816)	(128.463)	(128.936)
Average air temperature in degrees Celsius	24.889	24.818	24.816
	(4.784)	(4.761)	(4.857)

Table 2: Means and standard deviations of exogenous characteristics by year continued.

Variable	1992	1998	2005
Average water temperature in	26.824	26.385	26.185
degrees Celsius	(3.628)	(3.824)	(3.932)
Number of malaria cases and TB	0.001	0.001	0.002
deaths normalized by state pop.	(0.002)	(0.002)	(0.002)
Number of external (bites, stings,	0.0001	0.0001	0.0001
accidents, suicides) deaths norm.	(0.0001)	(0.0001)	(0.0001)
Number of live births	54223.150	59108.560	62149.390
	(40411.800)	(45594.220)	(47935.260)
Number of live births normalized	0.001	0.001	0.001
by state population	(0.001)	(0.001)	(0.001)
Wheat yield (tons/hectare)	1.438	1.624	2.027
	(0.856)	(0.970)	(1.250)
Rice yield (tons/hectare)	2.151	3.033	3.950
	(1.760)	(2.485)	(3.040)
Average distance from the sea	270.198	265.906	270.404
in kilometers	(170.162	(169.631)	(170.190)
Average elevation in meters	346.137	341.506	340.894
	(77.959)	(78.732)	(82.093)
Rice crop area autumn and	0.161	0.163	0.169
winter norm. by state area	(0.112)	(0.118)	(0.122)
Rice crop area summer	0.009	0.012	0.014
normalized by state area	(0.018)	(0.024)	(0.030)
Wheat crop area winter	0.109	0.109	0.117
normalized by state area	(0.120)	(0.123)	(0.132)
Dummy for sowing months	0.344	0.351	0.344
for rice crop winter and autumn	(0.475)	(0.477)	(0.475)
Dummy for sowing months for	0.195	0.194	0.191
rice crop summer	(0.396)	(0.396)	(0.393)
Dummy for sowing months for	0.530	0.535	0.536
wheat crop winter	(0.499)	(0.499)	(0.499)
Dummy for northern states	0.398	0.374	0.386
	(0.489)	(0.484)	(0.487)
Dummy for eastern states	0.081	0.098	0.116
	(0.273)	(0.298)	(0.320)
Dummy for southern states	0.217	0.221	0.194
	(0.412)	(0.415)	(0.395)
Dummy for western states	0.305	0.307	0.305
	(0.460)	(0.461)	(0.460)

Notes: Authors' calculations. Weighted to national levels by weights provided by the DHS. Standard deviations in parentheses. Number of observations in 1992 is 89, 347, number of observations in 1998 is 136, 689, and number of observations in 2005 is 176, 564.

Table 3: Means and standard deviations of outcomes by year.

Outcomes	1992	1998	2005
Infant was born alive but died at or less than eleven months (infant mortality)	0.087 (0.282)	0.078 (0.269)	0.076 (0.264)
Infant was born alive but died in the first month (neo-natal mortality)	0.054 (0.226)	0.051 (0.221)	0.051 (0.219)
Infant was born alive but died between the first and eleventh month (post-natal mortality)	0.033 (0.178)	0.027 (0.162)	0.025 (0.156)
Gender of child is male	0.513 (0.500)	0.518 (0.500)	0.518 (0.500)
Birth weight (in kilograms)	2.799 (0.799)	2.787 (0.704)	2.809 (0.694)
Height-for-age z score for child (less than 5 years old)	-2.118 (1.705)	-1.857 (1.654)	-1.732 (1.581)
Weight-for-age z score for child (less than 5 years old)	-2.094 (1.269)	-1.874 (1.320)	-1.887 (1.161)

Notes: Authors' calculations. Weighted to national levels by weights provided by the DHS. Standard deviations in parentheses. Number of observations in 1992 is 89, 347 number of observations in 1998 is 136, 689 and number of observations in 2005 is 176, 564. Birth weight, height-for-age z score, and weight-for-age z score have fewer observations in each year.

Table 4: Pairwise correlation coefficients of outcomes and presence of fertilizer agrichemicals in the month of conception.

	Outcomes						
	Infant mortality	Neo-natal mortality	Post-natal mortality	Gender of child is male	Low birth weight (< 2.5 kgs. at birth)	Height-for-age z score (less than 5 years old)	Weight-for-age z score (less than 5 years old)
Fertilizer in first month	0.115^{**}	0.099^{**}	0.088^{**}	-0.004^{**}	0.014^{**}	-0.032^{**}	-0.024^{**}

Notes: Authors' calculations. The notation *** is p<0.01, ** is p<0.05, * is p<0.10.

Table 5: Pairwise correlation coefficients of outcomes and trimester averages of fertilizer agrichemicals.

	Infant mortality	Neo-natal mortality	Post-natal mortality	Gender of child is male	Low birth-weight baby (< 2.5 kgs.)	Height-for-age z score	Weight-for age z score
Trimester I average of fertilizer agrichemicals in water	0.125^{**}	0.112^{**}	0.088^{**}	-0.004^{**}	0.016^{**}	-0.028^{**}	-0.020^{**}
Trimester II average of fertilizer agrichemicals in water	0.122^{**}	0.108^{**}	0.088^{**}	-0.003	0.014^{**}	-0.013^{**}	-0.009^{**}
Trimester III average of fertilizer agrichemicals in water	0.118^{**}	0.105^{**}	0.086^{**}	-0.002	0.020^{**}	-0.015^{**}	-0.009^{**}

Notes: Authors' calculations. The notation *** is p<0.01, ** is p<0.05, * is p<0.10.

Table 6: First-stage regressions of fertilizer agrichemicals on identifying instruments.

Identifying instruments	*Endogenous variable: Average of the dummy for presence of fertilizer agrichemicals in month of conception*		
Rice crop area x Rice sowing months	0.078^{*}	0.677^{***}	0.432
	(0.042)	(0.209)	(0.459)
Wheat crop area x Wheat sowing months	0.019	0.408^{***}	0.597^{**}
	(0.023)	(0.127)	(0.262)
Includes measures of crop area and crop sowing months	YES	YES	YES
Includes child-specific characteristics	NO	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	NO	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	NO	NO	YES
R-squared	0.002	0.099	0.242
F-statistic	1.81	8.42	10.29
	[0.186]	[0.002]	[0.001]
Observations	401554	11855	11855

Notes: Weighted to national level with weights provided by the DHS. Table reports OLS regressions. Standard errors in parentheses are clustered by state. *p*-values in square brackets. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. F-statistics reported are for the identifying instruments. Regressions include a constant term and other characteristics as noted in the table.

Table 7: Instrumental variables effects of fertilizer agrichemicals on outcomes that are most impacted in the first trimester.

	Infant mortality	Neo-natal mortality	Post-natal mortality	Gender of child is male
Average of the dummy for the presence of fertilizer chemicals in month of conception	0.028**	0.034**	-0.006	-0.003
	(0.014)	(0.013)	(0.008)	(0.041)
Log of faecal coliform in month of conception	-0.104	-0.114	0.009	-0.786**
	(0.164)	(0.148)	(0.036)	(0.363)
Log of biochemical oxygen demand in month of conception	-0.003*	-0.002	-0.001	0.003
	(0.002)	(0.002)	(0.001)	(0.005)
Log of dissolved oxygen in month of conception	-0.005	0.007	-0.013	0.034
	(0.017)	(0.014)	(0.010)	(0.037)
Anderson-Rubin Wald test	1.940	2.740	0.210	0.600
	[0.171]	[0.090]	[0.810]	[0.559]
Includes measures of crop area and crop sowing months	YES	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES	YES
Number of observations	11855	11855	11855	11855

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with two stage least squares models. *p*-values in square brackets.

Table 8: Instrumental variables effects of fertilizer agrichemicals on outcomes that are most impacted in the third trimester and long-run outcomes.

	Birth weight in kilograms	Height-for-age z score	Weight-for-age z score
Average of the dummy for the presence of fertilizer chemicals in month of conception	-0.337	-2.652^{*}	-2.795^{***}
	(0.354)	(1.522)	(1.073)
Log of faecal coliform in month of conception	-1.250	-17.691	-12.663
	(0.826)	(10.947)	(8.124)
Log of biochemical oxygen demand in month of conception	0.045	-1.722	-1.312
	(0.040)	(1.199)	(1.074)
Log of dissolved oxygen in month of conception	0.187	-1.261	-1.912
	(0.256)	(1.508)	(1.235)
Anderson-Rubin Wald test	0.990	0.930	1.640
	[0.388]	[0.413]	[0.222]
Includes measures of crop area and crop sowing months	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES
Number of observations	3865	7409	7409

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with two stage least squares models. *p*-values in square brackets.

Table 9: Disaggregated instrumental variables effects of the presence of fertilizer agrichemicals in month of conception.

	Neo-natal mortality					
	Uneducated women	Educated women	Rural areas	Urban areas	Poor households	Rich households
Average of the dummy for the presence of fertilizer chemicals in month of conception	0.030***	0.031	0.029***	0.019	0.028***	-0.052
	(0.010)	(0.023)	(0.011)	(0.028)	(0.011)	(0.059)
Log of faecal coliform in month of conception	-0.238	-0.087	-0.521***	-0.008	-0.374***	0.044
	(0.198)	(0.115)	(0.104)	(0.081)	(0.136)	(0.053)
Log of biochemical oxygen demand in month of conception	-0.002	-0.001	-0.0004	-0.005**	-0.001	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Log of dissolved oxygen in month of conception	0.012	0.001	0.012	-0.015	0.010	-0.017
	(0.010)	(0.020)	(0.014)	(0.021)	(0.011)	(0.022)
Includes measures of crop area and crop sowing months	YES	YES	YES	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES	YES	YES	YES
Number of observations	6991	5132	9275	2580	7635	532

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with two stage least squares models. Uneducated women have no schooling; educated women either have some or all primary school, some secondary school, or have completed secondary school or higher. Uneducated women form 59 percent of the sample. Rich households are those who own a refrigerator, television, and motorcycle; the poor households are those who own none of these assets.

Table 10: Instrumental variables effects: impact of first trimester average of the presence of fertilizer agrichemicals in water.

	Infant mortality	Neo-natal mortality	Post-natal mortality
Average of the dummy for the presence of fertilizer in the first trimester months	0.029* (0.016)	0.033* (0.017)	-0.004 (0.008)
Log of the first trimester average of faecal coliform	0.002 (0.002)	-0.002 (0.003)	0.004 (0.003)
Log of the first trimester average of biochemical oxygen demand	-0.001 (0.001)	-0.0004 (0.002)	-0.001 (0.001)
Log of the first trimester average of dissolved oxygen	-0.002 (0.010)	0.006 (0.008)	-0.008 (0.006)
Includes measures of crop area and crop sowing months	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES
Number of observations	11053	11053	11053

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with two stage least squares models.

Table 11: Robustness checks with respect to accidental deaths, prenatal or antenatal care, number of living births, and income.

Identifying instruments	*Log of number of accidental deaths*	*Access to prenatal or antenatal doctor*	*Log of the number of living births per month*	*Rich household*
Rice crop area x Rice sowing months	0.0002	-0.058	-1.040	-0.049
	(0.001)	(0.097)	(3.172)	(0.064)
Wheat crop area x Wheat sowing months	-0.0003	-0.168	0.415	0.026
	(0.0003)	(0.109)	(2.241)	(0.047)
Includes measures of crop area and crop sowing months	YES	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES	YES
R-squared	0.754	0.387	0.922	0.246
F-statistic	1.060	1.480	0.070	0.420
	[0.372]	[0.252]	[0.933]	[0.660]
Observations	7797	11855	1097	11855

Notes: Weighted to national level with weights provided by the DHS. Table reports OLS regressions. Standard errors in parentheses are clustered by state. *p*-values in square brackets. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. F-statistics reported are for the identifying instruments. Accidental deaths include those from bites/stings, accidental burns, falls, drowning, accidental poisoning, transport and other accidents, suicides and homicides. Rich households are those who own a refrigerator, television, and motorcycle. Regressions include a constant term and other characteristics as noted in the table.

Table 12: Robustness checks with respect to monthly air temperature, malaria cases and TB deaths, women's labor, and wheat and rice yields

	Infant mortality	Infant mortality	Infant mortality	Infant mortality	Neo-natal mortality	Neo-natal mortality	Neo-natal mortality	Neo-natal mortality
Average of the dummy for presence of fertilizer chemicals in month of conception	0.040^{*}	0.079^{*}	0.033^{**}	0.028^{**}	0.033^{**}	0.094^{**}	0.032^{*}	0.034^{**}
	(0.023)	(0.041)	(0.017)	(0.014)	(0.015)	(0.039)	(0.017)	(0.013)
Monthly air temperature	0.008				0.003			
	(0.016)				(0.010)			
Log number of malaria cases and TB deaths		0.004				0.001		
		(0.013)				(0.010)		
Log of wheat yield			-0.0005				-0.0002	
			(0.002)				(0.002)	
Log of rice yield			-0.005				-0.007	
			(0.004)				(0.003)	
Woman works in agriculture				0.001				0.001
				(0.001)				(0.001)
Woman works for family member				-0.0004				-0.00002
				(0.001)				(0.001)
Woman is self-employed				0.001				0.001
				(0.001)				(0.001)
Woman works at home				-0.00004				-0.0001
				(0.001)				(0.001)
Includes measures of water pollutants	YES	YES	YES	YES	YES	YES	YES	YES
Includes measures of crop area and crop sowing months	YES	YES	YES	YES	YES	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Includes woman-specific chars., husband-specific chars., and state-specific chars.	YES	YES	YES	YES	YES	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES	YES	YES	YES	YES	YES
Number of observations	10899	7620	10996	11855	10899	8569	10996	11855

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with two stage least squares models. Number of malaria cases and TB deaths are measured by state and year of conception. Wheat and rice yields are also measured by state and year of conception. Results for post-natal mortality are not reported in table due to lack of space. Regressions that include rice and wheat yields also include measures on distance from sea and average elevation as controls for market integration.

Appendix Table 1: OLS effects of fertilizer agrichemicals on outcomes that are most impacted in the first trimester

	Infant mortality	Neo-natal mortality	Post-natal mortality	Gender of child is male
Average of the dummy for the presence of fertilizer chemicals in month of conception	0.001	0.002	-0.001	-0.002
	(0.003)	(0.002)	(0.002)	(0.009)
Log of faecal coliform in month of conception	-0.116	-0.109	-0.007	-0.786**
	(0.193)	(0.172)	(0.038)	(0.376)
Log of biochemical oxygen demand in month of conception	-0.001	0.0002	-0.001	0.003
	(0.002)	(0.002)	(0.001)	(0.004)
Log of dissolved oxygen in month of conception	-0.012	-0.001	-0.011	0.034
	(0.020)	(0.016)	(0.011)	(0.039)
Includes measures of crop area and crop sowing months	YES	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES	YES
Number of observations	11855	11855	11855	11855

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with linear models.

Appendix Table 2: OLS effects of fertilizer agrichemicals on outcomes that are most impacted in the third trimester and long-run outcomes

	Birth weight in kilograms	Height-for-age z score	Weight-for-age z score
Average of the dummy for the presence of fertilizer chemicals in month of conception	0.044^{**}	0.283^{***}	0.158^{***}
	(0.017)	(0.057)	(0.052)
Log of faecal coliform in month of conception	-1.534^{*}	-3.887^{*}	1.222
	(0.791)	(2.053)	(2.753)
Log of biochemical oxygen demand in month of conception	0.015	-0.358	0.060
	(0.018)	(0.442)	(0.520)
Log of dissolved oxygen in month of conception	0.269	-0.086	-0.731
	(0.234)	(0.565)	(0.465)
Includes measures of crop area and crop sowing months	YES	YES	YES
Includes child-specific characteristics	YES	YES	YES
Includes woman-specific characteristics, husband -specific characteristics, and state-specific chars.	YES	YES	YES
Includes month and year of conception dummies, region dummies, and their interactions	YES	YES	YES
Number of observations	3865	7409	7409

Notes: Weighted to national level using weights provided by the DHS. Standard errors in parentheses are clustered by state. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Regressions are estimated with linear models.