Poisoned Fruits: The Legacy of Arsenic Pesticides in the Early Twentieth-Century United States

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Abstract

This paper provides the first systematic evidence on the health consequences of arsenic-based pesticides, the dominant insecticides in U.S. agriculture until 1945. I digitize county rural vital statistics and link them to historical pesticide use in apple orchards. I find that exposed areas experienced an increase in rural infant mortality. Linking Army enlistment records to census manuscripts, I show that exposed cohorts were shorter on average. Distinguishing trees by farm and production status, I show the effects are driven by pesticide use rather than orchard presence. Groundwater data reveal lasting contamination, underscoring the environmental legacy of the early chemical revolution.

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1 Introduction

The emergence of modern agriculture in the late nineteenth century vastly expanded the capacity to feed a rapidly growing population.[1] However, it also introduced significant environmental costs as farmers increasingly depended on irrigation and chemical inputs. Between 1920 and 1950, aspirations for higher yields spurred widespread adoption of arsenic-based insecticides. Although arsenic's toxicity is well documented, the consequences of this historical pesticide use for human health and the rural environment have not been systematically documented. This paper aims to fill this gap by estimating the effects of arsenic-based pesticides on rural infant and adult health outcomes in the early twentieth-century United States, and by assessing the long-run legacy of arsenic in domestic well water.

To achieve this, I exploit both the timing and geographical variation in the adoption of arsenic-based pesticides. Figure 1 illustrates that during the interwar period, agricultural consumption of arsenic rose to millions of pounds annually, declining only after the introduction of DDT in 1945. My analysis focuses on lead arsenate, the dominant arsenical used in apple-growing regions.[2] The concentration of lead arsenate use in commercial apple orchards provides a natural contrast: counties specializing in apples relied far more heavily on lead arsenate than nearby counties cultivating other fruits and crops. This spatial variation allows me to compare otherwise similar rural areas that differed sharply in their exposure to arsenic-based pesticides.

Building on this variation, I first identify counties with potentially higher exposure using detailed information on actual lead arsenate spraying from the 1928 National Apple Industry Survey and apple-bearing tree density from the 1925 Agricultural Census. Figure 2 illustrates the resulting geographical variation in proxied exposure levels across the United States, with high-intensity spraying concentrated in a subset of apple-growing regions.

To examine the health effects of these pesticides, I first digitize county-level vital statistics for rural areas from the early twentieth century and combine these data with measures of pesticide exposure based on lead arsenate sprays per acre and apple tree density. Comparing counties with intensive spraying to nearby areas that relied less on arsenical pesticides, I find that rural infant mortality increased by roughly 1–2 deaths per 1,000 live births (1.2-2.4 percent) per standard deviation of exposure in the 1920s and 1930s, relative to the 1910s when spraying was not yet

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[1] Biological innovations played a central role. Olmstead and Rhode (2008) attribute roughly half of early twentieth-century labor productivity growth in U.S. agriculture to the adoption of pest-resistant wheat varieties. Likewise, the campaign against the boll weevil relied heavily on frequent arsenic applications during the first chemical revolution (Smith, 1925).

[2] In this compound, arsenic served as the active ingredient while lead was added to improve adherence. Lead arsenate was particularly effective in apple orchards, where codling moths bored into fruit and sprays needed to remain on fruits and leaves for weeks. While also used on other orchard fruits such as peaches, its application was far heavier in apples. By contrast, pests of cereals like wheat attacked also stems and roots, making a heavy, insoluble compound like lead arsenate both ineffective and impractical.

widespread, while I find no corresponding effects in urban areas of affected counties.

Next, I link individual-level U.S. Army enlistment records from World War II to childhood census manuscripts, allowing me to trace the long-run effects of early-life exposure. Linked records provide anthropometric and family background information for men born in the 1910s and 1920s. The analysis shows that sons of farmers growing up in lead-arsenate-intensive counties were, on average, about 0.04 inches shorter (0.1 percent) and 5 percent more likely to fall below the 25th percentile of the height distribution, indicating lasting developmental costs concentrated among children from farming households.

A key concern is that the estimated effects may reflect broader structural changes across apple-growing counties rather than the direct health consequences of lead arsenate exposure. I address this in several ways. First, placebo analyses show no systematic relationship between pesticide intensity and changes in migration, school attendance, farm structure, or occupational composition. Second, distinguishing between commercial orchards and home farms, and between fruit-bearing and non-bearing trees, reveals that the effects are concentrated in segments of apple production most closely associated with intensive spraying. The results are also robust to alternative specifications and sample restrictions.

Beyond the baseline estimates, I examine whether the effects on rural infant health and adult height are concentrated in counties with the highest levels of pesticide use. Focusing on counties in the top decile of spraying intensity—those reporting one or more sprays per acre and corresponding to commercial apple-producing areas—the estimated impacts are substantially larger. This pattern indicates that the health consequences were concentrated in the most heavily sprayed locations, consistent with a dose–response interpretation.

Finally, I examine the long-run legacy of arsenic pesticide use for groundwater quality. Using data from the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program, I link historical apple cultivation intensity to domestic well samples collected between 1991 and 2004. The analysis shows that counties with greater 1920s apple-growing intensity are nearly twice as likely to have domestic wells exceeding the current EPA safety standard for arsenic (10 μg/L). By contrast, there is no consistent relationship with other trace elements, underscoring that the results are specific to arsenic rather than reflecting broader groundwater deterioration. These findings highlight the persistence of arsenical compounds in soils and their capacity to leach into groundwater decades after pesticide use had ceased.

This paper contributes to the growing literature on agrichemical exposure and health. Prior studies show that pesticide and fertilizer contamination reduces newborn health in contemporary developing country settings (Brainerd and Menon, 2014; Dias, Rocha and Soares, 2023; Calzada, Gisbert and Moscoso, 2023) and that agricultural pesticide use in California's San Joaquin Valley increases the risk of adverse birth outcomes (Larsen, Gaines and Deschênes, 2017). In related work, Fletcher and Noghanibehambari (2024) exploit variation in early-life pesticide exposure during cicada events in the 1930s and document long-run increases in male mortality.

I extend this literature in three key ways. First, I shift the focus to the early twentieth-century United States, a period when arsenic-based pesticides represented the first large-scale pesticide innovation in agriculture, yet for which there is little systematic evidence on population health impacts. Second, I examine both short-run and long-run outcomes, linking agricultural exposure not only to infant mortality but also to adult stature measured decades later, as well as to persistent contamination of local water sources. Third, this historical setting provides insight into the health costs of pesticide adoption in a context with minimal environmental regulation and limited residential sorting due to low public awareness of environmental risks.

This paper is also related to the broader literature on environmental pollution and health. A large body of work has shown that exposure to ambient pollutants worsens infant and child health, both in historical and modern settings (Chay and Greenstone, 2003; Currie and Walker, 2011; Ferrie, Rolf and Troesken, 2012; Clay, Troesken and Haines, 2013; Billings and Schnepel, 2018; Clay, Portnykh and Severnini, 2019; Persico, Figlio and Roth, 2020). I extend this work by showing that, in addition to industrial and urban pollution, agricultural chemicals were an important and previously understudied source of environmental health risk, linking agricultural production to both early-life health conditions and long-term environmental contamination in U.S. history.

Understanding the consequences of past economic activities for environmental quality and human health is especially important when scientific uncertainty delays regulation. The history of pesticide use illustrates this pattern. The United States has often been slower than other developed countries to restrict hazardous chemicals due to differences in regulatory standards.[3] By documenting the persistent health and environmental effects of one of the earliest widely used pesticides, this paper provides historical evidence on the costs of regulatory delay.

The rest of the paper is organized as follows. Section 2 provides historical background on arsenic-based pesticides, their potential health effects and exposure pathways. Section 3 describes the data, including measures on lead arsenate use, vital statistics, Army enlistment records, and groundwater quality. Section 4 outlines the empirical strategy, and Section 5 presents the results, along with robustness checks. Section 6 summarizes the results and discusses implications for environmental regulation and public health.

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[3] In 2016, for example, one-quarter of pesticides used in the U.S. were already banned in Europe, where approval requires proof that substances are not mutagens, carcinogens, reproductive toxicants, or endocrine disruptors unless exposure is negligible. By contrast, in the U.S., health effects generally must be documented before a product can be withdrawn from the market (Donley, 2019).

2 Background

2.1 Rise and Fall of Arsenic-Based Pesticides

With the advent of commercial farming in the late 19th century, pest threat quickly became a national emergency (Whorton, 1974). Traditional methods could not keep up with increasing abundance of insects and new species introduced to the country by foreign trade. As a result, pest control through use of chemicals became a standard practice in American agriculture. In the early years of 20th century, some states began to strongly recommend crop spraying:

> Spraying is no longer an experiment. It is an accepted practice, as tillage, pruning, and fertilizing are. It may not be necessary to spray every year, but the farmer should be prepared to spray every year. In case of doubt, spray.[4]

When timely applied, small amounts of arsenical compounds were sufficient to kill the target insect without injuring the plants, which made them the leading insecticides until the end of World War II.[5] The most important types were lead arsenate ($PbHAsO_4$), calcium arsenate ($Ca_3(AsO_4)_2$), and Paris Green or copper acetoarsenite ($C_4H_6As_6Cu_4O_{16}$). Lead arsenate, studied in this paper, was largely used in the apple producing regions against codling moth in the North, whereas Paris Green and calcium arsenate use were concentrated in the Cotton South.[6]

Although arsenic-based pesticides were initially considered highly effective relative to any alternative, the amount required to protect crops rose steadily as target insects developed resistance (Hough, 1928). In 1915, commercial apple orchards used about 0.5 pounds of lead arsenate per tree per season, but by 1937 this figure had surged to 12 pounds per tree (Neal, Dreesen and Edwards, 1941). The rising dose and frequency of applications left increasing amounts of arsenic and lead residue on fruits and other crops. Public concern over these residues came to a head in 1926, when several cases of illness in England were attributed to "eating American apples." In response, the British government announced that it would ban imports of American apples unless the U.S. government established limits on allowable lead arsenate residues.

Stricter regulations on insecticide residue followed in the 1930s, requiring producers to wash their fruit with chemical solutions to remove lead arsenate deposits. Because chemical washing

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[4] Cornell University Agricultural Experiment Station (1901).

[5] Apple orchard experiments done in New York between 1922 and 1923 showed that yield loss due to injury by codling moth could be 9 to 28 percent if apples were left untreated compared to 1 to 5 percent injury if sprayed with lead arsenate (Parrott, 1924). In 1932, annual yield loss in apple production was estimated to be 10 to 40 percent if spraying recommendations were not followed (Gilmer and Parker, 1932).

[6] See Online Appendix Table 1 for recommended use on other crops. Data on calcium arsenate use in the Deep South are not available at the local level, which makes it impossible to separately account for its effects in those states. Online Appendix Table 11 shows that the main results are robust to excluding the Deep South from the main analysis sample.

substantially reduced growers' profits, pressure mounted to identify alternatives that were cheaper and safer for humans. The pesticide industry and growers experimented with compounds such as fluoride and nicotine sprays with some success, but the decisive shift occurred in 1946 with the introduction of DDT, a synthetic insecticide developed during World War II. DDT quickly supplanted arsenicals, as it proved more potent across a wider range of pests and was initially believed to pose minimal risk to human health (Dunlap, 1981).[7]

Over the following decades, the development of synthetic organochlorines, organophosphates, and other novel pesticide classes further reduced reliance on arsenic-based pesticides. Ultimately, the U.S. Environmental Protection Agency (EPA) formally banned new use of arsenic pesticides in 1988, citing its persistence in soil, risks to human health (especially children), and the availability of safer alternatives (EPA, 1988).

2.2 Potential Health Consequences and Exposure Pathways of Arsenic-Based Pesticides

Although arsenic was well recognized as toxic, arsenical pesticides became a staple of commercial apple production in the early twentieth century. Lead arsenate in particular created joint exposure to both arsenic and lead, affecting not only orchard workers but also rural families residing near treated land through multiple channels operating during gestation and early childhood, and in some settings persisting through contaminated soils and groundwater.

A large medical and epidemiological literature documents severe health risks from arsenic. Acute exposures can cause immediate poisoning, while chronic low-to-moderate exposures have been linked to impaired fetal growth and elevated infant mortality risk, consistent with arsenic's ability to cross the placenta and interfere with fetal development (Rahman et al., 2007; Ahmed, Ahsan and Barker, 2011). Early-life exposure has also been associated with stunting, potentially through disruptions to endocrine regulation and nutrient absorption (Smith, Lingas and Rahman, 2000; Rahman et al., 2009). In adulthood, long-run exposure increases cardiovascular risk and is strongly associated with multiple cancers, including cancers of the skin, lung, and bladder (Chen et al., 2011; Moon, Guallar and Navas-Acien, 2012; Smith and Steinmaus, 2002; ATSDR, 2007).

Lead arsenate also implies meaningful lead exposure. Prior research shows that in-utero and early-life lead exposure increases infant mortality risk (Bui et al., 2022; Clay et al., 2024), impairs linear growth and skeletal development (Ignasiak et al., 2006; Renzetti et al., 2017), and generates persistent deficits in human capital and later-life outcomes (Aizer et al., 2018; Aizer and Currie, 2019). These mechanisms are directly relevant for the infant mortality and adult height outcomes

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[7] DDT, initially hailed as a safer and more powerful substitute, soon faced the same problems as arsenicals: declining effectiveness, pest resistance, and ecological damage. By the 1960s, growing public concern over synthetic pesticides culminated in Rachel Carson's *Silent Spring* (1962), which drew attention to their environmental harms. Publicity around the book contributed to political debate and the eventual ban of DDT in 1972 (Dunlap, 1981).

examined in this paper.

Several exposure channels were present in orchard settings. First, occupational exposure occurred through inhalation and dermal contact during spraying. Farmers operating treated orchards were repeatedly exposed throughout the growing season; for 8 to 12 weeks each year, spraying generated substantial airborne arsenic concentrations (Occupational Safety and Health Administration, 1983). Exposure likely intensified during harvest, as pickers encountered residues directly on fruit and foliage through skin contact (Neal, Dreesen and Edwards, 1941). Second, ingestion was an important pathway. Contemporary records describe residue concerns on fresh apples, and fruit consumed locally in producing districts was often less intensively washed and could carry about 20 times higher residues than apples shipped longer distances (EPA, 1972). Third, indirect household exposure could arise through take-home contamination and household dust, as residues were transported on clothing, equipment, or soil tracked indoors (Wolz et al., 2003).

Finally, historical orchard applications deposited large quantities of arsenical compounds onto soils, creating a potential long-run pathway through groundwater. Evidence from orchard sites documents markedly elevated arsenic concentrations in treated soils relative to background levels.[8] While both arsenic and lead can persist in orchard soils, soil chemistry research suggests that arsenic is more mobile in subsoils, increasing its potential to reach shallow groundwater (Elfving et al., 1994; Peryea and Creger, 1994). Lead, by contrast, tends to bind more tightly to surface soils and has also been subject to relatively stringent drinking water standards and established treatment technologies that reduce its presence in well water.

Taken together, the toxicological evidence and documented exposure channels indicate that lead arsenate could plausibly affect infant survival and adult height through prenatal and early-childhood exposure, with risks most acute for farm families directly engaged in orchard production and potentially persistent for communities residing near contaminated orchard lands.

3 Data, Sample Selection, and Descriptive Statistics

3.1 Data on Apple Growing and Pesticide Use

To create a proxy for lead arsenate use, I first use the 1928 National Apple Industry Survey, a unique survey of commercial apple orchards that reports county-level statistics on apple growing and pesticide spraying during the growing season of 1925 for 19 states (U.S. Bureau of Agricultural Economics, 1931).[9] Focusing on these states, I am able to capture a sizable portion of American

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[8] Records from one commercial orchard indicate that more than 3,500 pounds of lead arsenate were applied per acre over its first 25 years of operation (Jones and Hatch, 1937). Soil arsenic concentrations in orchard lands subsequently reached 1.8 to 830 ppm, compared with background levels of 0.5 to 14 ppm in untreated areas (EPA, 1972).

[9] Commercial apple orchards are defined orchards with 100 or more fruit-bearing apple trees. State-level numbers of commercial apple trees were reported for all 48 states, but complete data on lead arsenate spraying were only

apple growing business and arsenic pesticide use. According to the survey, sample states included 76 percent of all commercial apple trees in the United States. Furthermore, they used 66 percent of all lead arsenate sold in the United States (USDA, 1944).

A key advantage of these data is that they provide direct evidence on lead arsenate use in agriculture by reporting both the number of commercial apple trees and the average number of lead arsenate sprays applied per season at the local level. This focus on commercial orchards is important: unlike measures based on all apple trees or acreage devoted to apples, it excludes home farms with only a handful of trees, which were far less likely to invest in lead arsenate or other pesticides.

I construct the main proxy for lead arsenate spraying in two steps. First, within each reporting area I calculate the total number of sprayed trees by orchard group, obtained by multiplying the number of commercial apple trees in the group by the average number of sprays per season.[10] Second, I sum these totals across all orchard groups in the county and normalize by total county land area:

$$\text{SpraysPerArea}_c \;=\; \frac{1}{\text{LandArea}_c} \sum_{g \in G_c} \Big(\text{Trees}_{cg} \times \text{Sprays}_{cg} \Big), \tag{1}$$

where c indexes counties and $g \in G_c$ indexes orchard size groups. When the survey reports data at the agricultural district level rather than by county, I distribute total number of sprays across counties in the district in proportion to the number of apple trees recorded in the agricultural census. The resulting measure—lead arsenate sprays per acre—serves as my primary proxy for pesticide intensity.

An important pattern in the data is that larger orchard groups not only account for more trees but also report higher numbers of sprays per season.[11] This underscores the importance of the orchard survey, as proxies based solely on land area or total tree counts would systematically understate pesticide intensity in areas characterized by large-scale commercial orchards. By accounting for both orchard size and spraying frequency, the constructed proxy provides a more precise measure of local arsenic use.

In addition to the orchard survey, I construct an alternative measure of pesticide exposure—apple tree density—defined as the number of apple-bearing trees reported in the 1925 U.S. Agricultural Census divided by county land area (Haines, Fishback and Rhode, 2018). Although these data include trees from small home farms that were unlikely to use arsenic-based pesticides, they provide a comprehensive measure of the intensity of apple cultivation across 47 states.[12] For use in falsifi-

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available at the local level in the 19 states covered here. Online Appendix Table 2 provides details on state-level data availability across all datasets.

[10] Orchards are grouped by size into 100–199, 200–299, 500–999, 1,000–4,999, and 5,000 or more trees.

[11] The average number of sprays per season increases with orchard size: 2.2 for orchards with 100–199 trees, 2.7 for 200–299 trees, 3.5 for 500–999 trees, 4.1 for 1,000–4,999 trees, and 4.9 for orchards with 5,000 or more trees.

[12] In 1925, Florida reported only a state total of apple trees (2,592), which is a negligible number. The main results

cation tests, I also collect data on the density of non-bearing apple trees, which were too young to produce fruit and thus unlikely to have been heavily sprayed.

Figure 2 highlights that spraying and tree density were geographically concentrated in major apple-growing regions of the Pacific Northwest, the Midwest, and the Northeast. While many counties had little or no orchard activity, some recorded extremely high values: number of sprayings reached as many as 18 per acre per season, and tree density was as high as 3 apple trees per acre of county land. This variation suggests that although most counties experienced limited direct exposure, a subset with intensive apple cultivation faced much higher risks of environmental contamination and potential health impacts.

3.2 Vital Statistics Data

Another novel contribution of this paper is the construction of county-level measures of rural natality and infant mortality by digitizing annual vital statistics reports published by the National Center for Health Statistics (NCHS, 1917-1941). These reports present births and infant deaths within each county using a consistent layout. Counts are listed separately for cities with 10,000 population or above in the most recent census, while all remaining events are reported as "rural" or "balance of county." I interpret these balance figures as representing rural births and rural infant deaths. This approach allows me to isolate rural outcomes within counties while preserving comparability across places and over time.[13]

An important limitation is that not all states were part of the federal Vital Statistics birth registration system during this period. County-level rural natality and infant mortality data are available beginning in 1917 for the 19 states that had joined the federal birth registration area.[14] Also, natality and mortality data were reported based on place of occurrence prior to 1941. However, after 1941 a change in reporting restricted the data to county of residence. To ensure consistency over time, I therefore limit the analysis to the years 1917 through 1941. Finally, I exclude highly populated counties (500,000 or more residents) with limited orchard activity, as well as counties reporting zero rural births.[15]

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are robust to including Florida by distributing the state total across counties in proportion to apple tree counts from the 1920 Census of Agriculture. These results are available upon request.

[13] Because the set of cities exceeding the 10,000 population threshold expands over time, the definition of "balance of county" would mechanically shrink even without true changes in rural population. To maintain a consistent rural definition, I fix the list of cities based on those reported as having populations above 10,000 in the 1917 reports (reflecting 1910 Census populations). Cities that newly exceed the threshold in later years are therefore aggregated back into the balance-of-county category. See Online Appendix Table 3 for the list of cities with populations of 10,000 or more as of 1910.

[14] I use 1917 as the start year to maximize the sample size. Although data on births and infant mortality are available starting in 1915, coverage is limited to only nine states. The birth registration states as of 1917 are: CT, IN, KS, KY, ME, MD, MA, MI, MN, NH, NY, NC, OH, PA, UT, VT, VA, WA, and WI.

[15] Online Appendix Figure 7 demonstrates that the results are robust to including large population centers with

3.3 Linked Army Enlistment Records

To analyze the long-run health effects of lead arsenate exposure, I use World War II U.S. Army Enlistment Records (National Archives and Records Administration, 2002). This dataset has individual records for 9 million men who enlisted during the early 1940s. The large sample size and near-universal coverage of enlistments offer a unique opportunity to study population-level impacts, while the inclusion of both anthropometric and educational variables allows me to assess effects on physical development and human capital.

The individual-level data includes information on first and last name, birth year and state, race, citizenship, education, recorded height and weight, and month and year of enlistment. I clean the height and weight data by using minimum and maximum measurements from Grumstrup-Scott et al. (1992) and Karpinos (1958).[16] To construct my analysis sample, I restrict attention to enlistees born between 1910 and 1929 who were ages 18–34 at the time of enlistment. This restriction ensures comparability across cohorts while excluding outliers who either fall outside the main treatment window or enlisted outside the typical age range.[17]

To examine how early-life exposure to arsenic-based pesticides translated into adult outcomes, I link enlistment records to the 1920 and 1930 Federal Census manuscripts using IPUMS complete-count data (Ruggles et al., 2020) and an automated linkage procedure following Abramitzky et al. (2021).[18] This linkage allows me to observe enlistees in their childhood households (at age 10 or younger) and to collect information on family and household characteristics, including number of siblings, farm residence, father's nativity, occupation, and literacy. To allow meaningful comparisons between farming households and others, I further restrict attention to counties with at least one linked enlistee per birth decade whose father was recorded as a farmer.[19] The final analysis sample consists of 519,597 enlistees for whom I observe adult height alongside information on childhood residence and parental characteristics.

3.4 Data on Domestic Well Water Quality

To examine the potential long-run effects of arsenic-based pesticides on groundwater resources, I use data from the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program, which conducted a national study of domestic wells, assessing water-quality conditions in

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500,000 or more residents in the analysis.

[16] I first use minimum and maximum height and weight from Table 3-4 in Grumstrup-Scott et al. (1992). I extend the lower and upper bounds using the bounds from Table 412 in Karpinos (1958) and add/substract 4 lbs to these values to slightly widen the weight range.

[17] Among enlistees in my sample, 2.5 percent were born in 1908 or 1909 and only 0.2 percent were born before 1908. Online Appendix Table 10 shows that including these earlier cohorts yields similar results.

[18] See Online Appendix A for details on the construction of the linked enlistee sample.

[19] Online Appendix Table 12 shows that the main results are robust to dropping these sample restrictions.

about 2,100 wells across 48 states and 30 regionally extensive aquifers between 1991 and 2004 (DeSimone, Hamilton and Gilliom, 2009). The NAWQA program provides the most comprehensive dataset on domestic well water quality in the United States, measuring a comprehensive set of water properties and contaminants—including pH, major ions, nutrients, trace elements, radionuclides (such as radon), and volatile organic compounds—using consistent sampling and quality assurance methods.

For the purposes of this study, I focus on filtered water samples, using measurements of selected elements such as arsenic and lead, as well as other trace elements including cadmium, nickel and zinc. I also incorporate key water quality characteristics such as pH, dissolved oxygen, and total dissolved solids. The final analysis sample consists of 1,298 observations of arsenic concentrations in domestic well water from 44 states, reported in micrograms per liter (μg/L). In addition, I construct a binary indicator that equals one if arsenic levels exceed the Maximum Contaminant Level (MCL) of 10 μg/L set by the U.S. Environmental Protection Agency, and zero otherwise (EPA, 2001).

3.5 Contemporary County Characteristics Data

To account for demographic and agricultural conditions, I compile county-level characteristics from the U.S. Census of Population and Agriculture for 1910, 1920, 1930, and 1940 (Haines and ICPSR, 2010; Haines, Fishback and Rhode, 2018). These include total population, racial composition (share White), share rural, literacy rates (except for 1940), number of farms, share of land in farms, share of land in crops, share of farms operated by owners, share of farms with 10 acres or more, and the value of farmland and buildings per acre. For robustness checks, I also create and use alternative outcome variables including the share of farm households, the share of migrants, the share of children ages 7–17 attending school, and the share of adults ages 25–64 employed in agriculture.

3.6 Descriptive Statistics

Table 1 presents summary statistics across several panels describing pesticide exposure proxies, health outcomes, individual characteristics, contaminant levels in domestic well water, and county-level demographics. Panel A summarizes the distribution of the several pesticide exposure proxies. On average, counties reported 0.73 lead arsenate sprays per acre per season, though the standard deviation was large, reflecting substantial heterogeneity across space. Apple tree density was similarly skewed: while the typical county had only 0.15 fruit-bearing trees per acre, a small number of counties reported densities nearly twenty times higher. Commercial orchard tree intensity was also limited on average, with counties reporting just 0.20 commercial orchard trees per acre, though again with substantial variation across locations. These statistics underscore that lead arsenate exposure was highly uneven, with most counties experiencing minimal activity but a subset showing much more intensive orchard production and pesticide use.

Panel B highlights considerable variation in infant mortality: while the mean rural infant mortality rate was about 62 deaths per 1,000 births, some counties recorded rates exceeding 300, and birth counts ranged from very small counties (3 births) to those exceeding 12,000. Panel C, which draws on linked Army enlistment records, indicates that the average enlistee was 23 years old, 91 percent of enlistees were White, and 38 percent had fathers engaged in farming; nearly half had completed high school or more, and average height and weight were 69 inches and 149 pounds, respectively. Panel D focuses on domestic well water contamination. On average, arsenic concentrations in filtered water from domestic wells were 4.06 µg/L, close to half the U.S. Environmental Protection Agency's (EPA) Maximum Contaminant Level (MCL) of 10 µg/L, though highly skewed with extreme values up to 243 µg/L. About 8 percent of samples exceeded the federal MCL, indicating nontrivial exposure risk. Lead was also detected, with mean concentrations of about 1 µg/L and some wells reaching as high as 14 µg/L. Finally, Panel E shows that the average county had about 71,000 residents, was 88 percent White, and predominantly rural and literate, with agriculture playing a central role: farms averaged nearly 3,000 in number per county, most operated by owners, and about 45 percent of land in crops. Overall, the statistics illustrate both wide variation across counties and evidence of potentially high exposures to arsenic through both agriculture and drinking water.

4 Empirical Design

4.1 Arsenic-based pesticides and rural infant mortality

This section examines how the spread of arsenic-based pesticides beginning in the 1920s influenced rural infant mortality across U.S. counties. The analysis draws on both temporal and geographic variation. Specifically, I contrast rural infant mortality rates in the 1910s with those in subsequent decades, thereby tracing changes that coincided with the rise of lead arsenate spraying in agriculture. At the same time, I exploit cross-county differences in exposure, measured by apple tree density and the number of sprays applied per acre. Counties with limited or no apple growing serve as a contrast to those with intensive orchard production, where reliance on pesticides was much greater. Formally, I estimate the following:

$$IM_{ct} = \alpha_0 + \sum_{d=1920}^{1940} \alpha_d \cdot \mathit{Proxy}_c \times I_{d,t} + \boldsymbol{\Gamma'_{ct}} \cdot \boldsymbol{\alpha_2} + \boldsymbol{\lambda_c} + \boldsymbol{\lambda_t} + t \cdot \boldsymbol{\lambda_s} + \eta_{ct} \tag{2}$$

where IM_{ct} denotes the rural infant mortality rate in county c and year t, measured as the number of rural infant deaths per 1,000 rural live births. The variable Proxy_c captures county-level exposure to arsenic-based pesticides, measured either as lead arsenate sprays per acre or apple-bearing tree density. $I_{d,t}$ is an indicator equal to one if year t is in decade $d \in \{1920, 1930, 1940\}$, with the 1910s omitted as the reference group. The vector $\boldsymbol{\Gamma'_{ct}}$ accounts for contemporary demographic and agricultural characteristics that may shape infant health. These controls include log total population, share White, rural share, number of farms, the proportion of land in farms and in crops, the share of owner-operated farms, the share of farms larger than ten acres, and the average value of farmland per acre. County fixed effects ($\boldsymbol{\lambda_c}$) account for time-invariant differences across counties, year fixed effects ($\boldsymbol{\lambda_t}$) capture common shocks across all counties in a given year, and state-specific linear time trends ($t \cdot \boldsymbol{\lambda_s}$) allow for different underlying trajectories by state. Standard errors are clustered at the county level and regressions are weighted by county rural births. The error term η_{ct} captures unobserved factors affecting rural infant mortality that are not accounted for by the included county covariates, fixed effects, or time trends.

The coefficients α_{1920}, α_{1930}, and α_{1940} indicate whether counties with greater baseline exposure to arsenic-based pesticides experienced higher rural infant mortality in the 1920s, 1930s, and 1940s, respectively, relative to the 1910s baseline. Because treatment intensity is fixed at the county level, interacting it with decade indicators allows the estimated effects to vary over time, capturing changes in spraying intensity across decades. In particular, arsenic use intensified during the 1930s and early 1940s before declining sharply, and this specification traces whether mortality differentials across counties evolved in line with those historical patterns.

4.2 Arsenic-based pesticides and adult outcomes

In this section, I examine how childhood exposure to lead arsenate translated into differences in adult outcomes across birth cohorts and counties of residence. The empirical strategy exploits spatial variation in county-level spraying intensity and temporal variation before and after the widespread adoption of arsenic-based pesticides in the 1920s. Because annual spraying data are unavailable, short-run fluctuations in arsenical use within decades cannot be precisely measured; I therefore compare cohorts at the decade-of-birth level. This aggregation aligns with historical evidence that children born in the 1920s were, on average, exposed to substantially greater arsenical use than those born in the 1910s. I implement this approach by combining county-level pesticide proxy data with Army enlistment records linked to the U.S. Census and estimate the following:

$$\begin{aligned} Y_{ict} \quad = \quad & \beta_0 + \beta_1 \cdot \mathit{Proxy}_c \times \mathit{Post}_t + \beta_2 \cdot \mathit{Proxy}_c \times \mathit{Post}_t \times \mathit{Father\ is\ farmer}_i + \\ & \beta_3 \cdot \mathit{Proxy}_c \times \mathit{Father\ is\ farmer}_i + \boldsymbol{X'_i} \cdot \boldsymbol{\beta_4} + \boldsymbol{\Gamma'_{ct}} \cdot \boldsymbol{\beta_5} + \boldsymbol{\lambda_c} + \boldsymbol{\lambda_t} + t \cdot \boldsymbol{\lambda_s} + \varepsilon_{ict} \quad (3) \end{aligned}$$

where Y_{ict} denotes adult height outcomes for individual i born in year t and residing in county c, measured as either height in inches or an indicator for whether the individual's height falls below the 25th percentile.[20] The variable Proxy_c captures county-level exposure to arsenic-based pesticides, measured either as the number of lead arsenate sprays applied per acre of county land or as apple tree density (the number of apple-bearing trees per acre). The indicator Post_t takes the value of one if the individual was born in the 1920s, after widespread lead arsenate spraying began, and zero for the 1910s control cohorts. The variable $\mathit{Father\ is\ farmer}_i$ is an indicator equal to one if the individual's father was recorded as a farmer in the Census, capturing differential exposure risks for children growing up in farming households.

The vector $\boldsymbol{X_i'}$ includes individual-level characteristics such as race, childhood farm residence, number of siblings, age at enlistment, and separate parental indicators for whether the father was native-born, literate, or a farmer. The vector $\boldsymbol{\Gamma_{ct}'}$ captures contemporary county characteristics that may influence children's development, including log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and the value of farmland per acre.

Similar to Equation 2, the specification includes county fixed effects ($\boldsymbol{\lambda_c}$), year fixed effects ($\boldsymbol{\lambda_t}$), and state-specific linear trends ($t \cdot \boldsymbol{\lambda_s}$) to account for unobserved heterogeneity across space and time. The error term ε_{ict} captures remaining unexplained variation, and standard errors are clustered at the county level. All regressions are weighted by county population.

Intuitively, β_1 captures whether individuals born in lead-arsenate-intensive counties after spraying began experienced different adult outcomes compared to earlier cohorts, while β_2 tests whether these effects were concentrated among children of farmers, who likely faced greater direct exposure through household agricultural activities. Finally, β_3 accounts for baseline differences between farmers' children and others in arsenic-intensive counties, irrespective of cohort.

4.3 Arsenic-based pesticides and domestic well water quality in the long run

This section investigates whether historical lead arsenate use had a persistent impact on groundwater resources. The empirical strategy follows the same logic as in Sections 4.1 and 4.2, combining cross-county variation in apple growing intensity with later-period measurements of well water quality. Specifically, I link county-level proxies for lead arsenate exposure—measured by apple tree density—to water-quality readings from the U.S. Geological Survey's NAWQA domestic well program, collected between 1991 and 2004 and estimate the following:

$$WQ_c = \gamma_0 + \gamma_1 \cdot \mathit{Proxy}_c + \boldsymbol{\Gamma_c'} \cdot \boldsymbol{\gamma_2} + \boldsymbol{\lambda_s} + \nu_c, \qquad (4)$$

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[20] Online Appendix Table 4 reports results for additional outcomes, including an indicator for whether height is below the median, individual's weight in pounds, and whether the individual completed at least high school.

where WQ_c denotes long-run water-quality outcomes for domestic wells in county c, measured either as arsenic concentration in $\mu g/L$, an indicator for exceeding the EPA's maximum contaminant level (10 $\mu g/L$), or concentrations of other trace elements such as lead and cadmium. The key variable of interest, $\textit{Proxy}_c$ is the 1925 apple-bearing tree density, captures county-level intensity of historical lead arsenate exposure from apple growing.[21] The vector $\boldsymbol{\Gamma'_c}$ controls for historical county demographics and agricultural characteristics, while $\boldsymbol{\lambda_s}$ denotes state fixed effects. The error term ν_c captures unobserved factors, and standard errors are clustered at the county level. All regressions are weighted by county population.

The coefficient γ_1 captures whether counties with more intensive apple cultivation in the 1920s exhibit higher levels of contamination in domestic wells measured many decades later. When the outcome is arsenic concentration or an indicator for exceeding the EPA's maximum contaminant level, a positive and significant γ_1 would indicate a persistent legacy of pesticide use in groundwater.

By contrast, no systematic relationship should be observed for other trace elements not associated with orchard spraying. For example, cadmium may co-occur with arsenic in soils due to natural geologic variation, but it was not directly tied to arsenical pesticide use. Lead, by comparison, was deliberately combined with arsenic to improve adherence. However, prior research shows that although both metals remain elevated in orchard topsoils, arsenic penetrates more deeply into subsoils, reflecting its greater downward mobility and making it more likely to contaminate domestic well water (Elfving et al., 1994; Peryea and Creger, 1994). In addition, lead has long been subject to relatively stringent drinking water standards, and established filtration and treatment technologies are particularly effective at removing lead from water, which may further limit its persistence in groundwater relative to arsenic.

5 Estimation Results

5.1 Balancing tests

Before turning to the main estimates, I examine whether counties with higher exposure to arsenic-based pesticides differed systematically in their observable characteristics. Online Appendix Figure 1 reports balance tests for both county- and individual-level covariates using the two exposure proxies. Panel (a) shows that counties with greater spraying intensity or apple tree density tended to differ along several agricultural dimensions as early as 1910—for instance, they had more farms, larger shares of land devoted to farming and crops, and higher values of farmland per

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[21] When merged to groundwater quality data, the sample includes 1,298 county–well observations using apple tree density, compared to only 470 when using the spraying survey. Because the latter substantially limits statistical power and representativeness, I rely on apple tree density as the proxy for historical lead arsenate exposure.

acre. These differences highlight the importance of controlling for contemporaneous county-level covariates in all specifications. Panel (b), by contrast, shows that coefficients on the interaction between exposure proxies and birth decade are small and statistically insignificant for individual characteristics of linked Army enlistees—including race, sibship size, and father's nativity and literacy—indicating no systematic differential evolution across exposure groups.

A natural concern is that even if baseline differences exist, they might evolve differentially over time, biasing estimates of health effects. Online Appendix Figure 2 addresses this possibility by tracing the evolution of county-level demographic and agricultural characteristics across decades. While a few coefficients move over time, the magnitudes are generally modest and imprecisely estimated. For example, the association between apple tree density and the share rural is negative in the 1920s and 1930s but remains below roughly half a percentage point in magnitude, and changes in literacy and racial composition are similarly small. Even for agricultural variables such as the share of land in crops or owner-operated farms, point estimates fluctuate within narrow bands and confidence intervals typically include zero. Overall, there is no evidence of large or systematic divergence between high- and low-exposure counties after conditioning on county and year fixed effects and state-specific trends.

Online Appendix Figure 3 further strengthens this interpretation by presenting placebo tests for additional county-level outcomes that could plausibly explain the observed health effects. In particular, I examine the share of farm households, share of migrants, school attendance among children ages 7–17, and agricultural employment among adults ages 25–64. Across both exposure proxies, the estimated coefficients are small and statistically insignificant. There is no indication that high-exposure counties experienced meaningful shifts in schooling, migration, or occupational structure over time. In other words, children in more heavily sprayed counties did not systematically leave school earlier, nor did adults become more likely to work in agriculture. The absence of differential changes in these socioeconomic outcomes makes it unlikely that the main findings are driven by evolving county composition rather than lead arsenate exposure itself.

5.2 Effects of lead arsenate on rural infant health

I begin by presenting the main estimates linking lead arsenate exposure to rural infant mortality. Figure 3 plots coefficients from Equation 2, which interact county-level exposure proxies with decade indicators. The results show that counties with higher spraying intensity or apple tree density experienced significant increases in infant mortality beginning in the 1920s, coinciding with the diffusion of arsenic-based pesticides. The estimates in Figure 3 Panel (a) indicate that greater reliance on lead arsenate spraying is associated with significant increases in rural infant mortality. The coefficient on the 1930s interaction term is 1.5, implying that a one standard deviation increase in sprays per acre raised infant mortality by about 1.5 deaths per 1,000 live births relative to the 1910s baseline. Given a sample mean of 63.8 deaths per 1,000, this corresponds to roughly a 2.4 percent increase. These effects persist and intensify through early 1940s, consistent with the growing reliance on and increasing application of arsenic-based pesticides documented in Figure 1.

Results using apple-bearing tree density as the proxy, shown in Figure 3 Panel (b), reveal a largely similar pattern, with higher-density counties experiencing increases in rural infant mortality beginning in the 1920s. This demonstrates that the findings are not limited to the states covered by the apple orchard survey, although the estimates are less precise, likely because tree density introduces more noise relative to the spraying proxy. Taken together, the results across both exposure proxies provide consistent evidence that the diffusion of arsenic-based pesticides in the 1920s raised rural infant mortality, with effects that intensified as lead arsenate use expanded.

Figure 4 examines urban and total infant mortality. In contrast to the rural results, the coefficients for urban infant deaths are small and statistically insignificant across decades for both exposure proxies. Estimates for total infant mortality are also imprecise, consistent with the effect being concentrated in rural populations. This pattern aligns with the historical application of lead arsenate, which was sprayed directly onto orchard soils and, as shown in prior soil chemistry studies, binds strongly and remains near the site of application for long periods (Peryea and Creger, 1994; Veneman, Murray and Baker, 1983). The absence of urban effects therefore supports the interpretation that the rural mortality increases reflect localized environmental contamination rather than broader county-level shocks.[22]

5.3 Effects of lead arsenate on adult height

I next turn to adult outcomes. Table 2 reports estimates from Equation 3 using linked Army enlistment records. Across both exposure proxies, the interaction between exposure, post-spraying birth cohorts, and father's farming status is negative and statistically significant. In the preferred specification (Column 3), I find that a one standard deviation increase in sprays per acre lowered adult height by about 0.04 inches (0.1 percent) among sons of farmers born in the 1920s relative to the 1910s baseline. The results also indicate increased likelihood of falling below the 25th percentile of the height distribution. In Column 6, the coefficient implies that a one standard deviation increase in sprays per acre raised the probability of being below the 25th percentile by about 0.01 (5 percent). This suggests that exposure to arsenic-based pesticides had not only average effects but also disproportionately shifted the lower tail of the height distribution.

Panel B, which uses apple tree density for all available states as the exposure proxy, supports these findings. The interaction effects remain negative for adult height and positive for the

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[22] Online Appendix Figure 4 shows no significant changes in county rural, urban, or total births associated with pesticide exposure, indicating that the results are unlikely to be driven by differential fertility responses or changes in the composition of births.

likelihood of falling below the 25th percentile. Although the estimates are somewhat weaker in magnitude, they remain statistically significant, reinforcing the conclusion that childhood exposure to arsenic-based pesticides adversely affected both average height and the lower tail of the distribution.

Adult height estimates provide evidence that the long-run health costs of arsenic-based pesticides were borne disproportionately by children in farming households. This likely reflects more intensive prenatal or early childhood exposure through direct contact during spraying or harvest seasons, as well as indirect pathways such as contaminated household dust or consumption of unwashed produce with lead arsenate residue. The concentration of height effects within farm families complements the infant mortality findings, which are similarly confined to the rural portions of exposed counties.

5.4 Alternative Explanations

I then assess whether the main findings could be driven by alternative mechanisms unrelated to lead arsenate exposure. One concern is whether the estimated effects reflect lead arsenate exposure specifically, rather than the presence of orchards or apple cultivation more generally. Counties with more apple trees may differ for structural agricultural reasons unrelated to pesticide intensity. To address this, I exploit variation in tree type and production status.

Figure 5 and Table 3 distinguish between apple trees in commercial orchards, where spraying was intensive, and trees on home farms, where chemical application was likely less frequent. They also separate fruit-bearing trees from non-bearing trees, the latter being less directly exposed to repeated spraying. This breakdown allows for a falsification test of whether the estimated effects are driven by arsenical pesticide use rather than orchard presence.

The evidence supports the main findings. In Figure 5, increases in rural infant mortality are concentrated in commercial orchards and fruit-bearing trees, while coefficients for home farms and non-bearing trees are small or of opposite sign. Table 3 shows a similar pattern for adult height. The triple interaction term is negative and statistically significant for commercial orchards and apple-bearing trees, but not for home farm or non-bearing trees. Together, these results indicate that the effects are tied to segments of apple production most directly associated with intensive spraying, rather than to orchards or apple trees more broadly.

Another concern is that counties with higher pesticide use may have simultaneously experienced changes in demographic or socioeconomic conditions—such as increased demand for child labor, in-migration of poorer farm families, or broader deterioration in living standards—that could independently worsen infant and child health outcomes. To assess this possibility, I examine a set of complementary outcomes at both the county and individual levels.

At the individual level, Online Appendix Table 4 extends the analysis to alternative adult outcomes, including whether height falls below the median, weight in pounds, and high school completion. While I find evidence of an elevated probability of being below the median height, this does not translate into significantly lower or higher weight, nor into worsened schooling outcomes as measured by high school completion. Across both sprays per acre and tree density proxies, the estimated coefficients for weight and education are small in magnitude and statistically indistinguishable from zero.

At the county level, this concern is addressed by the placebo evidence presented in Online Appendix Figure 3. I find no systematic association between pesticide exposure and changes in migration, schooling, farm structure, or agricultural employment over time. This absence of parallel socioeconomic shifts, together with the null effects on adult weight and education, suggests that the main results are unlikely to be driven by broader demographic or living-standard changes.

5.5 Robustness Checks

I conduct a range of additional robustness exercises to evaluate the stability of the main results. I begin by examining the sensitivity of my main findings to alternative specifications. First, in Equation 3, I add county-by-birth-year fixed effects, thereby controlling for annual changes within the same county (Online Appendix Table 5). Second, I drop state-specific linear time trends (Online Appendix Figure 5 and Online Appendix Table 6). Third, I cluster standard errors at the agricultural district level rather than the county level (Online Appendix Figure 6 and Online Appendix Table 7). Across these alternative specifications, rural infant mortality estimates remain positive and stable, and the adult height results continue to show negative effects on height in inches and positive effects on the probability of being below the 25th percentile, with magnitudes close to the baseline.

I next consider alternative sample restrictions. Restricting the height analysis to Birth Registration states (Online Appendix Table 8) or excluding cohorts born before 1917 to align with the coverage of the Vital Statistics system (Online Appendix Table 9) yields estimates consistent with the baseline results. Extending the sample to include earlier birth cohorts from 1900–1909 (Online Appendix Table 10) does not materially alter the findings. Likewise, excluding Deep South states, where calcium arsenate was widely applied to cotton (Online Appendix Table 11), or dropping baseline sample restrictions (Online Appendix Table 12), produces very similar estimates. Finally, including counties with large urban populations (Online Appendix Figure 7 and Online Appendix Table 13) leaves the results largely unchanged.

5.6 Effects in High-Exposure Counties

I next examine whether the estimated effects are concentrated in counties with especially intensive pesticide use. As shown in Figure 2, counties reporting one or more sprays per acre correspond to commercial apple-producing areas and fall within the top decile of counties covered by the federal orchard survey (U.S. Bureau of Agricultural Economics, 1931). This threshold therefore captures locations where lead arsenate application was particularly intensive.

Online Appendix Figure 8 presents estimates comparing these high-exposure counties to all others. The effects are substantially larger and more precisely estimated than in the baseline specification. For rural infant mortality, the coefficient on the 1930 interaction term is 4.1 additional deaths per 1,000 births, corresponding to roughly a 6.4 percent increase relative to the mean.

Online Appendix Table 14 reports analogous estimates for adult height. Among sons of farmers born after the diffusion of lead arsenate, residing in a county with one or more sprays per acre is associated with a 0.035 higher probability of falling below the 25th percentile of the height distribution, which corresponds to roughly a 17 percent increase relative to the sample mean.

Together, these results indicate that the adverse health effects are considerably more pronounced in the most intensively sprayed counties, providing suggestive evidence consistent with a dose–response relationship.

5.7 Effects of arsenic-based pesticides on domestic well water quality

Finally, I examine whether intensive apple cultivation in the 1920s left a measurable legacy in domestic well water quality several decades later. Table 4 reports estimates from Equation 4, linking county-level apple tree density in 1925 to selected trace element concentrations in domestic wells sampled by the U.S. Geological Survey's NAWQA program between 1991 and 2004.

In Panel A of Table 4, counties with higher historical apple-bearing tree density exhibit a significantly higher likelihood that domestic wells exceed the EPA's maximum contaminant level (10 µg/L) for arsenic. A one standard deviation increase in tree density is associated with a 7.9 percentage point increase in exceedance probability. Given a baseline mean of approximately 8 percent, this magnitude implies nearly a doubling of the probability that a domestic well exceeds the federal safety threshold. By contrast, the coefficient on arsenic concentration in µg/L is positive and economically meaningful in size, though imprecisely estimated.

Panel B further distinguishes fruit-bearing and non-bearing trees. The positive and statistically significant relationship with arsenic exceedance is driven by fruit-bearing trees (0.099), whereas non-bearing tree density is small and statistically insignificant. This contrast reinforces the interpretation that the groundwater results reflect historical pesticide application rather than orchard presence more broadly.

The evidence for other trace elements is weaker and less systematic. While point estimates for lead, cadmium, nickel, and zinc vary in sign and are generally imprecisely estimated, none display a consistent positive pattern comparable to the arsenic exceedance result. Online Appendix Table 15 extends the analysis to broader water-quality characteristics—including pH, dissolved oxygen, and dissolved solids—and finds no statistically meaningful associations with historical apple tree density. These findings suggest that the results are not driven by generalized groundwater deterioration or broad geochemical shifts.

Taken together, these findings provide evidence that intensive arsenic pesticide use in the early twentieth century left a lasting legacy for groundwater quality, detectable many decades later in the elevated likelihood that domestic wells exceed current federal safety standards for arsenic. This reflects the persistence of arsenical compounds in soils and their capacity to leach into shallow groundwater long after spraying ceased.

6 Conclusion

This paper provides the first systematic evidence on the long-run health consequences of arsenic-based pesticides in the United States. Using newly digitized county-level vital statistics, I show that the diffusion of lead arsenate spraying in the 1920s and 1930s raised rural infant mortality. Linking Army enlistment records to childhood census manuscripts, I further demonstrate that sons of farmers born in arsenic-intensive counties were shorter on average and more likely to fall below the 25th percentile of the height distribution, indicating lasting developmental costs concentrated among children from farming households. In addition, groundwater data from the U.S. Geological Survey reveal that counties with higher historical arsenic use remain significantly more likely to have domestic wells exceeding current EPA safety standards for arsenic many decades later.

These results highlight that the first chemical revolution in American agriculture carried substantial and enduring health costs. Arsenic-based pesticides not only raised mortality in the short run but also left a long-lasting imprint on adult health and groundwater quality. These findings emphasize the risks of relying on hazardous agrichemicals without adequate foresight and regulation. As former agricultural lands continue to be converted into residential areas—roughly 150 million acres since the 1940s, or 15 percent of all U.S. farmland—and millions of households still rely on unregulated private wells, the legacy of arsenicals remains relevant for public health today.

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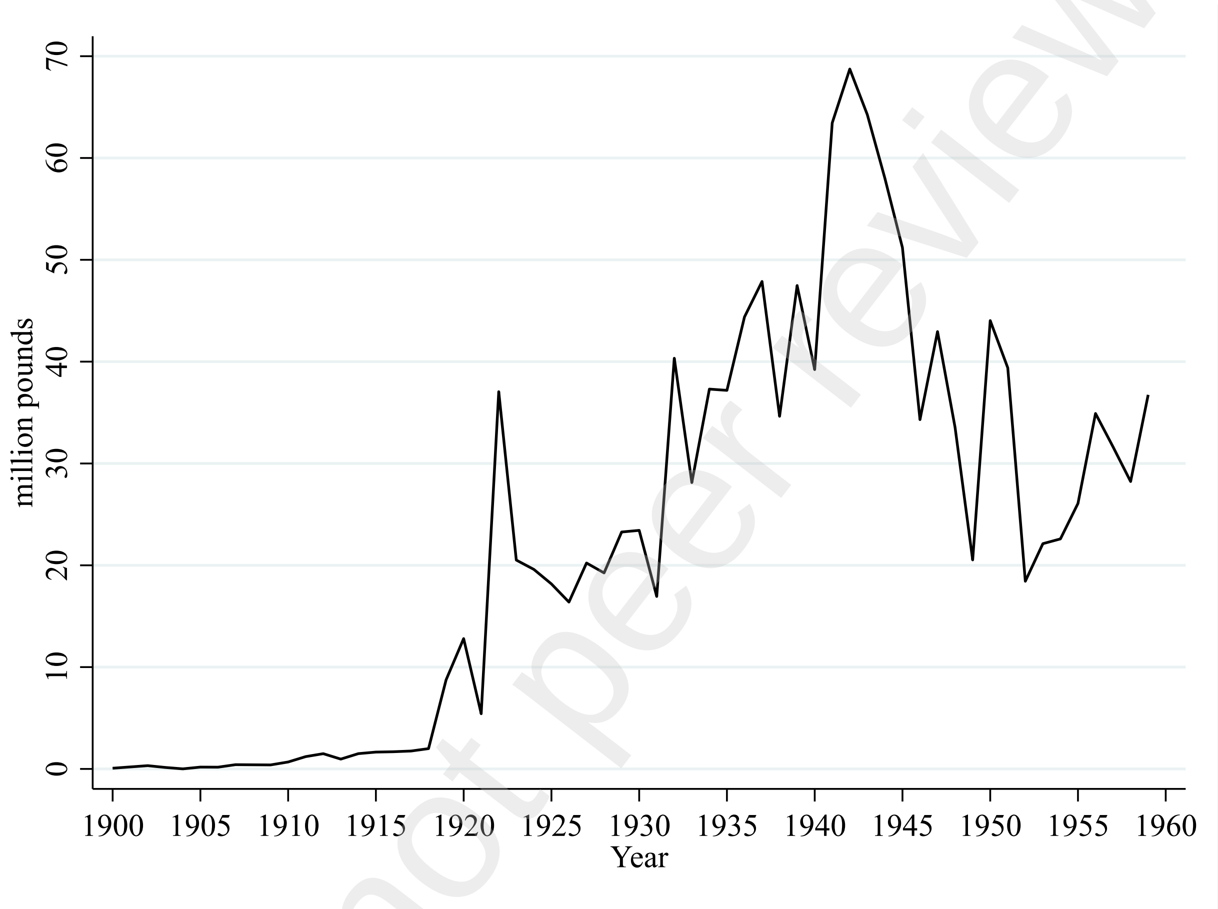
Main Figures and Tables

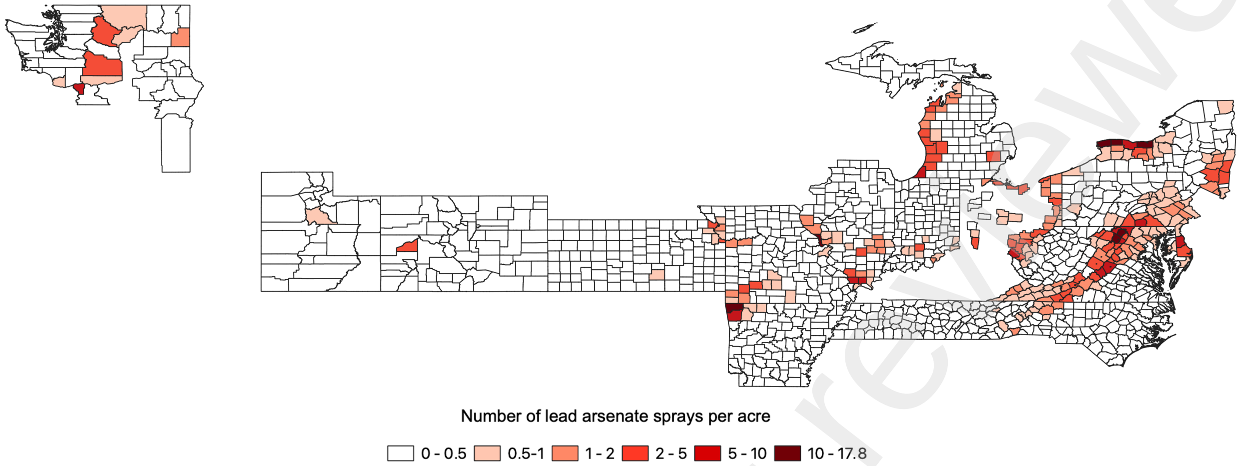
Figure 1: Agricultural Arsenic Consumption in the U.S. Over Time



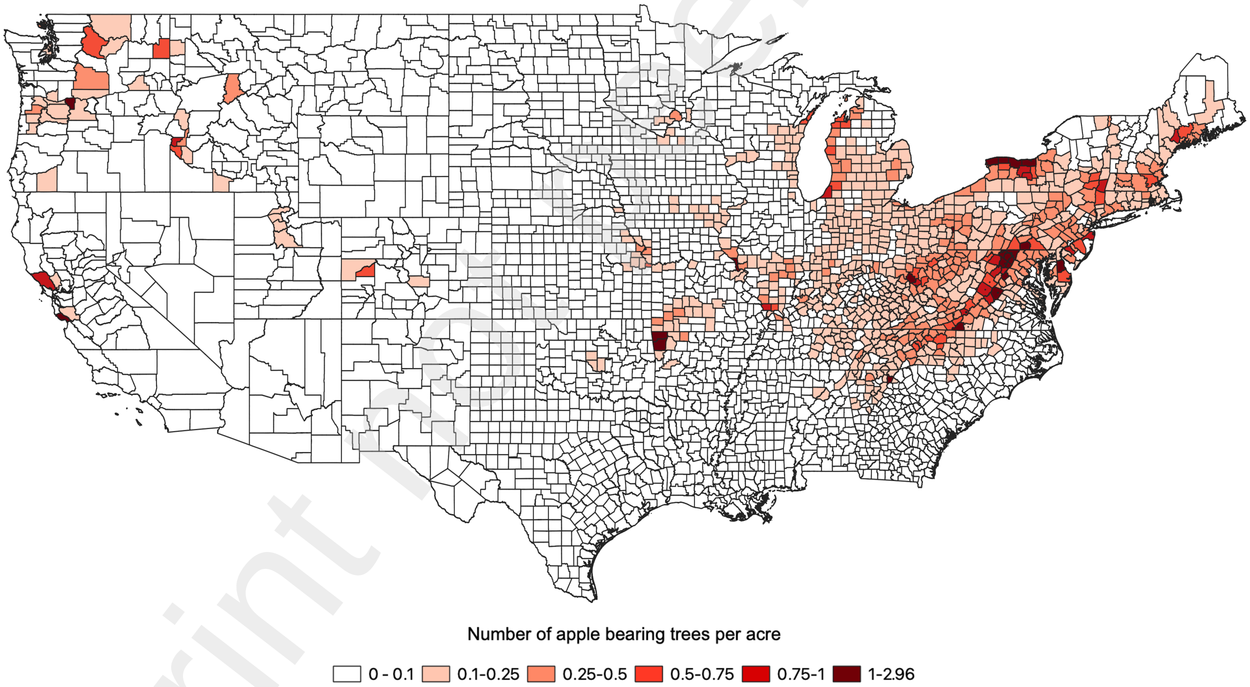
Notes: Figure shows estimated agricultural arsenic consumption in the United States from 1900 to 1960. Values are constructed following Murphy and Aucott (1998) by multiplying total arsenic consumption by the estimated share of arsenic used in agriculture based on U.S. Minerals Yearbooks for various years (U.S. Geological Survey, n.d.).

Figure 2: Geography of Apple Growing and Lead Arsenate Spraying in 1920s

(a) Number of sprays on apples per acre



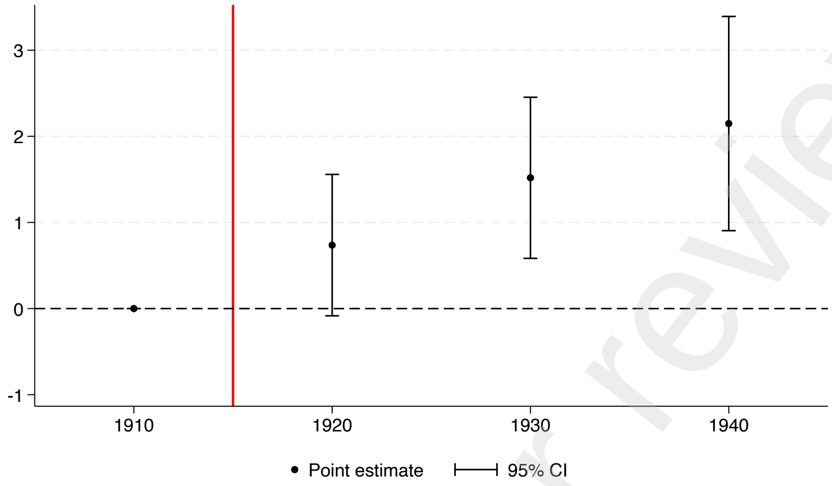
(b) Apple tree density



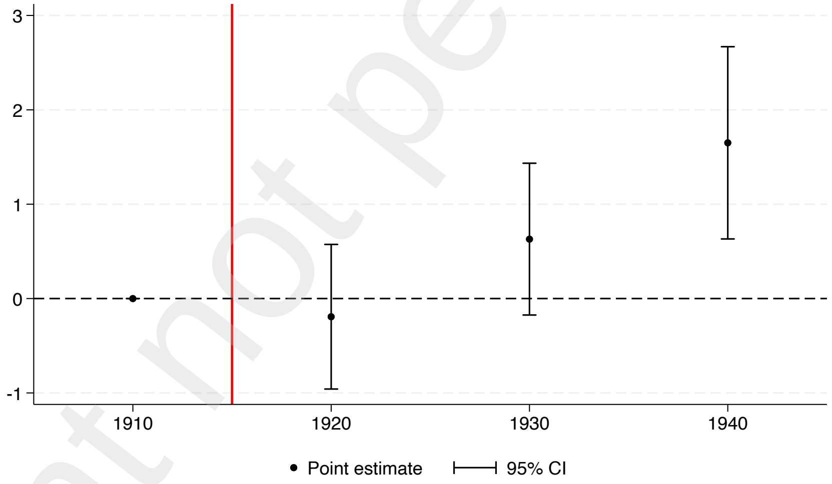
Notes: Figure displays the geographic distribution of arsenic pesticide exposure proxies in the 1920s. Panel (a) maps the number of lead arsenate sprays per acre, constructed from the 1928 National Apple Industry Survey (U.S. Bureau of Agricultural Economics, 1931), which reports county-level information on commercial apple orchards and spraying practices during the 1925 growing season in 19 states. Panel (b) maps apple tree density, measured as the number of apple-bearing trees reported in the 1925 U.S. Census of Agriculture divided by county land area (Haines, Fishback and Rhode, 2018).

Figure 3: Arsenic Pesticides and County Rural Infant Mortality

(a) County rural infant deaths per 1,000 births: Number of sprays per acre



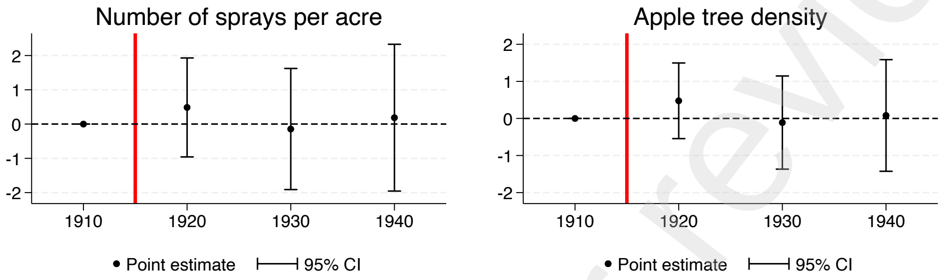
(b) County rural infant deaths per 1,000 births: Apple tree density



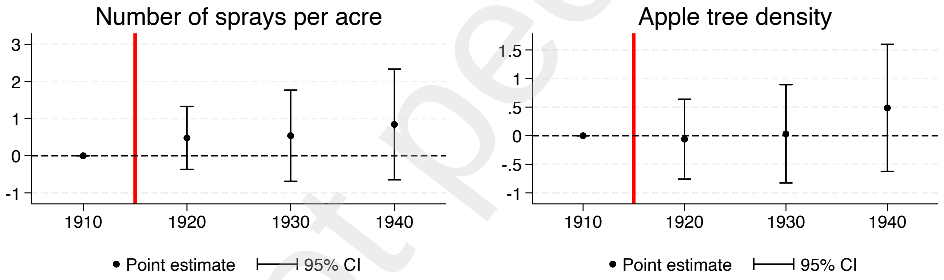
Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county-year level. Vital statistics data on births and infant deaths are from NCHS (1917-1941). Panel (a) uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931); Panel (b) uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural births. Sample covers 1917–1941 and includes counties located in states that were part of the federal birth registration area; see text and Online Appendix Table 2 for details on geographic coverage.

Figure 4: Arsenic Pesticides and Other Infant Mortality Outcomes

(a) County urban infant deaths per 1,000 births



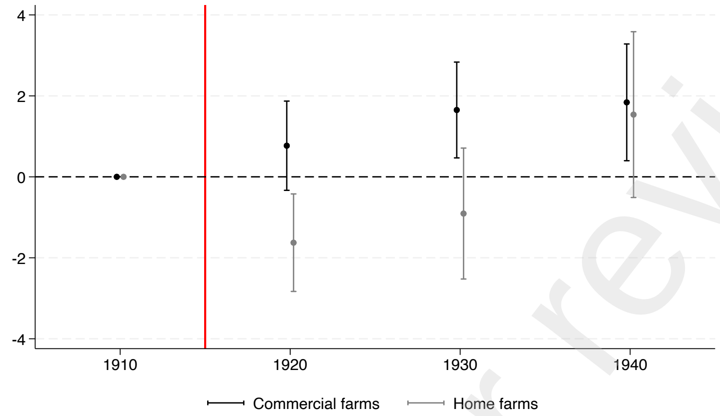
(b) County total infant deaths per 1,000 births



Notes: Figure displays estimates from Equation 2 for alternative county–year outcomes using vital statistics from NCHS (1917–1941). Panel (a) shows county urban infant deaths per 1,000 urban live births. Panel (b) shows county total infant deaths per 1,000 live births. In each panel, the left subplot uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931), and the right subplot uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county urban or total births depending on the outcome. Sample covers 1917–1941 and includes counties located in states that were part of the federal birth registration area; see text and Online Appendix Table 2 for details on geographic coverage.

Figure 5: Arsenic Pesticides and County Rural Infant Mortality, Alternative Specifications

(a) County rural infant deaths per 1,000 births: Tree density by farm status



(b) County rural infant deaths per 1,000 births: Tree density by fruit bearing status

Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county–year level. Vital statistics data on births and infant deaths are from NCHS (1917–1941). Panel (a) uses variation in apple tree density by farm type, distinguishing commercial farms with 100 or more apple trees from home farms (U.S. Bureau of Agricultural Economics, 1931). Panel (b) uses variation in apple tree density by production status, distinguishing fruit-bearing from non-bearing apple trees (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural births. The sample covers 1917–1941 and is limited to counties in states included in the federal birth registration area; see text and Online Appendix Table 2 for geographic coverage.

Table 1: Descriptive Statistics

	Mean (1)	SD (2)	Min (3)	Max (4)
Panel A: Arsenic Pesticide Proxies				
Lead arsenate spraying per acre per season	0.73	1.74	0	18
Commercial orchard trees per acre	0.20	0.40	0	5
Home farm trees per acre	0.11	0.08	0	1
Number of apple-bearing trees per acre	0.15	0.26	0	3
Number of non-bearing apple trees per acre	0.06	0.09	0	2
Panel B: County Natality and Mortality Statistics				
Rural infant mortality rate per 1000 births	62.15	24.13	0	333
Rural births	543.70	599.32	3	12183
Total infant mortality rate per 1000 births	62.79	23.84	0	333
Total births	776.03	1085.92	3	12183
Panel C: Linked Army Enlistment Records				
Birth decade is 1920	0.53	0.50	0	1
Age at enlistment	22.94	3.79	18	34
White	0.91	0.28	0	1
Black	0.08	0.27	0	1
Number of siblings	2.85	2.13	0	9
Farm residence	0.39	0.49	0	1
Rural non-farm residence	0.26	0.44	0	1
Father is native-born	0.87	0.33	0	1
Father is literate	0.94	0.24	0	1
Father is farmer	0.38	0.49	0	1
Height (inches)	68.78	3.20	59	82
Height is below 25th percentile	0.21	0.41	0	1
Height is below median	0.48	0.50	0	1
Weight (lbs)	149.30	19.42	90	253
Completed high school or higher	0.48	0.50	0	1
Panel D: Domestic Well Water Sample				
Arsenic in water filtered micrograms per liter	4.06	10.45	0	243
Arsenic in water exceeds MCL (10 ug/l)	0.08	0.27	0	1
Lead in water filtered micrograms per liter	1.02	1.26	0	14
Panel E: County Characteristics				
Total population (000s)	71.49	85.32	0	482
Share White	0.88	0.18	0	1
Share rural	0.65	0.30	0	1
Share literate	0.92	0.08	0	1
Number of farms (000s)	2.95	1.59	0	13
Share of land in farms	0.70	0.25	0	4
Share of land in crops	0.45	0.24	0	1
Share of farms operated by owner	0.66	0.19	0	1
Share of farms with 10 acres or more	0.93	0.06	0	1
Value of farmland and buildings per acre (USD 000s)	0.08	0.08	0	1

Notes: Panel A reports pesticide exposure proxies constructed from the 1928 National Apple Industry Survey (U.S. Bureau of Agricultural Economics, 1931) and the 1925 U.S. Census of Agriculture (Haines, Fishback and Rhode, 2018). Panel B reports natality and infant mortality statistics digitized from National Center for Health Statistics (NCHS) Vital Statistics (1917–1941). Panel C reports individual characteristics from World War II U.S. Army Enlistment Records (National Archives and Records Administration, 2002) linked to the U.S. Census manuscripts (Ruggles et al., 2020) following Abramitzky et al. (2021). Panel D reports contaminant levels in domestic well water from the U.S. Geological Survey's NAWQA program (DeSimone et al., 2009). Panel E reports county demographic and agricultural characteristics from the U.S. Census of Population and Agriculture (Haines and ICPSR, 2010; Haines, Fishback, and Rhode, 2018).

Table 2: Arsenic Pesticides and Adult Height

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.009		-0.003	0.001		-0.001
	(0.008)		(0.009)	(0.001)		(0.001)
Spray × Father is farmer		0.022	0.021		-0.002	-0.002
		(0.024)	(0.024)		(0.003)	(0.003)
Spray × Father is farmer × Post		-0.043**	-0.041**		0.009***	0.010***
		(0.018)	(0.019)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	243322	243322	243322	243322	243322	243322
Panel B: Agricultural Census Sample						
Tree density × Post	-0.006		-0.003	0.000		-0.000
	(0.006)		(0.006)	(0.001)		(0.001)
Tree density × Father is farmer		0.005	0.004		-0.001	-0.001
		(0.016)	(0.017)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.025*	-0.024*		0.006***	0.006***
		(0.013)	(0.014)		(0.002)	(0.002)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	519597	519597	519597	519597	519597	519597

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple-bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Arsenic Pesticide Exposure and Adult Height, Alternative Specifications

	Dependent variable =	
	Height in inches	Height is below 25th percentile
	(1)	(2)
Panel A: Tree density by farm status		
Commercial orchard trees per acre × Father is farmer × Post	-0.027	0.007**
	(0.023)	(0.003)
Home farm trees per acre × Father is farmer × Post	-0.025	0.004
	(0.025)	(0.004)
Panel B: Tree density by fruit bearing status		
Apple-bearing trees per acre × Father is farmer × Post	-0.062***	0.007**
	(0.021)	(0.003)
Non-bearing trees per acre × Father is farmer × Post	0.055*	-0.002
	(0.033)	(0.004)

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–2) or as an indicator for whether height falls below the 25th percentile (columns 3–4). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Panel A uses variation in apple tree density by farm type, distinguishing commercial orchards with 100 or more apple trees from home farms (U.S. Bureau of Agricultural Economics, 1931). Panel B uses variation in apple tree density by production status, distinguishing fruit-bearing from non-bearing apple trees (Haines, Fishback and Rhode, 2018). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Arsenic Pesticides and Domestic Well Water Quality in the Long Run

	Dependent variable =					
	Arsenic ug/L	Arsenic $\geq$ 10 ug/L	Lead ug/L	Cadmium ug/L	Nickel ug/L	Zinc ug/L
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Main Specification						
Tree density: Apple-bearing	1.356	0.079***	-0.136	0.039	-0.249	-0.520
	(0.874)	(0.025)	(0.155)	(0.036)	(0.338)	(4.395)
Panel B: Alternative Specification						
Tree density: Apple-bearing	1.586	0.099***	-0.075	0.059	-0.016	-1.937
	(1.346)	(0.034)	(0.151)	(0.044)	(0.419)	(4.907)
Tree density: Non-bearing	-0.333	-0.028	-0.088	-0.030	-0.338	2.051
	(0.874)	(0.024)	(0.113)	(0.044)	(0.500)	(5.224)
Dep Var Mean	4.1	0.1	1.0	0.7	2.0	41.3
R-squared	0.17	0.21	0.27	0.48	0.09	0.16
Observations	1298	1298	1304	1304	1304	1289

Notes: Table reports estimates from Equation 4, where the dependent variables are domestic well water quality outcomes from the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program: arsenic concentration in μg/L (column 1), an indicator for whether arsenic levels exceed the EPA's maximum contaminant level of 10 μg/L (column 2), and concentrations of lead, cadmium, nickel, and zinc in μg/L (columns 3–6). Panel A uses variation in fruit-bearing apple tree density as the exposure proxy. Panel B separates tree density by production status, distinguishing fruit-bearing and non-bearing apple trees (Haines, Fishback and Rhode, 2018). All coefficients are scaled to represent the effect of a one standard deviation increase in tree density. Specifications include historical county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture and state fixed effects. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Poisoned Fruits
Cavit Baran
Sabancı University
Online Appendix

A Linkage Procedure Details

I create a matched sample by linking men from the World War II Army Enlistment Records to the 1920 and 1930 complete-count Census manuscripts, provided by IPUMS and accessed through the NBER server. I restrict attention to men born between 1910 and 1929 who were ages 18–34 at the time of enlistment. Following the automated procedure developed by Abramitzky et al. (2021), I link men born between 1910 and 1919 to the 1920 Census, and those born between 1920 and 1929 to the 1930 Census, observing them in their childhood residence at age 10 or younger.[23] The procedure proceeds in the following steps:

1. In each dataset, I clean first and last names to remove any non-alphabetic characters and standardize nicknames.
2. I link individuals from enlistment records to census manuscripts in the following way:
   (a) For each enlistment record, I look for records in the census data that match on cleaned first and last name, race, birth state, and exact birth year. If the match is unique, I call this pair a match. If there is more than one observation, I drop the enlistment record from the search and call it unmatched.
   (b) For the remaining records that do not match in the previous step, I search for a unique match within $+/-1$ year of the birth year in the census. I again only accept unique matches.
   (c) I repeat the previous step by looking for a unique match within $+/-2$ years. If the record still has no unique match, I call it unmatched.
3. I repeat the same procedure in (2), but this time I link individuals from the census to enlistment records.
4. I then take the intersection of the two linked samples.

Match rates for the 1920 and 1930 Censuses are 12 and 13 percent, respectively. These are comparable to rates in the literature. For example, Eriksson (2019) reports a 27.3 percent match rate when linking men in 1940 to earlier Censuses, which is somewhat higher because individuals could be matched across multiple target years and because my procedure requires agreement from both directions before keeping a link.

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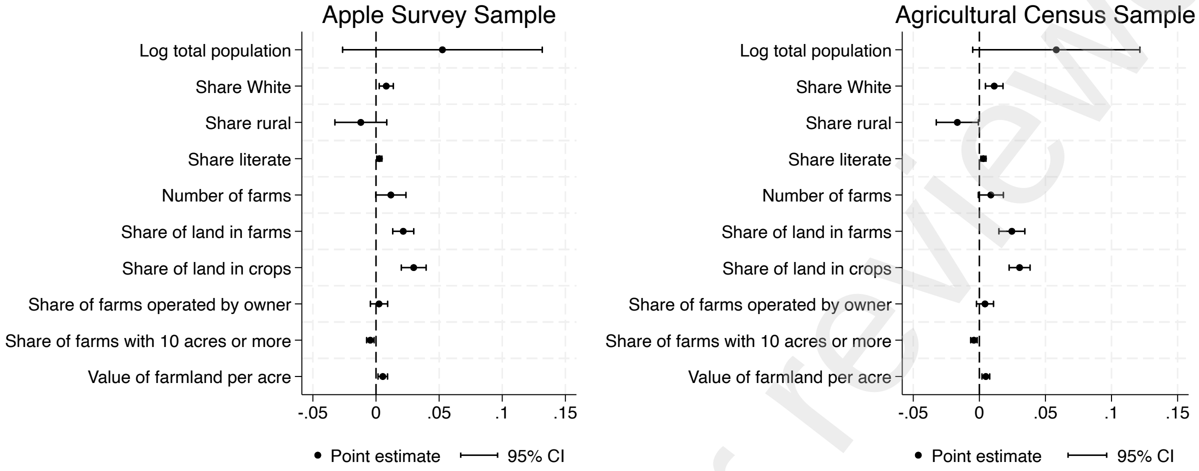
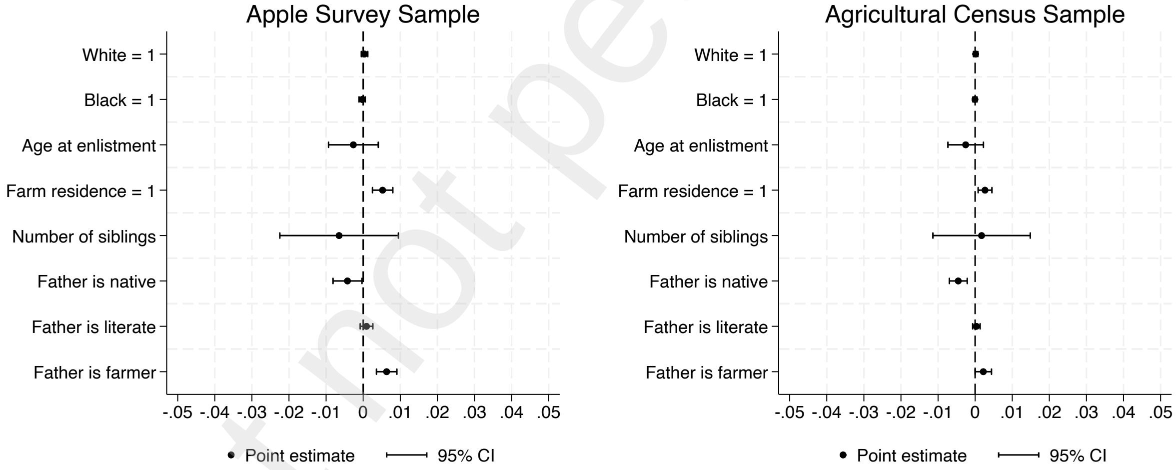
[23] In the linking procedure, I also download and use command files from Abramitzky et al. (2021).

Appendix Figure 1: Balance Test on Covariates

(a) County Characteristics in 1910

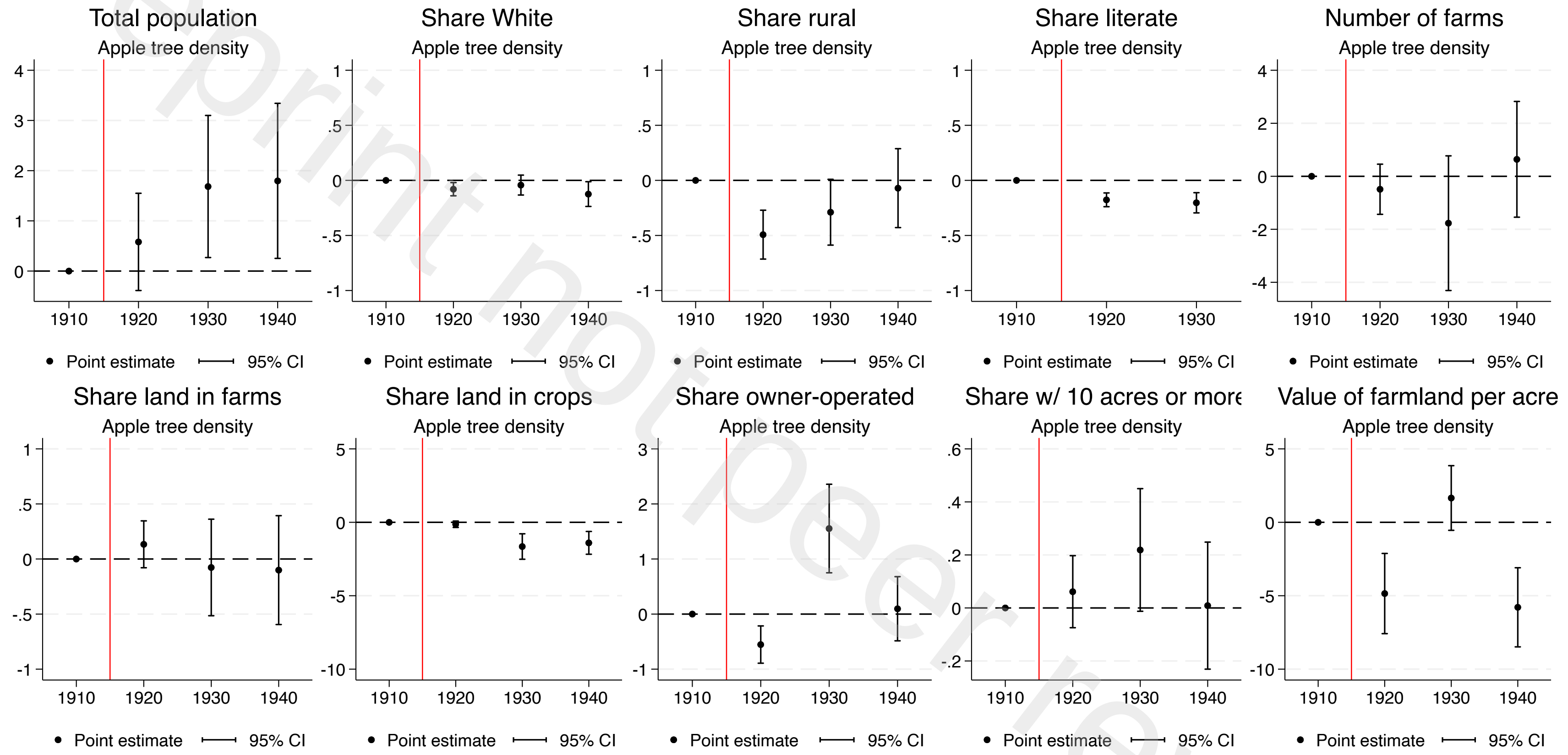


(b) Individual Characteristics in Army Enlistment Records



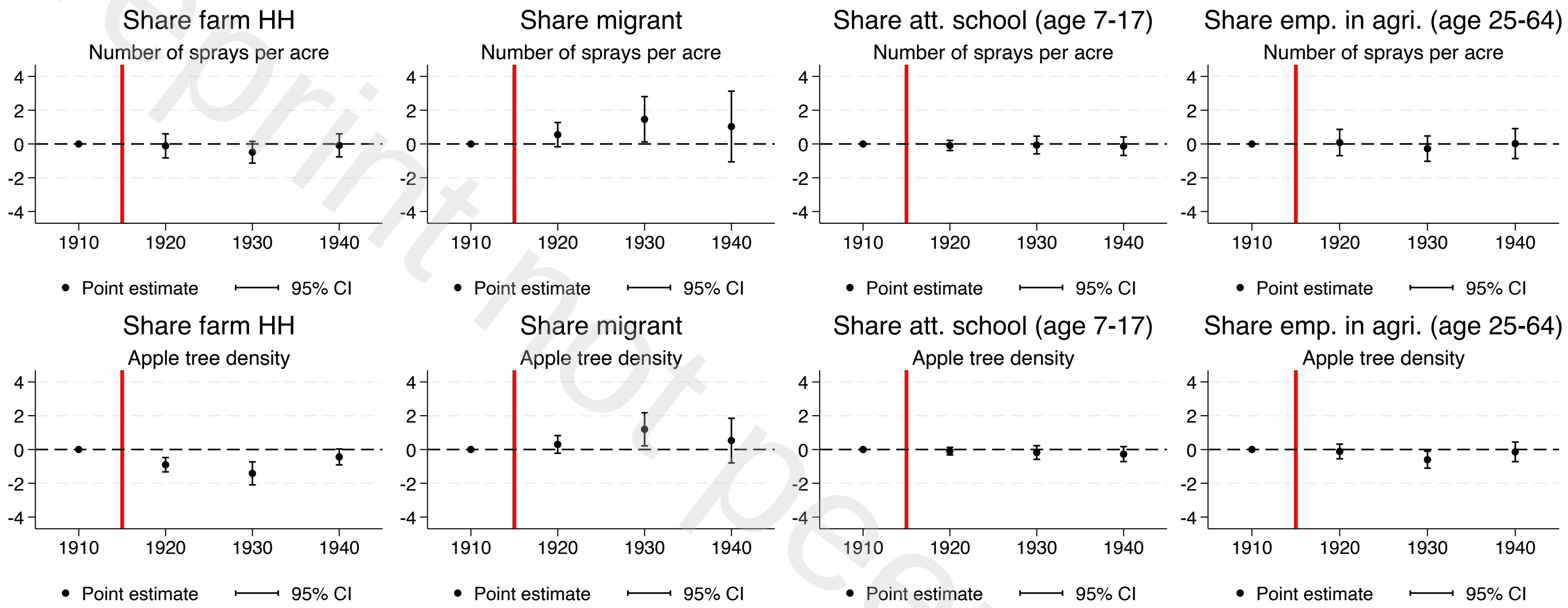
Notes: Figure reports balance tests for county- and individual-level characteristics using two alternative exposure proxies: number of lead arsenate sprays per acre (U.S. Bureau of Agricultural Economics, 1931) and apple-bearing tree density (Haines, Fishback and Rhode, 2018). Point estimates are scaled to represent the effect of a one–standard–deviation increase in the proxy; 95% confidence intervals are shown. All regressions cluster standard errors at the county level and apply population weights. Panel (a) reports county-level regressions of demographic and agricultural characteristics on exposure proxies separately for 1910. Outcomes include log total population, share White, share rural, literacy rates, number of farms, share of land in farms and crops, share of owner-operated farms, share of farms with 10 acres or more, and the value of farmland per acre (U.S. Census of Population and Agriculture, 1910–1940). Specifications include state fixed effects. Panel (b) reports individual-level regressions for linked Army enlistees born 1910–1929. Outcomes include race (White, Black), farm residence, number of siblings, father's nativity, literacy, and farming status, and age at enlistment. Specifications include county and birth-year fixed effects, as well as state-specific linear time trends. Individual characteristics come from Army enlistment records linked to childhood census households (National Archives and Records Administration, 2002; Ruggles et al., 2020).

Appendix Figure 2: Arsenic Pesticides and County Covariates Over Time



Notes: Figure displays estimates of the association between historical arsenic exposure and county-level covariates over time. Each panel reports results from regressions of the listed county characteristic on apple-bearing tree density (Haines, Fishback and Rhode, 2018) interacted with decade indicators, following Equation 2. Outcomes include log total population, racial composition (share White), share rural, share literate, number of farms, share of land in farms, share of land in crops, share of farms operated by owners, share of farms with 10 acres or more, and value of farmland per acre (U.S. Census of Population and Agriculture, 1910–1940). All specifications control for county fixed effects, year fixed effects, and state-specific linear time trends, and are weighted by county population. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. Standard errors are clustered at the county level.
]

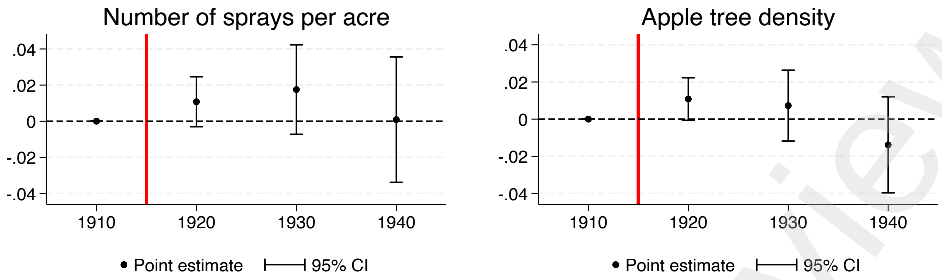
Appendix Figure 3: Arsenic Pesticides and County Level Outcomes Over Time



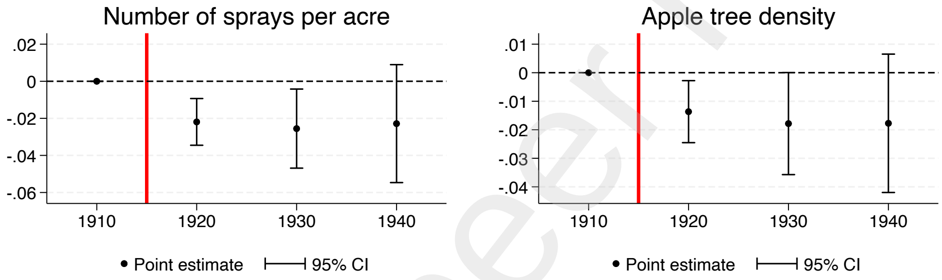
Notes: Figure displays estimates from county-level regressions of additional outcomes on arsenic exposure proxies. Outcomes include share of farm households, share of migrant households, share of children ages 7–17 attending school, and share of adults ages 25–64 employed in agriculture (U.S. Census of Population and Agriculture, 1910–1940). Proxies include number of lead arsenate sprays per acre (U.S. Bureau of Agricultural Economics, 1931) and apple-bearing tree density (Haines, Fishback and Rhode, 2018). All specifications control for county fixed effects, year fixed effects, and state-specific linear time trends, and are weighted by county population. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. Standard errors are clustered at the county level.

Appendix Figure 4: Arsenic Pesticides and County Natality Outcomes

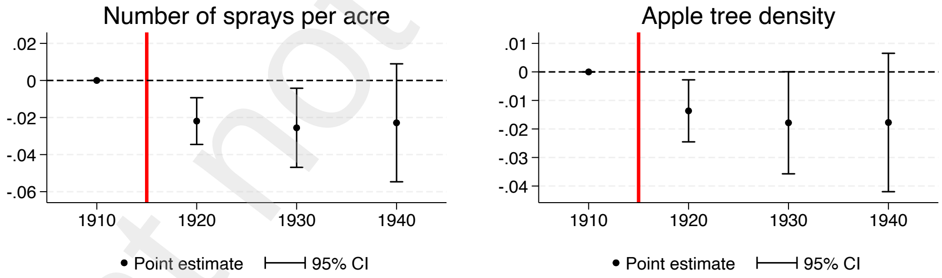
(a) Log number of county rural births



(b) Log number of county urban births



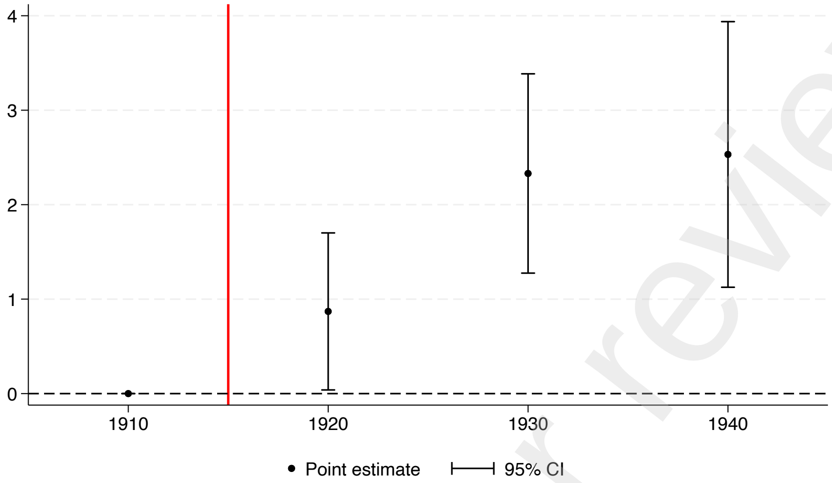
(c) Log number of county total births



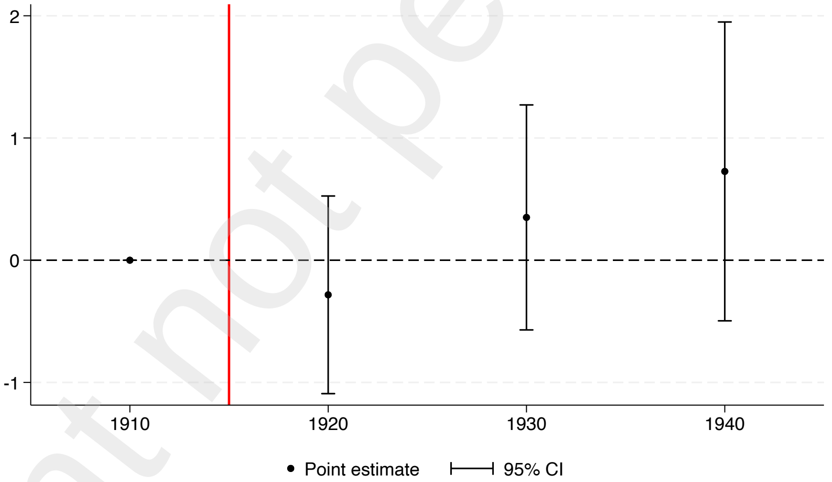
Notes: Figure displays estimates from Equation 2 for alternative county–year birth outcomes using vital statistics from NCHS (1917–1941). Panel (a) shows the log number of county rural births, panel (b) shows the log number of county urban births, and panel (c) shows the log number of county total births. In each panel, the left subplot uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931), and the right subplot uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural, urban, or total population depending on the outcome. The sample covers 1917–1941 and is limited to counties in states included in the federal birth registration area; see text and Online Appendix Table 2 for geographic coverage.

Appendix Figure 5: Arsenic Pesticides and Rural Infant Mortality, Dropping State-Specific Linear Time Trends

(a) Rural infant deaths per 1,000 births: Number of sprays per acre



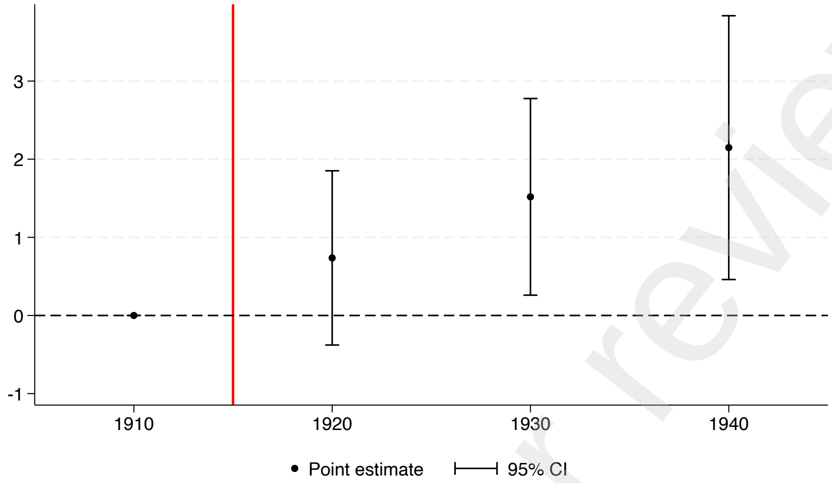
(b) Rural infant deaths per 1,000 births: Apple tree density



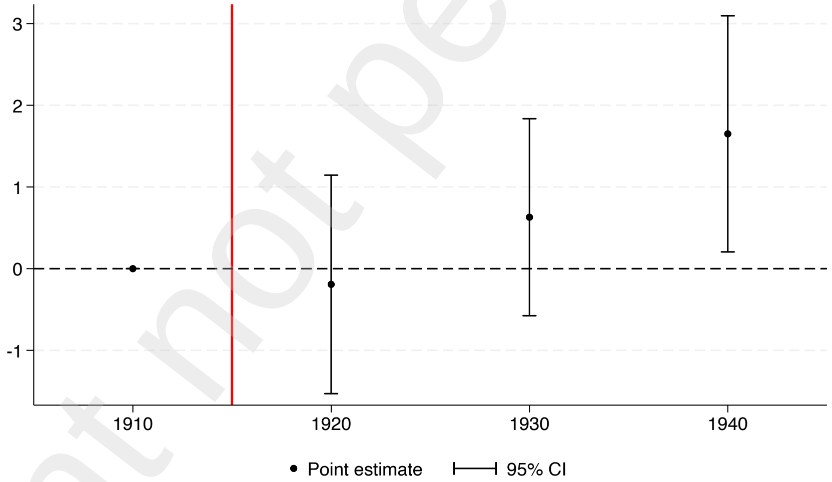
Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county-year level. Vital statistics data on births and infant deaths are from NCHS (1917-1941). Panel (a) uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931); Panel (b) uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. Unlike the baseline specification, these regressions do not include state-specific linear time trends. All specifications include county fixed effects, year fixed effects, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural births. Sample covers 1917–1941 and includes counties located in states that were part of the federal birth registration area; see text and Online Appendix Table 2 for details on geographic coverage.

Appendix Figure 6: Arsenic Pesticides and Rural Infant Mortality, Clustering Standard Errors at Agricultural District Level

(a) Rural infant deaths per 1,000 births: Number of sprays per acre



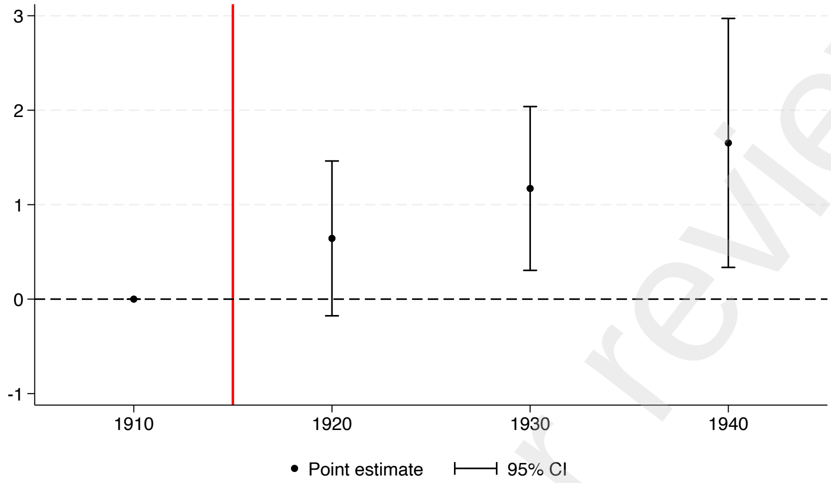
(b) Rural infant deaths per 1,000 births: Apple tree density



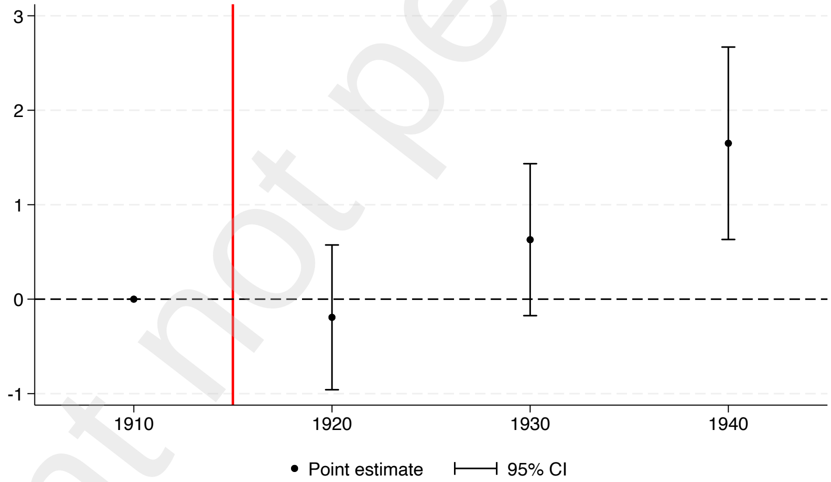
Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county-year level. Vital statistics data on births and infant deaths are from NCHS (1917-1941). Panel (a) uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931); Panel (b) uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Unlike the baseline specification, standard errors here are clustered at the agricultural district level. Regressions are weighted by county rural births. Sample covers 1917–1941 and includes counties located in states that were part of the federal birth registration area; see text and Online Appendix Table 2 for details on geographic coverage.

Appendix Figure 7: Arsenic Pesticides and Rural Infant Mortality, Including Large Population Centers

(a) Rural infant deaths per 1,000 births: Number of sprays per acre

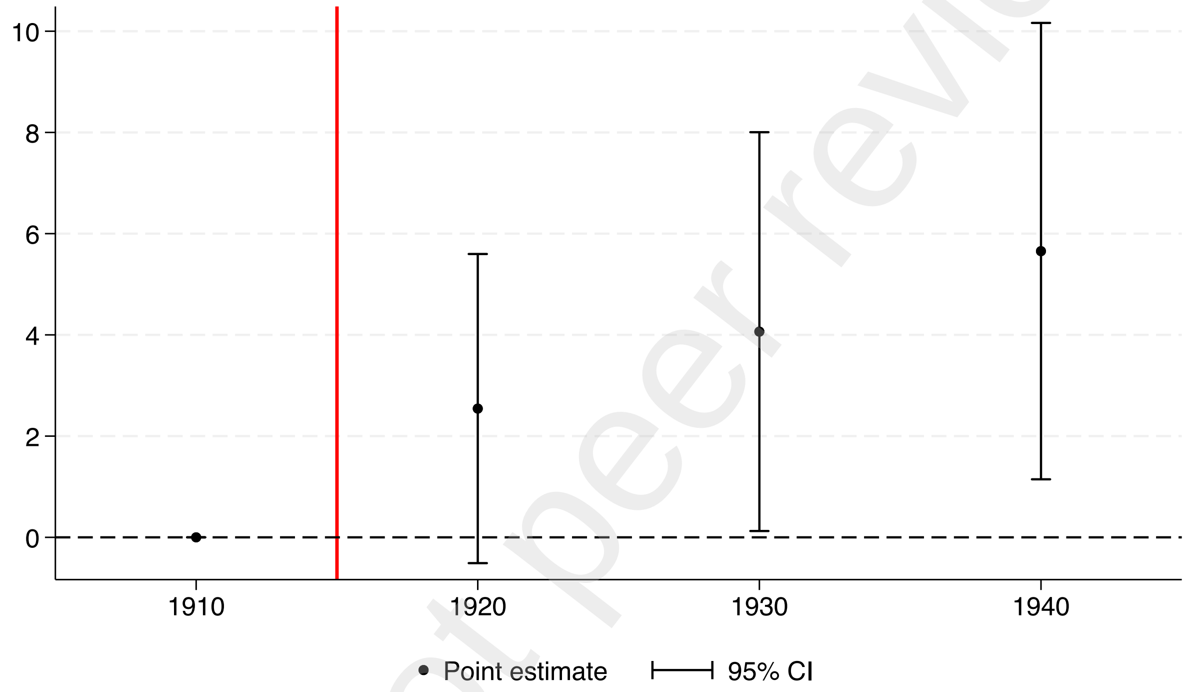


(b) Rural infant deaths per 1,000 births: Apple tree density



Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county-year level. Vital statistics data on births and infant deaths are from NCHS (1917-1941). Panel (a) uses number of lead arsenate sprays per acre as the exposure proxy (U.S. Bureau of Agricultural Economics, 1931); Panel (b) uses apple-bearing tree density (Haines, Fishback and Rhode, 2018). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates are scaled to represent the effect of a one standard deviation increase in the corresponding proxy; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural births. Regressions are weighted by county rural births. Sample here is expanded to include large population centers with 500,000 or more population; see text and Online Appendix Table 2 for details on geographic coverage.

Appendix Figure 8: Top-Decile Arsenic Pesticide Exposure and County Rural Infant Mortality



Notes: Figure displays estimates from Equation 2, where the dependent variable is county rural infant mortality rate (rural infant deaths per 1,000 rural live births) at the county-year level. Vital statistics data on births and infant deaths are from NCHS (1917-1941). The exposure measure is an indicator for whether a county had one or more lead arsenate sprays per acre, capturing top-decile arsenic pesticide exposure (U.S. Bureau of Agricultural Economics, 1931). The omitted category is the 1910s; coefficients for the 1920s, 1930s, and 1940s are reported relative to this baseline. Point estimates therefore represent the difference in infant mortality associated with high-exposure counties relative to lower-exposure counties; 95% confidence intervals are shown. All specifications include county fixed effects, year fixed effects, state-specific linear time trends, and contemporary county controls (U.S. Census of Population and Agriculture, 1910–1940): log total population, share White, share rural, share literate, number of farms, share of land in farms, share of land in crops, share of owner-operated farms, share of farms with 10 acres or more, and value of farmland per acre. Standard errors are clustered at the county level; regressions are weighted by county rural births. Sample covers 1917–1941 and includes counties located in states that were part of the federal birth registration area; see text and Online Appendix Table 2 for details on geographic coverage.

Appendix Table 1: USDA Spraying Recommedations for Insect Control

Crop	Insecticide	Dosage	# of Apps	Target insect	Source
Apple	Lead Arsenate	6 lbs	5-10 apps	Codling moth	FB No. 1666
Pear	Lead Arsenate	4-6 lbs	3 apps	Codling moth	FB No. 1666
Stone fruits	Lead Arsenate	4 lbs	2 apps	Curculio	FB No. 1666
Grape	Lead Arsenate	4-6 lbs	3 apps	Grape moth	FB No. 1666
Cotton	Calcium Arsenate	5-7 lbs	3 apps	Boll weevil	FB No. 1329
Tobacco	Calcium Arsenate	7-10 lbs	2 apps	Tobacco hornworm	FB No. 1356
Potato	Calcium Arsenate	3-4 lbs	3 apps	Colorado beetle	FB No. 1349
Corn	None	–	–	Corn earworm	FB No. 1310
Grains	None	–	–	Weevils and strawworms	FB No. 1323

Notes: Table summarizes USDA spraying recommendations for insect control across different crops. Dosage for lead arsenate is reported per 100 gallons of water, while dosage for calcium arsenate is reported per acre. Recommendations come from various USDA Farmer Bulletins (1923b, 1923c,1923a,1923d,1924,1932, 1937).

Appendix Table 2: Data availability by state and variable

State	Spraying	Apple Trees	Vital Statistics	NARA Records	Domestic Wells
Alabama		X		X	X
Arizona		X		X	X
Arkansas	X	X		X	X
California		X		X	X
Colorado	X	X		X	X
Connecticut		X	X	X	X
Delaware	X	X		X	X
Georgia		X		X	X
Idaho		X		X	X
Illinois	X	X		X	X
Indiana	X	X	X	X	X
Iowa		X		X	X
Kansas	X	X	X	X	X
Kentucky		X	X	X	
Louisiana		X		X	X
Maine		X	X	X	X
Maryland	X	X	X	X	X
Massachusetts		X	X	X	X
Michigan	X	X	X	X	X
Minnesota		X	X	X	X
Mississippi		X		X	X
Missouri	X	X		X	X
Montana		X		X	X
Nebraska		X		X	X
Nevada		X		X	X
New Hampshire		X	X	X	X
New Jersey		X		X	X
New Mexico		X		X	X
New York	X	X	X	X	X
North Carolina	X	X	X	X	X
North Dakota		X		X	X
Ohio	X	X	X	X	X
Oklahoma		X		X	X
Oregon	X	X		X	X
Pennsylvania	X	X	X	X	X
Rhode Island		X		X	X
South Carolina		X		X	X
South Dakota		X		X	X
Tennessee	X	X		X	X
Texas		X		X	X
Utah	X	X	X	X	X
Vermont		X	X	X	X
Virginia	X	X	X	X	X
Washington	X	X	X	X	X
West Virginia	X	X		X	X
Wisconsin		X	X	X	X
Wyoming		X		X	X

Notes: Table indicates the availability of different data sources by state, including arsenic spraying reports (U.S. Bureau of Agricultural Economics, 1931), apple tree density from the 1925 Agricultural Census (Haines, Fishback and Rhode, 2018), Vital Statistics birth and death records (NCHS, 1917-1941), linked enlistment records from National Archives and Records Administration (2002), and domestic well water data from NAQWA (DeSimone, Hamilton and Gilliom, 2009). An "X" denotes that the corresponding data source is available for that state.

Appendix Table 3: Birth Registration Cities by State, 1917

State Name	City Name
Connecticut	Bridgeport, Danbury, Norwalk, Stamford, Bristol, Hartford, New Britain, Torrington, Middletown Ansonia, Meriden, Naugatuck, New Haven, Wallingford, Waterbury, New London, Norwich, Windham
Indiana	Fort Wayne, Logansport, Jeffersonville, Muncie, Elkhart, New Albany, Marion, Kokomo Huntington, Vincennes, East Chicago, Gary, Hammond, Laporte, Michigan City, Anderson Elwood, Indianapolis, Peru, Mishawaka, South Bend, Lafayette, Evansville, Terre Haute, Richmond
Kansas	Atchison, Fort Scott, Pittsburg, Lawrence, Parsons, Leavenworth, Coffeyville, Independence Hutchinson, Wichita, Topeka, Kansas City
Kentucky	Newport, Owensboro, Lexington, Henderson, Louisville, Covington, Paducah
Maine	Auburn, Lewiston, Portland, Augusta, Waterville, Bangor, Biddeford
Maryland	Cumberland, Frederick, Hagerstown
Massachusetts	Adamstown, North Adams, Pittsfield, Attleboro, Fall River, New Bedford, Taunton, Beverly Gloucester, Haverhill, Lawrence, Lynn, Methuen town, Newburyport, Peabody, Salem, Greenfield Chicopee, Holyoke, Springfield, Westfield town, Northampton, Arlington town, Cambridge Everett, Framingham town, Lowell, Malden, Marlborough, Medford, Melrose, Newton Somerville, Wakefield town, Waltham, Watertown town, Woburn, Brookline town, Quincy, Weymouth Brockton, Plymouth town, Boston, Chelsea, Revere, Winthrop town, Clinton town, Fitchburg Gardner town, Leominster, Milford town, Southbridge town, Webster town, Worcester
Michigan	Alpena, Bay City, Battle Creek, Sault Ste Marie, Escanaba, Flint, Ironwood, Traverse City, Lansing Jackson, Kalamazoo, Grand Rapids, Adrian, Marquette, Muskegon, Pontiac, Holland, Saginaw Port Huron, Ann Arbor, Detroit
Minnesota	Mankato, Minneapolis, St Paul, Duluth, Virginia, St Cloud, Winona
New Hampshire	Laconia, Keene, Berlin, Manchester, Nashua, Concord, Portsmouth, Dover
New York	Albany, Cohoes, Watervliet, Binghamton, Olean, Auburn, Dunkirk, Jamestown, Elmira, Plattsburg Hudson, Cortland, Poughkeepsie, Buffalo, Lackawanna, Gloversville, Johnstown, Batavia, Little Falls Watertown, Rochester, Amsterdam, Lockport, Niagara Falls, North Tonawanda, Rome, Utica, Syracuse Geneva, Middletown, Newburgh, Fulton, Oswego, Rensselaer, Troy, Saratoga Springs, Schenectady Ogdensburg, Corning, Hornell, Ithaca, Kingston, Glens Falls, Mount Vernon, New Rochelle Ossining, Peekskill, Port Chester, White Plains, Yonkers
North Carolina	Asheville, Durham, Winston-Salem, Greensboro, Charlotte, Wilmington, Raleigh
Ohio	Lima, Ashtabula, Bellaire, Hamilton, Middletown, Springfield, East Liverpool, Cleveland, Lakewood Sandusky, Lancaster, Columbus, Cambridge, Cincinnati, Norwood, Findlay, Steubenville, Ironton Newark, Elyria, Lorain, Toledo, Youngstown, Marion, Piqua, Dayton, Zanesville Mansfield, Chillicothe, Portsmouth, Tiffin, Alliance, Canton, Massillon, Akron, Warren, Marietta
Pennsylvania	Braddock, Carnegie, Duquesne, Homestead, McKees Rocks, McKeesport, North Braddock, Pittsburgh Wilkinsburg, Beaver Falls, Reading, Altoona, Butler, Johnstown, Coatesville, Phoenixville West Chester, Dubois, Meadville, Carlisle, Harrisburg, Steelton, Chester, Erie, Connellsville Uniontown, Chambersburg, Carbondale, Dunmore, Old Forge, Scranton, Columbia, Lancaster New Castle, Allentown, Hazleton, Nanticoke, Pittston, Plymouth, Wilkes-Barre, Williamsport Bradford, Farrell, Sharon, Norristown, Pottstown, Bethlehem, Easton, Mount Carmel, Shamokin, Sunbury Mahanoy City, Pottsville, Shenandoah, Oil City, Warren, Washington, Greensburg, Monessen, York
Utah	Salt Lake City, Ogden
Vermont	Burlington, Rutland, Barre
Washington	Aberdeen, Seattle, Tacoma, Everett, Spokane, Walla Walla, Bellingham, Yakima
Wisconsin	Ashland, Green Bay, Madison, Superior, Eau Claire, Fond du Lac, Kenosha, La Crosse, Manitowoc Wausau, Marinette, Milwaukee, Appleton, Racine, Beloit, Janesville, Sheboygan, Oshkosh

Notes: Table lists the set of "registration cities" identified in the U.S. Bureau of the Census, *Vital Statistics of the United States*, 1917. Registration cities are defined as those with a population of 10,000 or more in the 1910 Census.

Appendix Table 4: Arsenic Pesticides and Other Adult Outcomes

	Dependent variable =								
	Height is below median			Weight in pounds			Completed high school or higher		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Apple Survey Sample									
Spray × Post	0.002		0.001	0.070		0.058	0.002*		0.003*
	(0.002)		(0.002)	(0.065)		(0.066)	(0.001)		(0.001)
Spray × Father is farmer		-0.004	-0.004		0.024	0.047		-0.002	-0.001
		(0.003)	(0.003)		(0.089)	(0.096)		(0.002)	(0.002)
Spray × Father is farmer × Post		0.009***	0.009***		0.121	0.082		-0.001	-0.003*
		(0.003)	(0.002)		(0.140)	(0.145)		(0.002)	(0.002)
Dep Var Mean	0.5	0.5	0.5	149.2	149.2	149.2	0.5	0.5	0.5
R-squared	0.02	0.02	0.02	0.02	0.02	0.02	0.09	0.09	0.09
Observations	243322	243322	243322	221384	221384	221384	364829	364829	364829
Panel B: Agricultural Census Sample									
Tree density × Post	0.001		0.000	0.031		0.022	0.001		0.002
	(0.001)		(0.001)	(0.036)		(0.035)	(0.001)		(0.001)
Tree density × Father is farmer		-0.003	-0.003		0.004	0.011		0.001	0.001
		(0.002)	(0.002)		(0.069)	(0.071)		(0.001)	(0.001)
Tree density × Father is farmer × Post		0.007***	0.007***		0.085	0.073		-0.002	-0.003*
		(0.002)	(0.002)		(0.099)	(0.098)		(0.002)	(0.002)
Dep Var Mean	0.5	0.5	0.5	149.3	149.3	149.3	0.5	0.5	0.5
R-squared	0.02	0.02	0.02	0.02	0.02	0.02	0.10	0.10	0.10
Observations	519597	519597	519597	472936	472936	472936	777511	777511	777511

Notes: Table reports estimates from Equation 3, where the dependent variables are alternative adult outcomes: an indicator for whether height is below the median (columns 1–3), weight in pounds (columns 4–6), and an indicator for completing high school or higher (columns 7–9). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample, Panel A), and Tree density refers to the number of apple-bearing trees per acre (Agricultural Census Sample, Panel B). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 5: Arsenic Pesticides and Adult Height, Controlling for County-by-Birth-Year Fixed Effects

	Dependent variable =			
	Height in inches		Height is below 25th percentile	
	(1)	(2)	(3)	(4)
Panel A: Apple Survey Sample				
Spray × Father is farmer	0.036	0.036	-0.003	-0.003
	(0.022)	(0.022)	(0.003)	(0.003)
Spray × Father is farmer × Post	-0.061***	-0.061***	0.011***	0.011***
	(0.019)	(0.019)	(0.003)	(0.003)
Dep Var Mean	68.7	68.7	0.2	0.2
R-squared	0.07	0.07	0.06	0.06
Observations	240962	240962	240962	240962
Panel B: Agricultural Census Sample				
Tree density × Father is farmer	0.007	0.007	-0.001	-0.001
	(0.017)	(0.017)	(0.002)	(0.002)
Tree density × Father is farmer × Post	-0.030**	-0.030**	0.006***	0.006***
	(0.015)	(0.015)	(0.002)	(0.002)
Dep Var Mean	68.8	68.8	0.2	0.2
R-squared	0.07	0.07	0.06	0.06
Observations	513414	513414	513414	513414

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and county-by-birth-year fixed effects. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 6: Arsenic Pesticides and Adult Height, Dropping State-Specific Linear Time Trends

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.013**		-0.007	0.001		-0.000
	(0.006)		(0.006)	(0.001)		(0.001)
Spray × Father is farmer		0.025	0.022		-0.002	-0.002
		(0.023)	(0.024)		(0.003)	(0.003)
Spray × Father is farmer × Post		-0.047***	-0.042**		0.010***	0.010***
		(0.018)	(0.018)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	243322	243322	243322	243322	243322	243322
Panel B: Agricultural Census Sample						
Tree density × Post	-0.003		-0.000	-0.001		-0.002**
	(0.005)		(0.005)	(0.001)		(0.001)
Tree density × Father is farmer		0.001	0.001		-0.000	-0.001
		(0.017)	(0.017)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.021	-0.021		0.005***	0.006***
		(0.014)	(0.014)		(0.002)	(0.002)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	519597	519597	519597	519597	519597	519597

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Unlike the baseline specification, these regressions do not include state- specific linear time trends. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, and birth-year fixed effects. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 7: Arsenic Pesticides and Adult Height, Clustering Standard Errors at Agricultural Districts

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.009		-0.003	0.001		-0.001
	(0.007)		(0.007)	(0.001)		(0.001)
Spray × Father is farmer		0.022	0.021		-0.002	-0.002
		(0.016)	(0.017)		(0.002)	(0.002)
Spray × Father is farmer × Post		-0.043***	-0.041***		0.009***	0.010***
		(0.010)	(0.011)		(0.001)	(0.001)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	243322	243322	243322	243322	243322	243322
Panel B: Agricultural Census Sample						
Tree density × Post	-0.006		-0.003	0.000		-0.000
	(0.005)		(0.006)	(0.001)		(0.001)
Tree density × Father is farmer		0.005	0.004		-0.001	-0.001
		(0.014)	(0.015)		(0.002)	(0.001)
Tree density × Father is farmer × Post		-0.025**	-0.024**		0.006***	0.006***
		(0.010)	(0.011)		(0.001)	(0.001)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	519597	519597	519597	519597	519597	519597

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and and state-specific linear time trends. Unlike baseline specification, standard errors here are clustered at the agricultural district level. Regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 8: Arsenic Pesticides and Adult Height, Restricting to Birth Registration States

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.004		0.004	-0.000		-0.002
	(0.009)		(0.009)	(0.001)		(0.001)
Spray × Father is farmer		0.032	0.034		-0.003	-0.003
		(0.024)	(0.024)		(0.004)	(0.004)
Spray × Father is farmer × Post		-0.049***	-0.052***		0.009***	0.010***
		(0.018)	(0.019)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.02	0.02	0.02
Observations	181570	181570	181570	181570	181570	181570
Panel B: Agricultural Census Sample						
Tree density × Post	-0.003		0.001	0.000		-0.001
	(0.007)		(0.007)	(0.001)		(0.001)
Tree density × Father is farmer		0.020	0.020		-0.002	-0.003
		(0.016)	(0.016)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.031**	-0.031**		0.006***	0.007***
		(0.014)	(0.015)		(0.002)	(0.002)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.02	0.02	0.02
Observations	276054	276054	276054	276054	276054	276054

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Relative to the baseline specification, the analysis sample here is restricted to counties located in the Birth Registration states during this period: CT, IN, KS, KY, ME, MD, MA, MI, MN, NH, NY, NC, OH, PA, UT, VT, VA, WA, and WI. Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 9: Arsenic Pesticides and Adult Height, Excluding Birth Cohorts Prior to 1917

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.010		-0.003	0.001		0.000
	(0.010)		(0.010)	(0.001)		(0.001)
Spray × Father is farmer		0.022	0.020		0.001	0.002
		(0.025)	(0.027)		(0.002)	(0.002)
Spray × Father is farmer × Post		-0.043**	-0.041*		0.006**	0.006*
		(0.021)	(0.023)		(0.003)	(0.003)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	185010	185010	185010	185010	185010	185010
Panel B: Agricultural Census Sample						
Tree density × Post	-0.001		0.003	0.001		0.000
	(0.009)		(0.009)	(0.001)		(0.001)
Tree density × Father is farmer		0.009	0.010		0.000	0.000
		(0.016)	(0.018)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.028*	-0.030*		0.005**	0.005**
		(0.015)	(0.016)		(0.002)	(0.002)
Dep Var Mean	68.9	68.9	68.9	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	393982	393982	393982	393982	393982	393982

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Relative to the baseline specification, the analysis sample here is restricted to enlistees born in 1917 or later to align with the coverage of the Vital Statistics birth registration data. Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix Table 10: Arsenic Pesticides and Adult Height, Including Birth Cohorts from 1900s

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.006		-0.000	-0.000		-0.002
	(0.008)		(0.009)	(0.001)		(0.001)
Spray × Father is farmer		0.011	0.011		-0.001	-0.002
		(0.016)	(0.016)		(0.003)	(0.003)
Spray × Father is farmer × Post		-0.034**	-0.033**		0.009***	0.010***
		(0.014)	(0.014)		(0.002)	(0.002)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.02	0.02	0.02
Observations	254586	254586	254586	254586	254586	254586
Panel B: Agricultural Census Sample						
Tree density × Post	-0.005		-0.003	-0.000		-0.001
	(0.006)		(0.006)	(0.001)		(0.001)
Tree density × Father is farmer		-0.003	-0.004		-0.000	-0.001
		(0.012)	(0.012)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.020*	-0.018		0.006***	0.006***
		(0.012)	(0.012)		(0.002)	(0.002)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	544053	544053	544053	544053	544053	544053

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Unlike the baseline specification, these estimates include additional birth cohorts from 1900–1909. Post is an indicator for being born in the 1920s relative to the 1900s and 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 11: Arsenic Pesticides and Adult Height, Excluding Southern States

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.009		-0.003	0.001		-0.001
	(0.009)		(0.009)	(0.001)		(0.001)
Spray × Father is farmer		0.022	0.021		-0.002	-0.002
		(0.024)	(0.025)		(0.004)	(0.003)
Spray × Father is farmer × Post		-0.043**	-0.041**		0.009***	0.010***
		(0.019)	(0.020)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	235196	235196	235196	235196	235196	235196
Panel B: Agricultural Census Sample						
Tree density × Post	-0.004		-0.001	0.000		-0.000
	(0.006)		(0.006)	(0.001)		(0.001)
Tree density × Father is farmer		0.013	0.012		-0.002	-0.002
		(0.015)	(0.016)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.025*	-0.024*		0.006***	0.006***
		(0.014)	(0.015)		(0.002)	(0.002)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	422396	422396	422396	422396	422396	422396

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Relative to the baseline specification, this table excludes enlistees from the Deep South states (AL, AR, FL, GA, MS, SC, and TX). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 12: Arsenic Pesticides and Adult Height, Dropping Sample Restrictions

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.009		-0.003	0.001		-0.001
	(0.008)		(0.009)	(0.001)		(0.001)
Spray × Father is farmer		0.022	0.021		-0.002	-0.002
		(0.024)	(0.024)		(0.003)	(0.003)
Spray × Father is farmer × Post		-0.043**	-0.041**		0.009***	0.010***
		(0.018)	(0.019)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	243634	243634	243634	243634	243634	243634
Panel B: Agricultural Census Sample						
Tree density × Post	-0.006		-0.003	0.001		-0.000
	(0.006)		(0.006)	(0.001)		(0.001)
Tree density × Father is farmer		0.005	0.004		-0.001	-0.001
		(0.016)	(0.017)		(0.002)	(0.002)
Tree density × Father is farmer × Post		-0.025*	-0.024*		0.006***	0.006***
		(0.013)	(0.014)		(0.002)	(0.002)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	521367	521367	521367	521367	521367	521367

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Unlike the baseline specification, these estimates drop the restriction that counties must contain at least one linked enlistee per birth decade with a father recorded as a farmer. Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 13: Arsenic Pesticides and Adult Height, Including Large Population Centers

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Apple Survey Sample						
Spray × Post	-0.005		0.001	0.002		0.000
	(0.010)		(0.011)	(0.001)		(0.001)
Spray × Father is farmer		0.006	0.006		-0.001	-0.001
		(0.024)	(0.027)		(0.003)	(0.004)
Spray × Father is farmer × Post		-0.040**	-0.041**		0.010***	0.009***
		(0.017)	(0.021)		(0.003)	(0.003)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	278251	278251	278251	278251	278251	278251
Panel B: Agricultural Census Sample						
Tree density × Post	-0.026***		-0.025**	0.003***		0.003***
	(0.010)		(0.011)	(0.001)		(0.001)
Tree density × Father is farmer		0.012	0.004		-0.003	-0.002
		(0.016)	(0.017)		(0.002)	(0.003)
Tree density × Father is farmer × Post		-0.024	-0.009		0.005*	0.003
		(0.018)	(0.021)		(0.003)	(0.004)
Dep Var Mean	68.8	68.8	68.8	0.2	0.2	0.2
R-squared	0.03	0.03	0.03	0.03	0.03	0.03
Observations	640416	640416	640416	640416	640416	640416

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Unlike the baseline specification, these estimates include counties with 500,000 or more residents. Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. Spray refers to the number of lead arsenate sprays per acre (Apple Survey Sample), and Tree density refers to the number of apple bearing trees per acre (Agricultural Census Sample). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding proxy. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 14: Top-Decile Arsenic Pesticide Exposure and Adult Height

	Dependent variable =					
	Height in inches			Height is below 25th percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
One or more sprays per acre × Post	-0.032		-0.013	-0.001		-0.007
	(0.040)		(0.044)	(0.004)		(0.005)
One or more sprays per acre × Father is farmer		-0.025	-0.030		0.003	0.000
		(0.075)	(0.073)		(0.011)	(0.011)
One or more sprays per acre × Father is farmer × Post		-0.152**	-0.143*		0.035***	0.039***
		(0.068)	(0.078)		(0.008)	(0.009)
Dep Var Mean	68.7	68.7	68.7	0.2	0.2	0.2
R-squared	0.02	0.02	0.02	0.02	0.02	0.02
Observations	243322	243322	243322	243322	243322	243322

Notes: Table reports estimates from Equation 3, where the dependent variable is adult height measured either in inches (columns 1–3) or as an indicator for whether height falls below the 25th percentile (columns 4–6). Data on enlistees are from National Archives and Records Administration (2002). Post is an indicator for being born in the 1920s relative to the 1910s; Father is farmer is an indicator for whether the father was recorded as a farmer in the Census. The exposure measure is an indicator for whether a county had one or more lead arsenate sprays per acre, capturing top-decile arsenic pesticide exposure (U.S. Bureau of Agricultural Economics, 1931). Coefficients therefore represent differences associated with high-exposure counties relative to lower-exposure counties. Specifications include individual-level controls (race, age at enlistment, farm residence, number of siblings, father's nativity, literacy, and occupation), county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture (1910–1940), county fixed effects, birth-year fixed effects, and state-specific linear time trends. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 15: Arsenic Pesticides and Other Domestic Well Water Characteristics

	Dependent variable =		
	pH	Dissolved oxygen mg/L	Dissolved solids mg/L
	(1)	(2)	(3)
Panel A: Main Specification			
Tree density: Apple bearing	-0.033	0.022	22.578
	(0.062)	(0.156)	(21.278)
Panel B: Alternative Specification			
Tree density: Apple-bearing	0.133	-0.101	35.593
	(0.112)	(0.220)	(31.797)
Tree density: Non-bearing	-0.198	0.138	-18.919
	(0.121)	(0.169)	(29.169)
Dep Var Mean	7.2	3.6	364.3
R-squared	0.33	0.24	0.27
Observations	3340	1949	1298

Notes: Table reports estimates from Equation 4, where the dependent variables are domestic well water quality outcomes from the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program: pH (column 1), dissolved oxygen in mg/L (column 2), and dissolved solids in mg/L (column 3). Panel A uses variation in fruit-bearing apple tree density as the exposure proxy. Panel B separates tree density by production status, distinguishing fruit-bearing and non-bearing apple trees (Haines, Fishback and Rhode, 2018). All coefficients are scaled to represent the effect of a one standard deviation increase in the corresponding tree-density measure. Specifications include historical county-level demographic and agricultural controls from the U.S. Census of Population and Agriculture and state fixed effects. Standard errors are clustered at the county level, and regressions are weighted by county population. *** p<0.01, ** p<0.05, * p<0.1.