The Rise in Automobile Adoption and The Fall in Mortality Rates in the Early 20^{th} Century

Hoa Nguyen

March 30, 2016

Abstract

Deaths from infectious diseases have declined in the United States during the 20^{th} century, in part due to a sharp drop in infant and child mortality. Many reasons have been advanced for this tendency: improvements in sanitation and hygiene, better nutrition, strategic vaccination programs, the invention of antimicrobial medicines, technological advances in detecting and monitoring infectious diseases, and more. This paper uses 2SLS method and county level data to examine the relationship between rapid automobile adoption and the fall in mortality rates, especially infant mortality rates, in the U.S. from 1921 to 1939. Cars replaced horses and reduced the number of horse stables in the cities, along with the manure that nourished millions of flies, the key carriers of the germs and bacteria responsible for infectious diseases. This trend helped improve sanitation on a macro (urban) and hygiene on a micro (individual) level, especially in large, crowded areas. This, in turn, drove down deaths from those diseases. I find that there is a significant and negative causality between number of car registrations and mortality rates, especially in crowded areas. A back of the envelop calculation suggests that the increase in automobile adoption from 1921 to 1939 saved 1782 lives. [1]

[1] I am very grateful to Price Fishback for his extreme patience and great guidance through all of my work. Any errors are my own.

1 Introduction

The relationship between automobile adoption and socioeconomic changes has been a popular topic because of its important role in American history. Automobile adoption was accompanied by a significant development of infrastructure, which often came with both positive and negative changes in society. For example, there were many opportunities for new businesses and jobs that came with the new method of transportation, such as the national and local businesses (gas stations, mechanical garages, fastfood restaurants and hotels) that popped up along highways to serve drivers and their fragile cars. Wegman (2001) argues that there was a positive impact on health as hygiene conditions improved when cars replaced horses and reduced the number of flies that came with tons of horse manure. Moreover, access to hospitals, schools and work was improved with more highways and faster transportation. On the other hand, automobiles may have raised mortality through accidents, potential air and noise pollution that came from new infrastructure construction and heavy traffic that used lead gasoline. As yet, no one has directly tested with panel data the impact of automobile adoption on mortality in the early 20^{th} century. Such a study is the contribution of this paper.

Mortality rates, especially infant mortality rates, are often used as one of the important indicators of socioeconomic development. Deaths from infectious diseases have declined in the United States during the 20^{th} century, in part due to a sharp drop in infant and child mortality. In 1900, 30.4% of all deaths occurred among children aged less than 5 years; in 1997, that percentage was only 1.4%. In 1900, the three leading causes of death were pneumonia, tuberculosis (TB), and diarrhea and enteritis. Of these deaths, 40% were among children aged less than 5 years. Many reasons have been listed for this tendency: improvements in sanitation and hygiene, better nutrition, strategic vaccination programs, the invention of antimicrobial medicines, technological advances in detecting and monitoring infectious diseases, and more. This paper examines the relationship between rapid automobile adoption and the fall in mortality rates, especially infant mortality, in the U.S. in the early 20^{th} century. Wegman (2001) claimed that cars "drove horses and their stables out of the cities", along with the manure that nourished generations of flies, key carriers of the germs and bacteria responsible for infectious diseases. This trend helped to improve sanitation on a macro (urban) and hygiene on a micro (individual) level, especially in large, crowded cities. This, in turn, drove down deaths from infectious diseases.

Using 2SLS model and data about automobile registrations and mortality rates at the county level with fixed effects to control for unobserved factors among counties, states and years, I find that there is a significant and negative causality between the number of car registrations and mortality rates, especially in counties with population density higher than 50 people per square mile. This causal effect disappears in counties with population density less than 50. From 1921 to 1939, a back of the envelop calculation estimates that the increase in automobile adoption saved 1782 lives. A similar effect was found on infant mortality rates. This finding suggests that in the crowded places, the positive impact of automobile adoption on hygiene condition through eliminating the sanitary problems with feces and flies who came with horses might dominate the negative impact of air pollution or accidents from having more cars on the roads. Using another data set for 114 cities, I find that there is a statistically significant and negative association between counties' number of car registrations and cities' deaths from diarrhea diseases.

2 Literature Review

2.1 Automobiles and Health

Automobiles have contributed significantly to public health in both negative and positive ways. Many lives are saved due to the rapid transportation by automobiles, which lead to faster access to hospitals. Common health is also improved by the recreation of motoring and people's migration to less crowded and less polluted countryside areas, which are made accessible by cars. However, at the beginning of the 20^{th} century, some compounds such as tetraethyl lead, were often added to motor fuels in order to increase their efficiency. Although Sayers et. al (1924) showed that lead gasoline hardly constituted a public health problem, the manufacture of tetraethyl lead was known to be dangerous for workers who participated in the production process, and the American public was highly concerned about the possible hazards that came with the uses of this compound in gasoline. The danger increased on cold days when the car owners tried to warm the engine up or made adjustments in closed places. Greater numbers of people may have been exposed to the toxic emissions from heavy traffic in poorly ventilated passage ways or tunnels. Because of this concern, the U. S. Bureau of Mines did research that led to a permissible maximum concentration of carbon monoxide of 4 parts per 10,000 for a period of one hour (Henderson, et. al. 1921). Given this standard, the frequent condition from 0.01 to 0.02 percent of carbon monoxide at the constantly crowded Fifth Avenue in New York City was not be considered serious (Henderson et. al. 1923).

In the modern era, exposure to pollution, especially airborne particulate matter, has been the subject of much scholarship. It has been shown that high exposure at an early age can have lasting effects in later life that do not reveal themselves immediately (Currie et al. 2013). This further confirms the conclusion about health harzards of air pollution that was found by the Committee of Environmental and Occupational Health Assembly (American Thoracic Society, 1996), Dockery et. al (1993), Pope et. al. (1995) and Goldsmith et. al. (1999). In the U.S, cars and trucks are currently responsible for about 30% of emissions of oxides of nitrogen, and 30% of hydrocarbon emissions (excluding emissions from related sources, such as fuel storage facilities and filling stations).[2] And since the highest air pollution level might not be at the formation point but downwind, air pollution is not only a problem along the roads but for the whole region. Therefore, automobile adoption partially contributes to those health problems in the modern world. Currie and Walker (2011) made the striking discovery that electronic open-road toll collection devices (E-Z Pass) reduced the amount of automobile exhaust produced during idling and acceleration, eventually reducing the number of premature births in the vicinity. Later studies strengthened the link between traffic congestion and infant mortality.

There are some other ways that automobile adoption affects public health. One way is through car accidents. Automobiles claimed about 50,000 lives per year in 1960s.[3]

[2]Environmental Protection Agency (US). National Emissions Inventory. Air pollution emission trends. Current emissions trend summaries (2002)

[3]National Highway Traffic Safety Administration (US), National Center for Statistics and Analy-

"Automobile crashes are the leading cause of death among people from one to 24 years old, account for 3.4 millions nonfatal injuries annually, and cost an estimated $200 billion annually."[4] Another mechanism is through improving hygiene condition. Before the adoption of automobiles, the main transportation method besides trains was horse-drawn wagons and carriages. For a hundred years, from the early 1800s to the early 1900s, millions of Americans, especially in big cities, depended on a massive and sophisticated network of carriages and streetcars for their daily activities. By 1880, according the Railway Review (1882), New York had about 100,000 horses running and carrying 1.2 billion passengers a year. Given the fact that the average horse produces between 60 and 70 pounds of stall waste per day[5], those tens of thousands horses were working and coating the city's streets with urine and feces everyday. The manure turned into "fetid swamps in the rain and noxious dust in dry spells". In 1881, horses in New York City generated 2.5 million tons of manure and 60,000 gallons of urine as reported in White (1984). The ubiquitous manure caused widespread typhus and other diseases through clouds of millions of flies as they picked up bacteria and other pathogens, then transmitted them to humans through their food and water sources.

Morgan (2002) used a case study of Preston in the mid-19th century to show that the increasing population of horses in expanding towns was associated with high infant mortality rates due to the disease spead by flies which bred in horse manure. This changed with the mass production of automobiles. In 1900, 4192 cars were sold in the US; by 1912 that number had risen to 356,000. In 1912, traffic counts in New York showed more cars than horses for the first time. Wegman (2001) suggested that as more affordable cars rapidly replaced horses, especially in big cities, the number of flies also decreased dramatically since there was less feces for them to live on. This in turn improved the sanitation condition in those regions and helped stop the spread

---

sis Traffic Safety Facts 2000: a compilation of motor vehicle crash data from the Fatality Analysis Reporting System and the General Estimates System. Washington: NHTSA, 2001, Dec. Pub. No.: DOT HS 809 337

[4]Motor-vehicle safety: a 20th century public health achievement. MMWR Morb Mortal Wkly Rep. 1999, 48: 369-74

[5]"Horse Manure Management" Smith and Swanson (2009), retrieved at https://pubs.ext.vt.edu/406/406-208/406-208.html

of diarrhea and respiratory diseases, which used to be the leading causes of death. Figure 1 shows the causes of infant mortality in selected years in the U.S. The number of diarrheal diseases decreased significantly from 1912 to 1937, the period in which American aggressively adopted cars. Wegman also suggested the lack of quantitative research about this mechanism. My paper is among the first empirical ones that examine this relationship between automobile adoption and mortality rates in the U.S in the early 20^{th} century.

2.2 Other Factors that Affect Mortality Rates

At the root of much of the current debate about cross-national determinants of mortality is the association between economic growth (typically measured by rising income per capita) and trends in mortality. Samuel Preston provided the impetus for the study of the association of life expectancy and income, representing the strong correlation in his famous "Preston curve" for the 1900s, 1930s, and 1960s (Preston 1975, 1980). This has led to "fundamentalist" views like Pritchett and Summers (1996) "Wealthier Is Healthier" hypothesis, which predicts inevitable improvements to the overall health of countries' citizens given economic growth. However, a clear majority of scholarship doubts this. Cross-nationally, the decline of mortality in nearly all European states after World War II, despite vastly different levels of economic development, strongly suggests there is more determining the changes than income. The sharp drop in mortality rates across the U.S. after 1970 despite stagnating median real income growth drives the point home (Deaton 2004; Murphy and Topel 2005), as does research on the determinants of infant mortality in the developing world. Preston himself discredited the "fundamentalist" view from the start, demonstrating that life expectancy has been rising particularly fast for poorer countries at constant levels of income. On the whole, changes in income do not seem to be reflected in infant mortality rates or rates of overall mortality. Indeed, if there is one income-related trend that documents pro-cyclical mortality, it is that economic shocks and recession in the developed world correlate with decreases in mortality, whether by way of expanding welfare provisions for the poorest and their children, decreasing pollutant emissions, moderating the consumption of harmful goods, or simply encouraging people to lead healthier lives (Ruhm 2000, 2005; Deaton and Paxson 2004; Fishback, Haines and Kantor 2005). As Stolnitz (1965) suggests, “it now seems that economic misery as such is no longer an effective barrier to a vast surge in survival opportunities in the underdeveloped world.

The economic argument has become nuanced to encompass more than a direct effect of income growth on health. This includes studies that relate increased mortality rates as well as other indicators of poor health at birth to poverty and income inequality (Olson et al. 2010), finding moderate support for both. McKeown (1976) was the main proponent of the interesting but largely discredited argument that falling mortality in the UK in the 19th century was chiefly a result of improved nutrition and housing, themselves caused by rising incomes. McKeown did not produce any direct statistical evidence and explicitly downplayed the importance of public health measures as a contributing factor. This argument has won favor with some researchers. For example, Costa and Steckel (1997) point out the massive increases in agricultural yields and caloric intake since the mid-1700s, estimating that the impact of nutrition persisted well into the 20th century. However, most scholarship since has remained skeptical (e.g. Wrigley and Schofield 1981). Moreover, even if we were to recognize the effect of nutrition for one country, it does not seem to be generalizable, and once again points to the broader problems with using economic growth as an explanatory variable for health effects (Cutler, Deaton and Lleras-Muney 2006).

Perhaps, then, a more comprehensive approach is possible in which income and inequality levels are set aside in favor of the interplay of other socioeconomic factors with mortality. Such variables could include individual or area socioeconomic status (SES), access to transportation and other services, residential segregation, gender, education, ethnicity, and overall social cohesion (Kim and Saada 2013 , Solar and Irwin 2007 , Bird and Bauman 1995). These are generally subsumed under the catch-all term “structural” hypotheses, which encompass social, economic, political, and sometimes cultural factors. In these studies, such structural variables are often found to be more significant drivers of infant mortality than health services variables such as the number of physicians, GPs, and other professionals; number of uninsured individuals; access to prenatal care; and general health expenditures (e.g. Bird and Bauman (1995) for all 50 states). Though impressive in their breadth, these studies tend to obscure the historical effects of individual innovations and precisely because of their breadth rarely venture to detect trends over time.

Out of the pool of potential socio-economic determinants of infant mortality, arguably the most widely acknowledged as having an effect is education, particularly the education of mothers (Cutler, Deaton, Lleras-Muney 2006). Examining the dynamics of child mortality in the late 19th century, Preston and Haines (1991) find that 45 percent of all premature deaths were caused by infectious diseases. But in this period, before the large-scale endorsement of germ theory, mortality differentials across social classes were negligible. By the mid-1920s, however, the children of doctors and teachers had a mortality rate 55 percent lower than the national average (Soares 2007). The impact of maternal education is widely attested in the literature, and remains robust to alternative specifications as well as the distinction between developed and developing countries (Haines and Avery 1982; Haines et al. 1983; Hobcraft 1993). Several possible mechanisms underlie this. Among others, educated mothers are more likely to seek medical care, be aware of available health services, understand sanitary and nutritional precautions to a child's well-being, have their children immunized, and request professional assistance in childbirth. Besides that, Moehling and Thomasson (2012) also point out that public health programs that "provide one-on-one contact and opportunities for follow-up care such as home visits by public health nurses, reduce infant deaths" more than general public parenting classes.

The adoption and dissemination of technology, as well as survival rates when new technologies are involved, seems to be largely driven by characteristics at the individual level (Soares 2007, Caldwell 1986). Here, a number of authors make a powerful argument for education as the mediating variable in the adoption of innovations in health technology, eventually linking it to reduced mortality and higher survival rates past infancy. Much of the current research stresses the role of individual medical innovations. For instance, more educated individuals tend to use recently introduced or experimental drugs on a regular basis, which points to their greater ability to learn from experience (Glied and Lleras-Muney 2003; Lleras-Muney and Lichtenberg 2002). In the developing world particularly Sub-Saharan Africa, schooling is associated with greater receptivity to information campaigns on HIV/AIDS, and higher propensity to follow protective measures and behaviors such as testing or the use of condoms (de Walque 2006).

For all its benefits, this category of technology adoption follows the trend, common to both the developing and the developed world, of increasing mortality inequality in the short run, especially across countries (from the developed world to the developing) but also within them (Cutler, Deaton and Lleras-Muney 2006). For Link and Phelan (1995), education helps improve and maintain health by boosting human capital, but differences in education amount to power differences that will further entrench themselves whenever a new technology arises that the more knowledgeable can use to their advantage. This popular assertion helps explain different shifts of survival rates for specific diseases and conditions over time. For instance, pervasive, non-infectious conditions such as lung cancer and cardiovascular diseases used to be more prevalent among the educated, but they were also the first to reap the benefits of technological innovations that allowed them to screen for and avoid risk factors. On a macro-historical level, this has been true for the gap between the rich and the poor, both within countries and cross-nationally, but studies have investigated inequalities of access according to criteria such as race (Troesken 2004), occupational group and rank (Marmot et al. 1991), and urban/rural residence (Elo and Preston 1996). Interaction effects matter here: Pamuk et al. (1998) find that infants of black mothers have higher mortality rates than infants of white mothers for every level of education. Furthermore, black mothers with a college degree still struggle with greater infant mortality than their white counterparts who are also high-school dropouts. That said, the exact mechanisms by which this works, and whether micro-level technology adoption plays a role, are significantly understudied in the literature.

Soares (2007) contends that the above patterns are true for private goods. But technological innovations are often integrated into public goods as well. This distinction is important to the present study because the New Deal era abounded in large-scale infrastructure projects that often introduced new technologies indiscriminately, subsidizing and implementing them by tethering them to public policies. A relevant example is the activation of Public Works Administration (PWA) funds to build up to half of all the new sewers of the New Deal, as well as enhance water supply and implement waste treatment. Across the literature, scholars broadly agree that far-reaching infrastructure projects with the technological overhauls that accompanied them had a major impact on mortality rates in the developed world (Szreter 1988). This coincided with the final triumph of germ theory over miasma ("bad air") theory, driven in particular by concerns over waterborne diseases. The implications of the new theory could be readily applied to technology diffusion in urban infrastructure. In the fifth and final European cholera pandemic (1892), for instance, the mortality rate in Hamburg (7,611), which initially rejected innovations based on germ theory, dwarfed that of Altona, just across the river (328) because Altona had previously installed a more effective water and sewage filtration system that ultimately kept the spread of the disease in check (Evans 2005). Episodes like this brought about a greater push for new water treatment mechanisms worldwide.

In the case of public goods, the positive health externalities of improving infrastructure are often seen across distinctions of class, race, and occupation, thereby contributing to reduced inequality in mortality (Annez and Buckley 2009). This effect is especially strong if the level of analysis is a single country, region, or municipality. Troesken (2004) argues this in the context of massive water projects involving water filtration and the placement of water mains in the early 20th century. Looking at black-white mortality ratios, he finds that major reductions were achieved in overall urban waterborne disease mortality (typhoid, diarrheal diseases), and that blacks benefited disproportionately from these innovations, aided by less discriminatory residential patterns than in the later civil rights era. Thus, both today and in the past, major technological investments such as this one make it difficult to service neighboring groups with separate infrastructure, effectively opening the benefits of new infrastructure to more people.

Other authors have bolstered the argument on the efficacy of major public-health reforms. Costa and Kahn (2003) find that state expenditures on public health in the U.S. drastically reduced mortality rates from dysentery, typhoid, and diphtheria while municipal public health spending especially on water and sewage filtration slashed infant and childhood mortality rates between 1910 and 1940. Once sanitation problems in the city were under control, preventive medical care took over as the main saver of lives. Similar recommendations have been made with respect to the developing world, in which many countries have the sanitation infrastructure of the U.S. in the 1940s. In one World Bank estimation, providing flush toilets and private water connections to every child's home in Sub-Saharan Africa would cut child mortality by 25 deaths per 1,000 live births, on average, and higher-end solutions would be even more effective (Gunther and Fink 2011). Even beyond sweeping health-care reforms, state expenditure on health care-related programs has also been seen as a driver of lower infant mortality. Conley and Springer (2001), for example, find that each addition 1 percent spent on health care in OECD countries yields a roughly 0.2 percent decrease in infant mortality rates; Fishback, Haines, Kantor (2005) show that general relief spending in the New Deal era reinforced the decline of infant deaths and infectious disease mortality. Meanwhile, Grossman and Jacobowitz (1981) posit that a hypothetical modern day ban on abortions would actually drive the neonatal mortality rate up by up to 3 deaths per 1,000 live births.

The impact of massive infrastructural innovation is not to be discounted because of its ability to tip the scales either way. Troesken (2003, 2006) provides persuasive evidence from large urban areas in the U.S. and Great Britain that the use of lead pipes, installed en masse in the mid-19th century, increased infant mortality and stillbirth rates by 25 to 50 percent. The cities with more recent mass pipe-laying projects, in fact, registered greater mortality rates due to the lack of oxidation in the pipes. Besides that, some studies have registered the association of lower birth weight and rising infant mortality rates with both carcinogenic air pollutants across U.S. counties (Agarwal et al. 2010) and shale gas exploitation in Pennsylvania (Hill 2013). But research has also produced informed policy recommendations based on contemporary programs that successfully slowed or reversed negative mortality trends through top-down changes to technology and infrastructure. One example from the developing world is the finding by Cesur et al. (2013) that a change in predominant fuel type and delivery (from coal to natural gas) yielded a 4-percent decline in infant mortality with every 1-percent increase in natural gas subscriptions. These counterexamples can be used as further support for the technical innovation argument, given that such blanket changes in public health seem to be have a potent effect regardless of which direction they take.

Contemporary innovations and historical innovations, when implemented on a large scale, may produce similar health effects. This is the niche in which the present study is placed, arguing that the replacement of horse-drawn carts with automobiles in urban environments was an innovation that intentionally or not contributed to the change of mortality rates in the interwar period, before the wide spread of antibiotic.

3 Empirical Model

Given the theories from the above literature about automobiles' impact on public health and the determinants of mortality in general and infant mortality in particular, I set up the following reduced form model to examine the relationship between the number of automobile registrations and mortality rates in the U.S at the county level from 1921 to 1939:

$$DeathRates_{ijt} = \alpha_0 + \alpha_1 Cars_{ijt} + \alpha_2 BirthRates_{ijt} + \alpha_3 StateIncome_{jt} +$$

$$\alpha_4 TaxReturn_{ijt} + \alpha_5 Color_{ijt} + \alpha_6 Hospitals_{ijt} + \alpha_7 Illiterate_{ijt} +$$

$$\alpha_8 AvgTemperature_{ijt} + \alpha_9 Female1544_{ijt} + \alpha_{10} Population +$$

$$\mathrm{D}_{Year} + D_{State} + D_{County} + \epsilon_{ijt}$$

$DeathRates_{ijt}$ is the mortality rates (per 100 people) in county i, state j and year t. I also examine the relationship between automobile adoption and infant mortality rates (per 100 people) with similar regressions, using infant mortality rates in county i, state j and year t as the dependent variable. $Cars_{ijt}$ is the number of car registrations in county i, state j and year t. The coefficient α_1 on cars is the coefficient of interest. α_1 is expected to be negative as I predict that cars replaced horses and reduced the number of flies. Therefore, it helped improving hygiene condition and mortality rates, especially in crowded regions. If α_1 turns out to be positive, that means there might be some negative impact of automobile adoption on public health that dominate its positive effects. They could be car accidents or toxic emissions from running engines that used lead gasoline at the begining of the 20^{th} century.

Because of the correlation between death rates and birth rates, I put birth rates on the right hand side. α_2 can take either negative or positive sign. The more infants are born, the higher the number of deaths might be, especially infant deaths and mother deaths at childbirth. At the same time, it also increases population which in turn helps decreasing death rates ceteris paribus. To cope with the concern about the potential relationship between numbers of cars and population, I include county population in my estimation too.

I use state income per capita $StateIncome_{jt}$ and the number of tax return files per capita in county i, state j and year t, to get some idea about the income level and distribution in different counties. As seen in the literature, the direct effect of income growth on health is unclear but higher income is associated with better nutrition, better living conditions, better education and knowledge about health care and protection, which in turn have positive impact on health outcomes. Therefore, α_3 and α_4 are expected to be negative.

To control for access to hospitals, I use $Hospitals_{ijt}$, which is the number of hospitals in county i, state j and year t. The more hospitals were opened, the easier it was for patients to get treatments. I expect that α_6 will be negative. It means that more access to hospitals is associated with lower mortality rates.

Education is one of the important determinants of health outcomes, I control for it by using the illiterate percentage of population that are 10 and older, $Illiterate_{ijt}$ in county i, state j and year t. The literature suggests that α_7 should be positive. Low education level (or high illiterature rate) is seen with high mortality rates. However, Pamuk et al. (1998) find that infants of black mothers have higher mortality rates than infants of white mothers for every level of education. Furthermore, black mothers with a college degree still struggle with greater infant mortality than their white counterparts who are also high-school dropouts. I try to control for this puzzle by adding in the variable $Color_{ijt}$, which is the percentage of color population in county i's population in year t. Its coefficient α_5 is supposed to be positive too.

Moreover, average temperature in each county over time are taken into account to control for the living condition. While cold weather is generally not good for human health, warm climate is a good environment for flies and other pathogens to develop and spread diseases. (Flies lay eggs when it is humid and warmer than 65 degrees.) Therefore, its coefficient α_8 is ambiguous. I also include the female population in the reproductive ages from 15 to 44 since it is presumably associated with mortality in general and infant mortality in particular. But the direction of its coefficient α_9 is unclear since more women in their reproductive years might mean that more babies are born, and this could either increase or decrease the mortality rates. It depends on the survival rates of mothers and babies after birth. Last but not least, I use year, county and state fixed effects to take care of the unobserved shocks every year and the specific characters in different counties and states that do not change over time.

Because of the endogeneity problem between the number of car registrations and the unobserved number of flies and feces in counties, my α_1 coefficient will be biased and inefficient. I have to look for some instrument variables (IVs) in order to still be able to derive causal effect of automobile adoption on death rates. I use the state highway mileages and postal road mileages to be two IVs for the number of car registrations. The logic is that there is a strong bond between cars and roads but not between roads and flies and horses' feces. Cars can not run without roads. More than that, car drivers, producers and enthusiasts were among pioneers and lobbiests for the Good Road Movement and highway construction in the U.S. at the beginning of the 20^{th} century. Where to build roads, where do the roads go and how many mileages to be built were decided by both local and federal governments based on a complicated process that evaluates socialeconomic and political conditions, topology and geology characteristics, and financial situations of different regions. Therefore, highway mileages and postal roads are not related directly to the amount of horse dung and flies in the unobserved term. Highway mileages and postal roads satisfy two conditions for a good IV. This could be tested in the first stage of the 2SLS estimation process.

For robustness check in 114 cities, I use the same 2SLS model with the same IVs for the number of car registrations at the county level. One might predict that this could affect the model's estimation power because the small sample of 114 cities does not have the variation of car adoption and road mileages at the city level. Even with this drawback, the estimation might still shed some light about the relationship between automobile adoption and deaths from diarrhea diseases and other infectious diseases at the city level.

4 Data

Table 1 presents the summary statistics of the variables included in the estimation. The total deaths variable and infant death rates are my dependent variables. They come from a series of reports from the U.S. Department of Commerce, Bureau of the Census with the title "Birth, Stillbirth, and Infant Mortality Statistics for the Birth Registration Area of the United States: Washington, D.C.: Government Printing Office" and "Births, Stillbirth, and Infant Mortality Statistics for the Continental United States. Washington, D.C., Government Reporting Office." The reports covering the years 1921 through 1936 are the 7^{th} through 26^{th} Annual Reports. From 1937 through 1940 the data are from the U.S. Bureau of the Census. Vital Statistics of the United States, Part I, Natality and Mortality Data for the United States Tabulated by Place of Occurrence. Washington, D.C., Government Reporting Office. For more details about the data, see Fishback, Fox, Kantor, and Haines "County Births, Deaths, Infant Deaths, and Stillbirths, 1921-1929", and "City Births, Deaths, Infant Deaths, and Noninfant Deaths by Place of Occurrence, 1921-1940." The mean of total deaths in 1921 was 1464. This decreased to 1383 in 1939 then slightly increased to 1411 in 1940. The total deaths variable has the minimum number zero in Loving county, Texas in 1937 and 1939, and highest number was 46362 in Cook county, Illinois in 1928. Cook is also the county with the highest number of infant deaths in 1923. In 1921, only Mono in California and Skamania in Washington had zero infant deaths. There were many more counties with zero infant deaths over time. The infant death mean was 232 in 1921 and went down to 82 in 1940.

There were many states that did not report information to the Birth Registration Area until later. From 1921 to 1924, there were 33 states that had total deaths and infant deaths data available. Idaho joined the group in 1926. Alabama, Arkansas, Louisiana and Tennessee started reporting in 1927. In 1928, Colorado, Georgia, Oklahoma and South Carolina came to the game. Nevada and New Mexico were added in 1929. South Dakota and Texas did not come until 1932 and 1933, respectively. After

1933, my sample has 48 states (no Alaska, Hawaii and Washington D.C) that reported the total deaths and infant deaths at the county level. Later on, I used the data about 114 cities in the U.S from 1929 to 1940 (from the same sources above) for the robustness check. This subsample had deaths from different causes at the city level such as respiratory tuberculosis (TB), infectious and parasitic diseases aside from TB, diarrheal diseases and motor vehicle accidents. 113 cities out of these 114 ones had populations larger than 50 thousand. Only Kenosha, WI had 48765 people. This serves well with my intention to examine the impact of car adoption on health, especially in crowded areas.

Automobile registration data from Tuttle Motor Co. are available in 12 years: 1921, 1923, 1928, 1930, 1931, 1935 and from 1937 to 1942. Except for 1921 in which I only know the total automobile registration number, in all other years the automobile data include both truck and passenger car registrations. In 1921, the mean number of car registrations in U.S counties was 7277. It increased to 27997 in 1939. Los Angeles county was the one with the highest number of car registration in 1942. It had more than one million cars. Daggett, Utah had the lowest number of car registrations in 1942, which was only 89 cars. Because the mortality data only goes up to 1939, I only look at 9 years during the period from 1921 to 1939. The sample that is used in this paper, was merged using ICPSR state codes and county codes.

State personal income comes from the U.S. Bureau of Economic Analysis (1989). It is in 1967 U.S dollar and starts from 1919. The percentage of population who filed for income tax return and county population density are also available from 1921. Other demographic data are from the U.S Department of Commerce and all are at the county level. For population percentage that enrolled at school aged seven to 20, I summed up all the percentages that enrolled aged seven to 13, 14 to 15, 16 to 17 and 18 to 20 reported by Fishback et. al (2007). These data were interpolated between census years 1920, 1930 and 1940 using a linear time trend. Percentage colored and percentage illiterate variables were also interpolated among those 3 censuses. For the number of women in reproductive ages 15 to 44, I summed up the reported numbers of women aged from 15 to 19, 20 to 24, 25 to 29, 30 to 34 and 35 to 44. For the total number of hospitals, I combined the number of hospitals with mental institutions and the one without mental institutions. Hospital variable starts from 1930. Finally, average annual temperature information is available from 1919. For a more detail description about the sources of the data, see Fishback et. al (2011) Information and the Impact of Climate and Weather on Mortality Rates During the Great Depression and Michael Haines (2004) ICPSR 2896 data set.

5 Results

Table 2 shows the OLS regression results for the total death rate and the number of car registrations in the time period from 1921 to 1939 in the U.S. after I control for other factors. The first column shows the association between automobile adoption and mortality rates in all the counties that have data available. The second column is the outcomes for counties with population density higher than 50 people per square mile. The third one is the results for counties with population density lower than 50. As expected, there is no significant relationship between automobile adoption and death rates in less concentrated areas. There is a positive relationship between automobile adoption and death rates in column one and two. This is not surprising because I predict that the coefficient of car registrations will be biased due to the endogeneity problem. There are unobserved things in the error term that affect death rates and are correlated with the number of car registrations, such as hygiene condition, which is undoubtably related to number of flies and amount of horse feces, the number of people who commute with cars and spread diseases as they go, etc.

Table 3 shows the OLS estimation with the dependent variable is infant death rate. Again, the variable of interest, the number of car registration, is biased in this case because of the endogeneity problem. I will use instrument variables to fix this issue. Even though the OLS coefficients are biased, the results in Table 2 and 3 still give us some idea about the statistically significant relationships between death rates and birth rates, income, colored percentage of the population, total number of hospitals, average temperature and the number of females who are in the reproductive ages. I will go back to interpret them using 2SLS results in Tables 5 and 6.

Because of the endogeneity problem in my variable of interest, I look for IVs that are correlated with the number of car registrations but not correlated with the number of flies and horse dung in counties. I use the state highway mileage per capita and postal road mileage per capita to be my IVs. Table 4 shows the first stage results from my 2SLS estimation. It shows that the first IV, state highway mileage per capita is individually statistically significant at 1%. The second IV, state postal road mileage per capita is not statistically significant. However, the F statistic suggests that all explanatory variables in my first stage are jointly significant at 1% level.

Table 5 has the 2SLS results for the death rates dependent variable in 3 different estimations. From the first column, the coefficient of automobile adoption is -1.72. It means that 100 percent increase in the number of car registrations leads to a decrease of 1.72 points in the predicted death rates. This change is about three standard deviations of the predicted death rate. In my sample, the average number of car registrations increases by more than 230 percent from 1921 to 1939. This leads to a decrease of almost 4 point in the total death rates, or 4 less deaths per 100 people. This is a significant change over 18 years. Given the average county population in 1939 is about 44538, a back-of-the-envelope calculation suggests that automobile adoption saved 1782 lives. The estimated coefficient does not change much (-1.11) for counties that have population density higher than 50. However, as predicted, it becomes not sigfinicant in counties that have population density less than 50 in column 3. This is because it is easier to see the impact of automobile adoption on hygiene and sanitary conditions in crowded areas with high number of horses and flies than in less concentrated areas, normally rural and isolated ones.

The birth rate variable has positive and significant coefficients in all 3 estimations in Table 5. If birth rate increases by 100 percent, the death rates will increase by 0.17 point, or almost two more death in every 1000 people. This is statistically significant at 1% but it is not practically significant. Income variable, which is proxied by state personal income per capita and tax return filing percentage, has more ambiguous effect. First, state personal income does not have statistically significant effect in the first and second estimations. It has the coefficient of -0.312 in rural areas, statistically significant at 1%. This suggests that little extra money goes a long way in less crowded and rural areas than in concentrated (and normally richer) areas. Besides that, percentage of the population files for tax return is used to be a proxy for the very rich group of the population because only them were able to file for tax return back there. The fact that its estimated coefficients are small (less than 0.07) is in the same line with what was found in the literature that the changes in income does not seem to be reflected in the changes in mortality rates.

County population has a positive connection with the total death rates in all the counties. 10% increase in population is seen with 0.16 point decrease in the death rates, statistically significant at 1% in column 1 and 2. It is not significant in the areas with population density less than 50 per square mile. The colored percentage of the population does not have a significant association with the total death rates in less crowded areas. Number of hospitals has an ambiguous relationship with death rates and it is not statistically significant. It might be because hospitals normally are places to cure patients, but many papers in the medical field point out that there is an increasing number of deaths from medical errors and from the culture that patients normally get to the doctors when it is too late. Moreover, if a patient went to a hospital in the neighbor county and died there, his death was counted toward the neighbor county's total deaths.

The illiterate percentage has a positive and significant relationship with the total death rates in crowded areas. One percent in crease in illiterate percentage is associated with 0.01 point higher in mortality rates in a county with population density higher than 50. Average temperature has a negative and significant association with the total death rates in all the counties. 10 degrees warmer on average is correlated with 0.04 point lower in total death rates. The last variable that has significant association with the death rates is the number of females between 15 and 44 years old. If the number of females in reproductive ages increases by 100 percent, the total death rates will increase by 0.01 point or one death per 100 people. This actually supports for the finding above that there is a positive relationship between birth rates and death rates.

One of the reasons for the decrease in the total death rates is the decline in the infant death rates. Children, especially infants are more sensitive with the change in the surrounding environment. So if cars are changing the living condition through either improving hygiene or polluting the air, those effects should be reflected in the changes in infant mortality rates. From 1921 to 1939, the average infant death rates in my sample decreased almost 50 percent, from 0.176 to 0.092. Table 6 shows that some part of this change is explained by the increase in automobile adoption. In the all county estimation (column 1), one hundred percent increase in the number of car registrations leads to 0.52 point decrease in the infant mortality rates, statistically significant at 1%. Given an increase of more than 230 percent in the number of car registrations, it leads to about one less baby dies in every 100 people. Again, the significant result holds for counties with high population density and does not hold for counties with low population density. In both Tables 5 and 6, because the magnitude of most of my variables (except car registrations and county population) is very small, and they are not my variable of interest, I will not go further into details about them.

Using data about diarrhea disease deaths, other infectious disease deaths and car accident deaths in 114 cities, I want to see if the results still hold at the city level. Table 7 shows the OLS outcomes. Column 1 suggests a negative relationship between automobile adoption and the number of diarrhea disease deaths. After controlling for other factors, 100 percent increase in the number of car registrations is associated with 32 less deaths from diarrhea diseases. However, there is no significant relationship between other infectious disease deaths, car accident deaths and automobile adoption. The 2SLS coefficients in Table 8 still have the expected signs: negative association between automobile adoption and infectious disease deaths, and positive association between automobile adoption and car accident deaths. But they are not significant. This is not surprising because I am using car registrations and IVs at the county level. Therefore, there is not much of variation in those variables at the city level to help explain the changes in cities' death counts. Even though each explanatory variable is not independently statistically significant, the F tests and Wald tests in all estimations in Table 7 and 8 show that my variables are jointly significant at 1% level.[6]

[6] I also try to use the lagged-one-year value of the death variables to control for unobserved factors at the city level but doing so does not improve the predicting power of the model. The results could be improved if I had the car registrations and road mileages in those cities.

6 Conclusion

This paper examines the link between automobile adoption and mortality rates in the U.S from 1921 to 1939. It fits into the literature about the impacts of technology adoption on socioeconomic development and contributes a new insight for determinants of mortality. Wegman (2001) suggested that as more affordable cars rapidly replaced horses, especially in crowded cities, the number of flies also decreased dramatically since there was less feces for them to live on. This in turn improved the sanitation condition in those places and helped stopping the spread of diarrhea and respiratory diseases, which used to be one of the leading causes of death in the early 20^{th} century.

Because of the endogeneity problem in the number of car registration, which is a proxy for automobile adoption, I use 2SLS model with two IVs constructed from state highway mileages and postal road mileages to estimate the causal effect of automobile adoption on death rates. These two IVs are highly related to the number of cars but not linked to the number of flies and horses. First stage results show that they are good IVs. I use the data about automobile registrations and mortality rates at the county level with county, state and year fixed effects to control for unobserved factors. I found that after controlling for other factors, there is a negative relationship between the number of car registrations and the mortality rates. 100 percent increase in the number of car registrations leads to almost 2 point decrease in the predicted mortality rates, statistically significant at one percent level. Given the number of car registrations increases by more than 230 percent from 1921 to 1939, the estimated coefficient suggests a decrease of about 4 deaths for every 100 people in 1939. A back of the envelop calculation suggests that thanks to automobile adoption, totally 1782 lives were saved.

The estimated coefficient holds for counties with population density higher than 50 people per square mile. It becomes not statistically significant in counties with population density lower than 50. This suggests that in the crowded places, the positive impact of automobile adoption on hygiene condition through eliminating tons of flies who came with horses, might dominate the negative impact of air pollution or accidents from having more cars on the roads. Because children are more sensitive with the change in surrounding environment, it is natural to look at the effect of car adoption on infant mortality. 2SLS estimations with the dependent variable is infant mortality rates also show similar findings with total death rates. 100 percent increase in the number of car registrations leads to 0.52 point decrease in the predicted infant mortality rates, or 5 less babies die in every 1000 people, statistically significant at one percent level. The result becomes not statistically significant in rural and less crowded areas.

Besides automobile adoption, I also control for other familiar factors that are related to mortality such as income, access to hospitals, education, colored population, female population who are in reproductive ages and average temperature. Even though most of them have statistically significant coefficients but their magnitude is not big. 100 percent increase in those explanatory variables is associated with less than 0.1 point change in mortality rates. I also run the same 2SLS model using data of deaths from different causes in 114 big cities (113 cities had population more than 50,000 and only one city had about 48,000 people). The estimations show that there is a negative association between infectious disease (include diarrhea) deaths and car registrations. The F tests and Wald tests suggest that even my explanatory variables are not individually statistically significant, my model is still valid in explaining the variance in diarrhea deaths, other infectious disease deaths and car accident deaths.

References

Agarwal, N., Banternghansa, C., Bui, L. (2010), *'Toxic exposure in America: Estimating fetal and infant health outcomes from 14 years of tri reporting'*, Journal of Health Economics, Vol. 29, No. 4, pp. 557-574.

Bird, S. and Bauman, K. (1995), *'The Relationship between Structural andHealthServicesVariables andState-LevelInfantMortality intheUnitedStates'*, American Journal of Public Health January 1995: Vol. 85, No. 1, pp. 26-29.

Conley, D, and Springer, K. (2011), *'Welfare State and Infant Mortality'*, American Journal of Sociology, Vol. 107, No. 3, pp. 768-807.

Costa, D., Kahn, M. (2003), *'Understanding the American Decline in Social Capital, 1952-1998'*, Kyklos Vol. 56, No. 1, pp. 17-46.

Costa, D. Steckel, R. (1997), *'Long-Term Trends in Health, Welfare, and Economic Growth in the United States'*, Health and Welfare during Industrialization, University of Chicago Press, Vol. ISBN: 0-226-77156-3.

Cutler, D., Deaton, A. and Lleras-Muney, A. (2006), *'The Determinants of Mortality'*, Journal of Economic Perspectives, Vol. 20, No. 3, pp. 97-120.

Currie, J., Davis, L., Greenstone, M. and Walker, R. (2013), *'Do housing prices reflect environmental health risks? evidence from more than 1600 toxic plant openings and closings'*, National Bureau of Economic Research Working paper

Currie, J., Zivin, J. Mullins, J. and Neidell, M. (2013), *'What Do We Know About Short- and Long-Term Effects of Early-Life Exposure to Pollution?'*, Annual Review of Resource Economics Vol. 6, pp. 217-247.

Currie, J. and Walker, R. (2011), *'Traffic Congestion and Infant Health: Evidence from E-ZPass'*, American Economic Journal: Applied Economics, Vol. 3, No. 1, pp. 65-90.

de Walque, D. (2006), *'The Determinants of HIV Infection and Sexual Behaviors in Burkina Faso, Cameroon, Ghana, Kenya And Tanzania'*, World Bank Working Paper 3844.

Deaton, A. (2004), *'Health in an Age of Globalization'*, Brookings Trade Forum, pp.83-130.

Deaton, A. and Paxson, C. (2004), *'Mortality, Income, and Income Inequality over Time in Britain and the US'*, Perspectives in the Economics of Aging, Chicago: University of Chicago Press.

Dockery, D., Pope, A., Xu, X., Spengler, J., Ware, J., Fay, M., Ferris, B., and Speizer F. (1993), *'An Association between Air Pollution and Mortality in Six U.S. Cities'*, the New England Journal of Medicine, Vol. 329, pp. 1753-1759.

Elo, T. and Preston, H. (1996), *'Educational differentials in mortality: United States, 1979-85'*, Social Science Medicine, Vol. 42, No. 1, pp. 47-57.

Evans, R. (2005), *'Death in Hamburg: Society and Politics in the Cholera Years, 1830-1910'*

Fishback, P., Haines, M. and Kantor, S. (2005), *'Births, Deaths, and New Deal Relief during the Great Depression'*, The Review of Economics and Statistics, Vol. 89, pp. 1-14.

Goldsmith, CA., Kobzik, L. (1999), *'Particulate air pollution and asthma: a review of epidemiological and biological studies'*, Reviews on Environmental Health, Vol.14, No.3, pp.121-134.

Grossman, M. and Jacobowitz, S. (1981), *'Variations in Infant Mortality Rates among Counties of the United States: The Roles of Public Policies and Programs.'*, Demography, Vol. 18, No. 4, pp. 695-713.

Gunther, I. and Fink, G. (2011), *'Policy Research Working Papers Water and sanitation to reduce child mortality: The impact and cost of water and sanitation infrastructure'*, Policy Research Working Paper, The World Bank Development Economics Prospects Group

Haines, R. and Avery, R. (1982). *'Differential infant and child mortality in Costa Rica: 1968-1973'*. Population Studies, Vol. 36, No. 1, pp. 31-43.

Haines, R., Avery, R. and Strong, M. (1983), *'Differentials in infant and child mortality and their change over time: Guatemala, 1959-1973'*, Demography, Vol. 20, No. 4, pp. 607-621.

Henderson, Y., Haggard, W. (1923), *'Health Hazard from Automobile Exhaust gas in City Streets, Garages and Repair Shops'*, the Journal of American Medical Association, Vol. 81, No. 5, pp. 385-391.

Henderson, Y., Haggard, W., Teague, C., Prince, L., Wunderlich, M. (1921), *'Physiological effects of automobile exhaust gas and standards of ventilation for brief exposure'*, Journal of Industrial Hygiene, Vol. 3, pp. 79-92.

Hill, E. (2013) *'Shale Gas Development and Infant Health: Evidence from Pennsylvania'*, Working Paper, The Charles H. Dyson School of Applied Economics and Management Cornell University.

Hobcraft, J. (1993), *'Womens education, child welfare and child survival: a review of the evidence'*, Health Transition Review, Vol. 3, No. 2, pp. 159-173.

Kim D. and Saada A. (2013), *'The Social Determinants of Infant Mortality and Birth Outcomes in Western Developed Nations: A Cross-Country Systematic Review'*, International Journal of Environmental Research and Public Health, Vol. 10, No. 6, pp. 2296-2335.

Link, B. and Tehranifar, P. (2010), *'Social Conditions as Fundamental Causes of Health Inequalities Theory, Evidence, and Policy Implications'*, Journal of Health and Social Behavior November 2010 Vol. 51 No. 1

Marmot, G.; Rose, G.; Shipley, M.; Hamilton, J. (1978), *'Employment grade and coronary heart disease in British civil servants'*, Journal of Epidemiology and Community Health Vol. 32, No. 4, pp. 244249.

McKeown, T. (1976), *'The Modern Rise of Population'*, Population Studies, Vol. 31, No. 1, pp. 179-181.

Moehling, C. and Thomasson, M. (2012), *'Saving Babies: The Contribution of Sheppard-Towner to the Decline in Infant Mortality in the 1920s'*, NBER Working Papers 17996, National Bureau of Economic Research, Inc.

Mokyr, J. (2003), *'The Oxford Encyclopedia of Economic History'*, Oxford University Press.

Morgan, N. (2002), *'Infant mortality, flies and horses in later-ninteenth-century towns: a case study of Preston'*, Continuity and Change Vol. 17, No. 1, pp. 97-132.

Murphy, K. and Topel, R. (2005), *'The Value of Health and Longevity'*, NBER Working paper 11405, Cambridge, MA: National Bureau of Economic Research.

Olson, M., Diekema, D., Elliott, B. and Renier, C. (2010), *'Impact of Income and Income Inequality on Infant Health Outcomes in the United States'*, PEDIATRICS, Vol. 126, pp. 1156-1173.

Pamuk, E., Makue, D., Heck, K. and Reuban, C. (1998), *'Socioeconomic Status and Health Chartbook'*, National Center for Health Statistics,

Pope, C., Thun, M., Namboodiri, M., Dockery, D., Evans, J., Speizer, F., and Heath, C., (1995), *'Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults'* American Journal of Respiratory and Critical Care Medicine, Vol. 151, No. 3, pp. 669-674.

Preston, S. (1975), *'The Changing Relation between Mortality and Level of Economic Development'*, Population Studies, Vol. 29, No. 2 (Jul., 1975), pp. 231-248.

Preston, S. (1980), *'Causes and Consequences of Mortality Declines in Less Developed Countries during the Twentieth Century'*, Population and Economic Change in Developing Countries, University of Chicago Press, pp. 289 - 360.

Preston, H. and Haines, R. (1991), *'Fatal Years Child Mortality in Late Nineteenth-Century America'*. Princeton University Press, Princeton.

Pritchett, L. Summers, L., (1996), *'Wealthier is healthier'*, The Journal of Human Resources, Vol. 31, No. 4 (Autumn, 1996), pp. 841-868.

Rasmussen, W., Baker, G. and Ward, J. (1976), *'A Short History of Agricultural Adjustment, 1933-1975'*, Economic Research Service, United States Department of Agriculture, Agriculture Information Bulletin No. 391, pp. 2

Ruhm, C.(2000), *'Are Recessions Good For Your Health?'* Quarterly Journal of Economics 115(2), pp. 617-650.

Ruhm, C.(2005), *'Healthy Living in Hard Times'* Journal of Health Economics 24(2), pp. 341-363.

Sayers, R., Fieldner, A., Yant, W. Thomas, B., McConnell, W., (1924), *'Exhaust Gases from Engines Using Ethyl Gasoline'*, U.S Bureau of Mines, Report of Investments, No. 2661.

Schofield, R. and Wrigley, E. (1989), *'The Population History of England 15411871'*, Cambridge Studies in Population, Economy and Society in Past Time.

Solar, O., Irwin, A. (2007), *'A Conceptual Framework for Action on the Social Determinants of Health'*. Discussion Paper for the Commission on Social Determinants of Health; World Health Organization: Geneva, Switzerland.

Spence, M., Annez, P. C., Buckley, R. M. (2009), *'Urbanization and growth'*, Washington, DC: Commission on Growth and Development.

Stolnitz G. (1965), *'Recent mortality trends in Latin America, Asia and Africa: Review and re-interpretation'*, Population Studies, Vol(19), pp. 117-138.

Soares, R. (2007), *'On the Determinants of Mortality Reductions in the Developing World'*, Population and Development Review, Vol. 33, No. 2, pp. 247287.

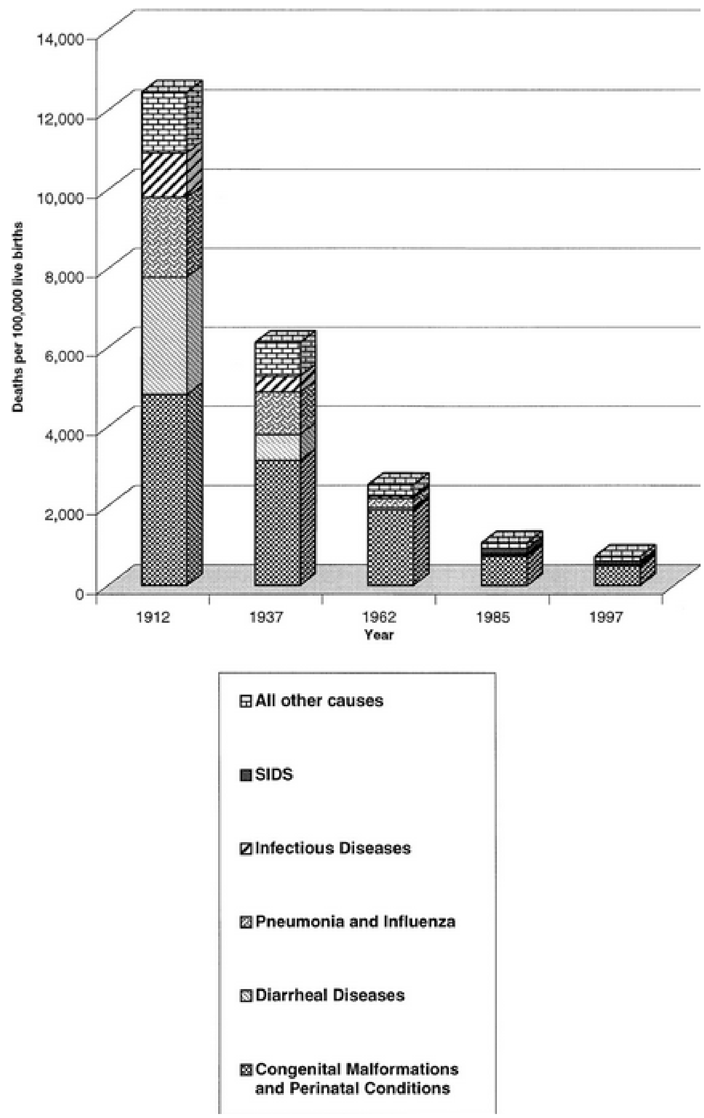
Szreter, S. (1988), *'The Importance of Social Intervention in Britain's mortality decline 1850-1914: a reinterpretation of the role of public health'*, Social History of Medicine, Vol. 1, No. 1, pp. 1-37.

Troesken, W. (2004), *'Water, Race, and Disease'*, MIT Press

Wegman, M. (2001), *'Infant Mortality in the 20th Century, Dramatic but Uneven Progress'*, The Journal of Nutrition, Vol. 131 No. 2 401-408.

White, J. (1984), *'Horsecars: City Transit Before the Age of Electricity'*

Figure 1: Causes of Infant Mortality, selected years, USA[7]



[7] Wegman (2001), "Infant Mortality in the 20th Century, Dramatic but Uneven Progress", The Journal of Nutrition, vol. 131 no. 2 401-408

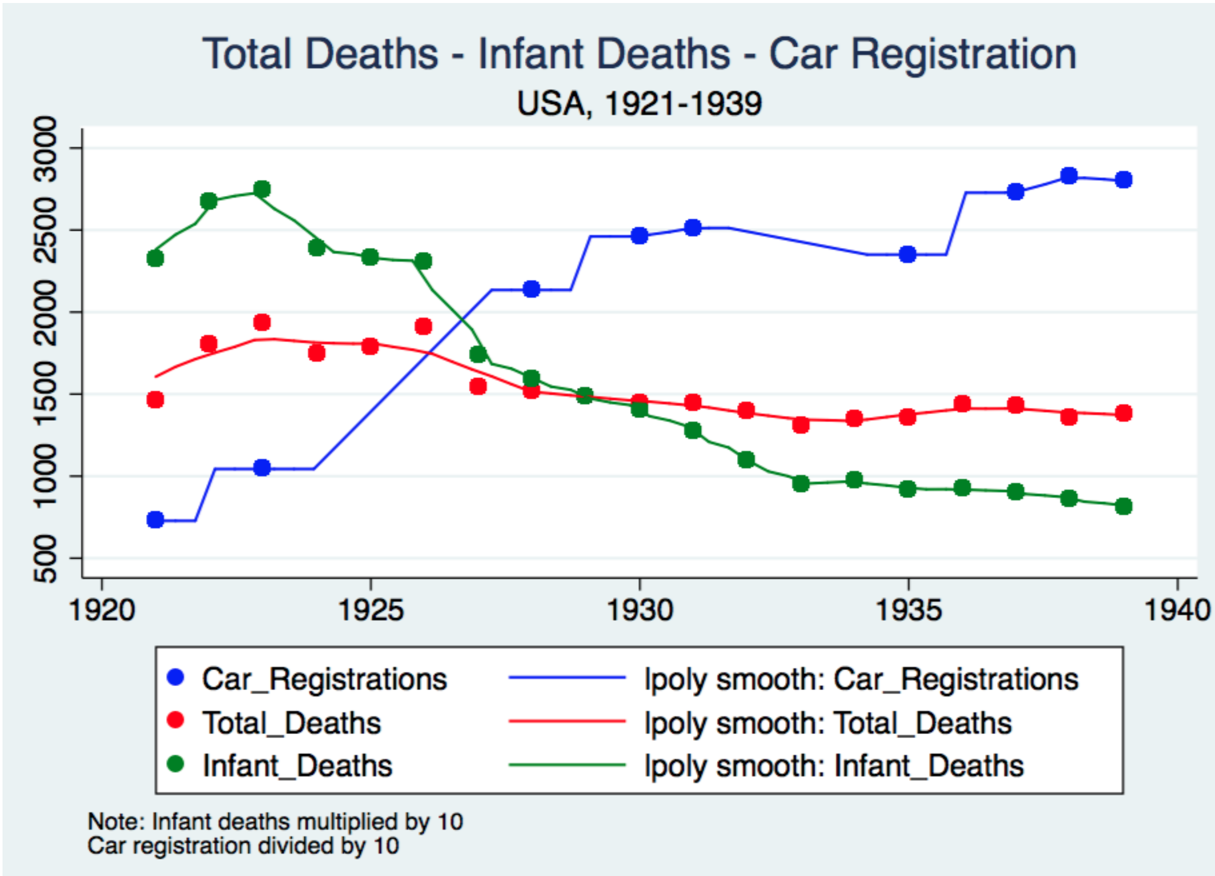

Total Deaths - Infant Deaths - Car Registration
USA, 1921-1939
500
1000
1500
2000
2500
3000
1920
1925
1930
1935
1940
Car_Registrations
Total_Deaths
Infant_Deaths
lpoly smooth: Car_Registrations
lpoly smooth: Total_Deaths
lpoly smooth: Infant_Deaths
Note: Infant deaths multiplied by 10
Car registration divided by 10

Table 1: Summary statistics

Variable	Mean	(Std. Dev.)	Min.	Max.	N
Total deaths	1494.916	(4589.05)	0	46362	50619
Death rate per 100	1.049	(0.318)	0.01	9.207	43752
Infant deaths	140.453	(419.003)	0	5467	50620
Infant death rate per 100	0.121	(0.066)	0.004	1.452	43753
Total cars	20667.207	(79359.011)	2	1261274	40106
Birth rate	0.0198	(0.006)	0	0.237	43669
County population	40035.95	(123492.6)	93.3	4071464	54789
St. psnl. income (pc)	1019.865	(399.845)	297.8957	3188.746	64311
Tax return filing per capita	0.025	(0.034)	0.00007	0.4994554	54856
Colored pct.	11.476	(17.844)	0.1	90.885	61860
Hospitals	6.137	(16.865)	1	172	31784
Illiterate pct.	5.619	(5.505)	0.1	50.981	61860
Avg. Temperature	53.99	(7.92)	34.633	76.044	64514
Females 15-44	28157.645	(89744.174)	47.4	897765.125	31773
Highway mileage (pc)	0.104	(0.005)	0.1	0.15	49471
Pop density	6.748	(32.099)	0.1	527.685	61839

Table 2: OLS Results for Death Rates per 100

	(1) All counties	(2) Pop. Density > 50	(3) Pop. Density < 50
Car Registrations	0.0307***	0.0428***	-0.0304
	(0.00853)	(0.00984)	(0.0246)
Birth Rate	0.143***	0.132***	0.170***
	(0.00707)	(0.00804)	(0.0207)
County population	0.166**	0.0514	0.473***
	(0.0794)	(0.100)	(0.165)
St. prsl. income per cap.	-0.156***	-0.0921***	-0.340***
	(0.0195)	(0.0215)	(0.0572)
Tax return filing pct.	0.0105***	0.00959**	0.0226**
	(0.00341)	(0.00420)	(0.00968)
Colored pct.	0.00341***	0.00194**	0.00786***
	(0.000593)	(0.000784)	(0.00130)
Hospitals	0.00795***	0.00626***	0.0105**
	(0.00205)	(0.00242)	(0.00532)
Illiterate pct.	0.00102	0.00497***	0
	(0.00146)	(0.00166)	(.)
Avg. Temperature	-0.00246**	-0.000144	0.00452
	(0.00108)	(0.00127)	(0.00312)
Female 15-44	-0.462***	-0.372***	-0.677***
	(0.0674)	(0.0859)	(0.137)
Constant	4.80***	4.550***	4.97***
	(0.312)	(0.388)	(0.706)
Observations	17438	14062	3376

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Years covered: 1921, 1923, 1928, 1930, 1931, 1935, 1937, 1938, 1939

All estimations have county, state and year fixed effects;

log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

Table 3: OLS Results for Infant Death Rates per 100

	(1) All counties	(2) Pop. Density > 50	(3) Pop. Density < 50
Car Registrations	0.00203	0.00275	0.00123
	(0.00232)	(0.00267)	(0.00655)
Birth Rate	0.0549***	0.0537***	0.0611***
	(0.00192)	(0.00219)	(0.00551)
County population	0.121***	0.157***	0.0894**
	(0.0216)	(0.0272)	(0.0440)
St. prsl. income per cap.	0.0000636	0.00647	-0.0264*
	(0.00529)	(0.00584)	(0.0153)
Tax return filing pct.	0.00197**	0.00357***	-0.0000890
	(0.000928)	(0.00114)	(0.00258)
Colored pct.	0.000918***	0.000292	0.00269***
	(0.000161)	(0.000213)	(0.000346)
Hospitals	-0.000421	-0.000343	-0.000917
	(0.000558)	(0.000658)	(0.00142)
Illiterate pct.	-0.000486	-0.000551	0
	(0.000397)	(0.000450)	(.)
Avg. Temperature	0.000710**	0.000843**	0.00197**
	(0.000294)	(0.000345)	(0.000832)
Female 15-44	-0.0987***	-0.126***	-0.0734**
	(0.0183)	(0.0233)	(0.0365)
Constant	-0.0809	-0.264**	0.134
	(0.0849)	(0.105)	(0.188)
Observations	17438	14062	3376

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Years covered: 1921, 1923, 1928, 1930, 1931, 1935, 1937, 1938, 1939

All estimations have county, state and year fixed effects;

log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

Table 4: First Stage Results for Car Registrations

	(1)
St. highway mileage per cap	0.0140***
	(0.0036)
St. postal road mileage per cap	-0.0263
	(0.0460)
Birth rate	0.0133**
	(0.0068)
County population	0.853***
	(0.076)
St. prsl. income per cap	0.050***
	(0.0187)
Tax return filing	0.0304***
	(0.0032)
Colored pct.	-0.0029***
	(0.00057)
Hospitals	0.001
	(0.002)
Illiterate pct.	0.0005
	(0.0014)
Avg. Temperature	-0.0008
	(0.0010)
Females between 15-44	0.246***
	(0.066)
Constant	-2.339
	(0.350)
Observations	17487

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

$Fstatistic = 593.50$; $Prob > F = 0.0000$

The IVs are state highway and postal road mileages, and all other exogenous explanatory variables

Table 5: 2SLS Results for Death Rates per 100

	(1) All counties	(2) Pop. Density > 50	(3) Pop. Density < 50
Car Registrations	-1.72***	-1.11***	1.46
	(0.508)	(0.307)	(2.52)
Birth Rate	0.166***	0.146***	0.153***
	(0.0154)	(0.0125)	(0.048)
County Population	1.63***	1.09***	-0.635
	(0.451)	(0.314)	(1.90)
St. prsl. income per cap.	-0.0620	0.0362	-0.312***
	(0.0468)	(0.0467)	(0.116)
Tax return filing pct.	0.0653***	0.0433***	-0.0554
	(0.0172)	(0.0109)	(0.133)
Colored pct.	-0.00145	-0.000334	0.0120
	(0.00183)	(0.00131)	(0.00741)
Hospitals	0.00948**	0.00634*	0.00686
	(0.00406)	(0.00359)	(0.0117)
Illiterate pct.	0.00169	0.0119***	0
	(0.00287)	(0.00307)	(.)
Avg. Temperature	-0.00372*	-0.00412*	-0.0195
	(0.00215)	(0.00216)	(0.0411)
Females between 15-44	0.0133	-0.0499	-1.03
	(0.191)	(0.154)	(0.646)
Constant	0.659	0.517	7.11*
	(1.34)	(1.20)	(3.92)
Observations	17438	14062	3376

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Years covered: 1921, 1923, 1928, 1930, 1931, 1935, 1937, 1938, 1939

All estimations have county, state and year fixed effects;

log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

Table 6: 2SLS Results for Infant Death Rates per 100

	(1) All counties	(2) Pop. Density > 50	(3) Pop. Density < 50
Car Registrations	-0.520***	-0.427***	-0.169
	(0.148)	(0.102)	(0.436)
Birth Rate	0.0618***	0.0589***	0.0630***
	(0.00449)	(0.00414)	(0.00832)
County Population	0.556***	0.545***	0.216
	(0.131)	(0.104)	(0.329)
St. prsl. income per cap.	0.0279**	0.0543***	-0.0296
	(0.0136)	(0.0154)	(0.0201)
Tax return filing pct.	0.0183***	0.0161***	0.00885
	(0.00501)	(0.00361)	(0.0231)
Colored pct.	-0.000530	-0.000555	0.00222*
	(0.000532)	(0.000433)	(0.00128)
Hospitals	0.0000342	-0.000314	-0.000496
	(0.00118)	(0.00119)	(0.00202)
Illiterate pct.	-0.000284	0.00203**	0
	(0.000836)	(0.00102)	(.)
Avg. Temperature	0.000335	-0.000639	0.00472
	(0.000627)	(0.000714)	(0.00711)
Females between 15-44	0.0429	-0.00587	-0.0332
	(0.0556)	(0.0508)	(0.112)
Constant	-1.33***	-1.78***	-1.37
	(0.391)	(0.398)	(0.678)
Observations	17438	14062	3376

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Years covered: 1921, 1923, 1928, 1930, 1931, 1935, 1937, 1938, 1939
All estimations have county, state and year fixed effects;
log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

Table 7: OLS Results for Deaths from Different Causes in 114 Cities

	(1) Diarrhea Disease Deaths	(2) Other Infectious Disease Deaths	(3) Car Accident Death
Car Registrations	-32.01	-6.800	-14.40
	(19.55)	(35.35)	(9.086)
City population	-114.4	-601.7**	62.43
	(159.1)	(288.1)	(121.1)
Avg. Temperature	3.403	6.194	3.650**
	(2.302)	(4.220)	(1.478)
St. prsl. income per cap.	22.79	-9.396	36.33*
	(26.65)	(47.34)	(19.95)
Tax return filing pct.	31.78*	38.37	6.774
	(18.53)	(33.44)	(10.09)
Colored pct.	-3.705	-5.045*	-2.996
	(2.925)	(2.619)	(2.141)
Hospitals	7.077	-19.44	-3.433
	(8.329)	(27.51)	(5.514)
Illiterate pct.	3.698	2.295	2.196
	(5.517)	(7.360)	(1.858)
City birth rate	21.55	83.83	11.20
	(21.35)	(55.82)	(11.11)
City female 15-44	194.3	525.2*	-41.84
	(167.4)	(267.2)	(109.7)
Constant	-624.0	1077.3	-591.4
	(415.3)	(1152.4)	(359.0)
Observations	402	402	402
F statistic	34.40	62.13	229.20

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Years covered: 1930, 1931, 1935, 1937, 1938, 1939.

All estimations have city, state and year fixed effects;

log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

113 cities had population more than 50,000. Only Kenosha, WI had 48,765 people

Table 8: 2SLS Results for Deaths from Different Causes in 114 Cities

	(1) Diarrhea Disease Deaths	(2) Other Infectious Disease Deaths	(3) Car Accident Death
Car Registrations	-243.3	-341.3	26.75
	(239.4)	(394.7)	(118.9)
City population	74.11	-302.8	25.59
	(329.0)	(542.5)	(163.4)
Avg. Temperature	3.831	6.871*	3.567***
	(2.467)	(4.066)	(1.225)
St. prsl. income per cap.	39.21	16.52	33.13
	(45.60)	(75.15)	(22.65)
Tax return filing pct.	76.27	108.8	-1.892
	(54.24)	(89.41)	(26.94)
Colored pct.	-5.816	-8.387	-2.585
	(3.550)	(5.852)	(1.764)
Hospitals	6.448	-20.44	-3.310
	(17.49)	(28.83)	(8.690)
Illiterate pct.	2.770	0.827	2.377
	(4.520)	(7.450)	(2.245)
City birth rate	3.574	55.41	14.70
	(37.18)	(61.29)	(18.47)
City female 15-44	239.7	596.5	-50.54
	(244.9)	(403.7)	(121.6)
Constant	-945.6	710.5	-537.7
	(977.9)	(1612.1)	(485.7)
Observations	402	402	402
Wald χ^2	1052.63	3875.03	21741.82

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Years covered: 1930, 1931, 1935, 1937, 1938, 1939.

All estimations have city, state and year fixed effects;

log on the RHS variables except for Colored pct., Illiterate pct. and Avg. Temperature

113 cities had population more than 50,000. Only Kenosha, WI had 48,765 people