Measles, Mexico and Labor Markets *

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Abstract

We investigate the long term impacts of a reduction in measles in Mexico stemming from a nationwide immunization program. The vaccination program led to significant improvements in childhood health as measles causes "immune amnesia", leaving infected individuals susceptible to illness from other diseases for several years. Using a difference-in-differences strategy we find the measles vaccine led to large increases in educational attainment, employment, and income for men. The effects are two to ten times larger than in the U.S. This shows disease eradication can have a larger effect in middle income countries like Mexico with a greater disease burden and reduced health care access. The educational increases also are greater than for malaria and hookworm. This is attributed to the universality of measles as a childhood disease, and the widespread health improvements generated by the vaccine.

Keywords: Measles, Mexico, Employment, Education, Migration

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1 Introduction

Does reducing the prevalence of disease improve domestic labor market outcomes and, in turn, change the incidence of migration abroad? We examine this question using the case of Mexico and its rollout of the measles vaccine in the 1970s. Measles offers an important example of a disease whose reduction may change behavior for two reasons. First, it is highly contagious, and prior to the invention and adoption of the measles vaccine it was a universal childhood disease. An estimated 95% of children contracted it before age 16 (Atwood 2022). Second, measles is unlike other infectious diseases in that it reduces immunity from *other* diseases, increasing morbidity beyond the effects of measles alone (Mina 2015). These two factors combined mean that the measles vaccine leads to improvements in childhood health for large segments of the population.

Several papers have documented the positive effects on public health of the measles vaccine in high, middle and low income counties (Aaby et al. 1984; Aaby et al. 2003; Aaby et al. 2014; Bloch et al. 1985; du Lou et al. 1995; Gadroen et al. 2018; Hinman et al. 1983; Mina et al. 2015). These papers primarily focus on short run impacts like decreased measles cases and spillover effects of the measles vaccine on infections disease morbidity and mortality. They find the introduction of mass measles vaccination has a profound impact on not only measles but on morbidity and mortality from other infectious diseases. Recent papers by Atwood (2022) and Chuard et al. (2022) also examine the long run impacts of the measles vaccine in the U.S. and finds positive long-run effects on labor market outcomes. This complements a large literature that finds positive long-run effects on employment and wages from the eradication of *other* diseases, principally malaria.

Less work has been done investigating the long run effects of the measles vaccine in middle to low income countries like Mexico. Filling this gap in the literature is important, as the effects of mass vaccination campaigns likely were greater than in high income countries. This is due to the fact that while the incidence of measles does not vary, the burden of the disease does due to the higher incidence of other infectious diseases coupled with less access to health care providers. For example, prior to the rollout of the vaccine in Mexico, the country's director of the Institute for Vaccines noted that the pre-vaccine measles mortality rate was 10 times higher in Mexico than in the U.S. during a similar period (Martín Sosa, 1970). Similarly, Bleakley (2010) finds the impact of campaigns to eradicate a different disease- malaria - were greater in Mexico, Brazil and Colombia than in the United States.

In this paper we examine Mexico's National Immunization Program (NIP), which began in 1973 and quickly administered millions of doses of the measles vaccine to young children throughout the country. We study the long run impacts of this program using a difference-in-differences empirical design which takes advantage of differential exposure to the vaccination campaign due to year of birth and cross area differences in pre-program measles incidence rates across states.[1] In testing the parallel trends assumption of this design we show the National Immunization Program led to near complete reductions in measles incidence, and that the declines were larger in states with higher pre-program incidence. Meanwhile, similar declines and differences across high and low incidence measles states are not seen for outcomes that should be unaffected by the measles vaccine, but would be affected by general improvements in public health infrastructure. These include sexually transmitted diseases, diseases with pre-existing vaccines (polio, diphtheria, tuberculosis), diseases caused by poor sanitation (dysentery), and adult mortality from childbirth or accidents and homicides. We also find no correlation between pre-vaccine measles incidence and state level income or geographic measures such as temperature or rainfall.

Using five different Mexican datasets we find significant evidence that the measles vaccine improved labor market outcomes for men in Mexico. For affected cohorts the incidence of employment increased approximately three percent while log wages increased between two and twelve percent. These estimates are two to ten times larger than those found by Atwood (2022) in the U.S., providing evidence that the long-term effects of the measles vaccine are

[1] This identification strategy is similar to that used in studies assessing the impact of hookworm, malaria, and measles eradication (Bleakley 2007; 2010; Cutler et al. 2010; Lucas 2010; Atwood 2022; Venkataramani 2012).

larger in countries with higher disease burdens.

We also find that a key channel through which labor market improvements occurred is through schooling, which increased between 0.5 and 0.8 years for affected cohorts. The increases are sufficient to drive changes in overall educational attainment, as we see a shift out of the completion of primary school or less and into the completion of lower or upper secondary school. The estimated changes are large, ranging from a six and fifteen per cent increase in the attainment of higher education levels. These findings are striking not just due to their size, but because they differ from existing literature that generally finds no educational effects for men from the eradication of other infectious diseases. For example, Bleakley (2007) finds that eradication campaigns for hookworm in the American South had a positive impact on earnings but not did have a statistically significant impact on educational attainment. Likewise, there is substantial evidence that malaria eradication campaigns have impacts on income and household consumption but no evidence of impact on educational attainment for men (Bleakley 2010, Cutler et al. 2010, Venkataramani 2012). We argue the combination of disease and context explains these disparities. The universality of measles means that eradication campaigns affect a larger percent of the population than for malaria or hookworm. Meanwhile, in a middle income country like Mexico measles sickness in childhood was more likely to lead individuals to drop out of school.

We next examine if improved labor market conditions in Mexico following the measles vaccine campaign affected international migration, almost all of which is to the U.S. On the one hand, improved labor market conditions in Mexico may dampen migration incentives for those who reap the most benefits from the measles vaccine. This argument is in line with several papers which find migration is responsive to labor market conditions in Mexico (Orrenius and Zavodny 2005, Lessem 2018, and Monras 2020). On the other hand, we cover a time period when migration rates are high, and previous work by Hanson and McIntosh (2010) finds that migration increased among the age cohorts we study as a result of rising cohort size and labor supply.

Overall we find that among affected cohorts international migration does increase significantly, but only for those in areas with a history of high migration. This aligns with a story in which migration responses differ by access to migration networks, which provide information about expected labor market outcomes in the U.S. In other words, among the cohorts most affected by the vaccine, only individuals with better information about labor market conditions in the U.S. become more likely to migrate abroad.

Our paper makes two main contributions to the literature. First, we provide strong evidence of a public health intervention that significantly reduced the incidence of infectious disease and, in turn, allowed individuals to increase their levels of education, employment and wages later on. Our estimates establish that the benefits to mass measles vaccination campaigns have greater returns in a middle income country than a high income country which is attributed to higher infectious disease burden. Given that measles is a childhood disease, this adds to the broader literature on the long term benefits of reducing childhood health shocks[2].

Second, we add to the literature documenting the benefits of widespread vaccine campaigns which reduce the incidence of highly contagious disease. Specifically for measles, advertising these benefits remains necessary as vaccination rates have declined recently due to increased vaccine hesitancy (Larson et al. 2022) and the decision by some countries to suspend measles vaccine campaigns during the Covid19 pandemic (Roberts 2020). Globally measles cases rose from 2021 to 2022 (WHO 2022). The findings of significant long-term impacts of the measles vaccine in Mexico provides additional evidence for policy makers and public health officials to use when framing the discussion around vaccination policy.

[2]For example: S. R. Bhalotra and Venkataramani 2013; Case, Fertig, and Paxson 2005; Case and Paxson 2009; Almond 2006; Currie and Moretti 2007; Bleakley 2007; 2010b; 2010a; Cutler et al. 2010; Lucas 2010; Venkataramani 2012; S. Bhalotra and Venkataramani 2015; Almond and Currie 2011a; 2011b; Atwood 2022.

2 Measles

2.1 Measles Virus

Caused by a paramyxovirus, measles is one of the most contagious of all infectious diseases. The virus is transmitted through direct contact with infectious droplets and by airborne spread - primarily by infectious individuals coughing, sneezing, or breathing - with the virus remaining infectious for up to two hours after an infected individual leaves the area (Fields et al. 2013). Due to its highly contagious nature nine out of ten susceptible individuals with close contact to a measles patient will develop measles (Banerjee et al. 2019). [3]

The classic symptom of measles is a rash that spreads over the body and is often accompanied by fever, runny nose, cough, red eyes, and sore throat (Fitzgerald et al. 2012; Fields et al. 2013; Robbins 1962). Measles patients are typically contagious during the four days preceding the appearance of the rash and for the first four days after the rash appears (Fields et al. 2013; Robbins 1962). Spreaders of the measles virus are typically in the pre-rash phase. This plus the highly contagious nature of measles allows for widespread infection before the spreader even knows they are contagious and for them to have exposed individuals without ever being in the room at the same time as each other.

Measles virus is a universal childhood disease. In the absence of the measles vaccination virtually everyone will naturally be infected by measles during childhood. Prior to vaccine availability 50-percent of all children will naturally contract measles by the age of 6 and 95-percent will naturally contract measles by the age of 16 (Atwood 2022; Perry and Halsey 2004; Langmuir 1962; Strebel 2017; Miller 1964).

In the absence of a vaccine there is no method of measles prevention. Morbidity of measles is universal during childhood. Individuals without measles antibodies are susceptible to measles. The key factor in measles transmission and infection rates is the susceptible population and its density in a given location. The primary site of measles transmission is

[3] https://www.cdc.gov/measles/hcp/index.html

schools. There is a long and extensive literature documenting a contagious individual in the classroom leads to explosive outbreaks immediately following the susceptible population's exposure (MMWR 1977; Hinman et al. 1983; Rota et al. 2016; Sencer, Dull, and Langmuir 1967; Hedrich 1930; Fine and Clarkson 1982). Prior to the vaccine and still the case today when an individual contracts measles medical advice is to stay at home for at least four days after the rash appears and take it easy.[4] [5] Lifelong immunity to the measles virus is obtained upon recovery from measles (Fox 1983).

Additionally, there is a global epidemic cycle of measles. Prior to vaccine development the major epidemic outbreaks across the globe occurred at a cycle of every two to three years. Measles is a ubiquitous disease and occurs in every climate and corner of the world. However, the local seasonal cycle of when measles cases peak during a given year is dependent on climate - incidence peaks during the dry season in tropical zones and in the late winter/early spring in temperate zones (Sencer, Dull, and Langmuir 1967; WHO 2017).

The measles vaccine is recognized as one of the most successful public health interventions of all time (Perry et al. 2014; Moss and Griffin 2012; Simons et al. 2012). This is due to the twofold impact of the measles vaccine. First, the measles vaccine reduces measles incidence. Second, preventing measles through vaccination also causes a reduction in morbidity and mortality from other pathogens due to the unique biology of the measles virus and its impact on our immune system. Following an infection our immune system is suppressed. This suppression is transient and our immune system restocks itself, to continue to provide future resistance to pathogens it had previously developed antibodies for, using its immune memory cells in the few weeks or months following illness (Perry et al. 2014; de Vries and de Stewart 2014; Schneider-Schaulies and Schneider-Schaulies 2009). However, the measles virus interacts differently with our immune system. Individuals who contract measles experience profound immunosuppression and are then susceptible to other pathogens (de Vries et al. 2012). Scientists have discovered that post measles infection one's body restocks

[4]National Health Service, England. https://www.nhs.uk/conditions/measles/treatment/
[5]National Foundation for Infectious Diseases, USA. https://www.nfid.org/infectious-diseases/measles/

memory cells within weeks but only restocks with measles-specific lymphocytes and not other antibodies that it had previously acquired. Therefore, the body must reacquire immunity through contact with antigens during this restocking period (Pirquet 1908; Lin et al. 2012). This phenomena has been termed ”immune amnesia” and it can take up to five years for the immune system to be restocked.[6]

Recent epidemiological and medical literature has documented the impact of ”immune amnesia”. Gadroen et al. (2018) showed using cohort analysis that antimicrobial therapies were prescribed at an increased rate to children for up to five years post measles infection due to a greater number of infections attributable to measles related immunosupression. Another study demonstrated in the United States, Denmark, and England and Wales that non-measles infectious disease mortality is correlated with measles incidence over a two- to three-year lag period (Mina et al. 2015). Additionally, biological evidence of ”immune amnesia” has been provided through two studies using pre- and post-natural measles infection which document the decrease post-infection in the body's immune memory cells. The studies use blood samples from children who are unvaccinated due to religious reasons in the Netherlands. One study documents previously formed memory cells went missing post measles infection (Petrova et al. 2019); and the other finds 11- to 73-percent of a child's antibody repertoire missing (Mina et al. 2019).

Antibody recovery post-measles infection only occurs after natural re-exposure to the pathogens. Thus, ”immune amnesia” can have a profound impact on health during childhood. Once mass measles vaccination occurs measles cases are virtually eliminated and children exposed to the vaccine will have healthier childhoods than those not exposed to the vaccine. A healthier childhood can improve cognitive and physical development, both of which can have long term impacts on education and in labor markets.

[6] For a comprehensive discussion of ”immune amnesia” see Atwood 2022.

2.2 Measles in Mexico and the National Immunization Program

With the exception of children in isolated villages most children in Mexico developed measles before entering school (Bravo and Diaz 1980; Santos 2004). The history of measles in Mexico as it relates to our project can be divided into four distinct periods. The earliest being 1950-1958. During this and subsequent periods outbreaks of measles occur on a two-year cycle that corresponds to when sufficient numbers of susceptible individuals accumulate. This period also sees a dramatic decrease in the death rate (while stable morbidity is exhibited during the period) which is attributed to the wide use of penicillin (de Castro 1983). During the next period, 1959-1966, the measles morbidity pattern remains consistent with the previous period and the mortality curve flattens, due to the broad spectrum use of antibiotics (de Castro 1983). From 1967-1972, measles continues to exhibit its bi-yearly epidemic pattern albeit at a slightly lower level than the previous two periods (de Castro 1983).[7] It is important to note that the mortality rate remains consistent from this period to the previous one, an indicator that there were no additional advances to impact measles related mortality. The national level measles incidence rate is 94.8 per 100,000 population, from 1967-1972, and the death rate is 18.5 per 100,000 population. Both of these measures decrease in the subsequent period, 1973-1981, with measles incidence rate dropping to 26.2 per 100,000 population and the death rate to 4 per 100,000 population (de Castro 1983). The drop is attributable to extensive vaccine use, which occurred because of the National Immunization Program that started in 1973 (Bravo and Diaz 1980; de Castro 1983; Santos 2004).

Mexico's launched its National Immunization Program in 1973, distributing the measles

[7]The measles vaccine was first licensed in the United States in 1963, and was available on the market. Vaccination rates were extremely low in Mexico prior to the National Immunization Program. But with the availability of a vaccine and the high uptake of it in other countries like the United States there were fewer measles cases in the world after the vaccine was licensed.

vaccine at no cost to children.[8] [9] The first phase of the program utilized a mass vaccination approach. In 1973 the program targeted children aged six months to five years and deployed vaccination brigades to make vaccines accessible (de Castro 1983). More than 3.6 million doses of the measles vaccine were administered to children aged nine months to five years in 1973 (Santos 2004). During the years 1974 and 1975 the program targeted children aged 6 months to 18 months but older children were not turned away if their family requested measles vaccination. The shift to more focused targeting of younger children in these years occurred because older children were included in the first year of the program (de Castro 1983). From 1976 to 1979 the National Immunization Program shifts its strategy to that of a routine immunization strategy through health centers. To make the population aware of this shift and to encourage vaccination intensive advertising of the program occurred as well as the establishment of the *Cartilla Nacional de Vacunación* (National Immunization Card) in 1976 (de Castro 1983). Then in 1980-1989, the government continued with its routine immunization strategy but also introduced intensive phases of immunization (pop-up mass vaccination opportunities) during the year into the routine immunization strategy (de Castro 1983).[10]

The National Immunization Program was very successful in vaccinating its target populations

[8]The program followed the recommendations of the World Health Organization and included four vaccines for children ages 0 to 5; measles, polio, tuberculosis, and diphtheria, pertussis and tetanus (DTP). However, as we discuss in section 4.1, the measles vaccine is the only new one, as the vaccines for polio, tuberculosis and DTP were in production and circulation since the 1950s and 1960s in Mexico. The low incidence and mortality rates for these diseases suggest vaccine uptake was high prior to 1973. Further, any observed reductions pale in comparison to measles. So while the NIP was not a measles only program, measles was the disease that, by far, was most affected by it.

[9]The National Immunization Program is a federal program that did not allow for state variation in strategy in how the program was implemented. Additionally, the program did not coincide with changes to the health system. Mexico's centralized health service system originated in 1943 with the establishment of the SSA (defines policies emanating from the federal department and provides health services to individuals without social security), IMSS (provides health services and social security to the private sector), and Mexican Children's Hospital (provides highly specialize services and conducts research). The ISSSTE was established in 1960 and is similar to the the IMSS but covers public sector workers (Castro 2014).

[10]An important feature of the rollout campaign is variation in the intensity by urban and rural areas. Until 1985 only communities with greater than 1500 people were programmed for routine immunization activities (Santos 2004). There are a great number of small villages with scattered population making it challenging for vaccination brigades to cover them all (de Castro 1983). For this reason we include urban/rural status as a control in the regressions.

(Bravo and Diaz 1980; de Castro 1983; Santos 2004). This is illustrated in Figures 1 and 2. Figure 1 shows both the number of reported measles cases and the number of measles deaths at the national level in Mexico over time. Prior to the government's mass measles immunization campaign the national incidence was roughly 40,000 reported cases a year[11] and after the mass immunization campaign is implemented in 1973 there is a swift and near full reduction in measles cases.[12] This is because the National Immunization Program was successful in vaccinating children against measles as measles morbidity is a direct mathematical function of the number of vaccine doses distributed (de Castro 1983). Mortality from measles also declined during this period as illustrated by the dashed line in Figure 1.[13] Figure 2 illustrates the reduction in measles cases from 1972 (the year prior to the measles immunization campaign) to 1978 plotted against the number of measles cases in that state in 1972. If the measles vaccine is successful in preventing measles and the mass vaccination campaign was successful we will observe a positive relationship in the figure. The data points in Figure 2 approximate a 45-degree line indicating the measles burden across the entire country was significantly reduced.

Due to the success of the National Immunization Program in vaccinating children to protect then from contracting measles, children exposed to the program will have healthier childhoods than those not exposed to the program. Experiencing a healthier childhood can improve cognitive and physical development. These gains can manifest in higher educational attainment and improved adult labor market outcomes.

[11]Prior to the introduction of mass measles vaccination campaigns in a country measles case count reporting is low around the world. In Mexico there is massive under reporting with academic papers estimating that only 3-percent of measles cases are actually reported. This is in line with under-reporting figures from the United States and Italy. Post immunization campaign reporting improves to 20-percent. Mortality is more accurately reported (de Castro 1983).

[12]In 1976 there was a worldwide measles epidemic which is indicated in the increase of measles cases.

[13]While measles mortality drops significantly post launch of the National Immunization Program it is unlikely to have a significant impact the composition of those that reach adulthood. Prior to 1973 about 8,000 measles deaths a year occurred, after mass immunization started the number of deaths drops to fewer than 500 a year nationally.

3 Data

3.1 Measles Incidence Rates

In 1965 Mexico introduced the Pan American Health Organization (PAHO) reporting format for the surveillance of transmissible diseases (Santos 2004). Annual state-level infectious disease incidence rate data come from the 1965 to 1978 annual epidemiological bulletins published in the *Salud Pública de México*. [14] These data report the number of reported cases and incidence rate per 100,000 populations in each state during a given year for notifiable infectious diseases. For a select number of years (1971-1974) mortality data by state and disease is also available. Measles is a notifiable disease in Mexico during this time period. State population for each year is also included in these reports.

3.2 Outcome Variables

To estimate the effects of the measles vaccine introduction on employment, wages, education and migration we use Mexican datasets that are representative at the state level, large enough to provide sufficient birth-year cohort variation and go back far enough to include when unaffected and affected cohorts reach the age to enter Mexican labor markets or make the decision to migrate. For example, the first cohorts to have maximum exposure to the measles vaccine were born in 1973, when the vaccine campaign began. Since we define age 18 as the age when individuals reach adulthood, individuals born in 1973 would reach that age in 1991. Meanwhile, individuals with zero exposure to the vaccine rollout before reaching the age of 18 were born on or before 1955.

Five datasets meet the criteria outlined above.[15] The first two are the 1995 Mexican

[14]Disease incidence data is less well measured than disease mortality data. This is particularly true for measles reporting across the world and in Mexico. However, there is no evidence that measles incidence reporting changes within states over time during the pre-vaccination period. Therefore by including both state-fixed effects and year-fixed effects in our empirical models we are able to control for under reporting of measles in the pre-period and its variation across states.

[15]The data and documentation for these datasets are publicly available on the website of the Instituto Nacional de Estadística, Geografía e Informática (INEGI): `www.inegi.gob.mx`.

Intercensal Count (Conteo) and the 2000 Mexican Census.[16] The last three datasets are Mexican labor force surveys: the National Survey of Urban Employment (Encuesta Nacional de Empleo Urbano, or *ENEU*) the National Survey of Employment (Encuesta Nacional de Empleo, or *ENE*) and the National Survey of Employment and Occupation (Encuesta Nacional de Ocupación y Empleo, or *ENOE*). All three are panel datasets which follow individuals for up to five quarters. To avoid double counting we construct a cross-section such that each individual only appears once. To do this we use individuals' age as of the first interview and the remaining responses as of the last interview.[17] We use all three datasets as they vary in terms of geographic coverage and timing. The ENE and ENEU are the earlier samples, and both were discontinued in Q12005 and replaced with the ENOE. The ENE and ENOE have greater geographic coverage, as they are representative of both urban and rural areas. For the ENE we use surveys from 2000 to 2004, while for the ENOE, to avoid including the Great Recession, we use surveys from 2005 to 2008. Meanwhile the ENEU has less geographic coverage, only including urban areas, but covers a longer time period, with samples that include state of birth from 1994 to 2004.

Another key feature of all five datasets is that they have information on migrants and non-migrants, and, given their size, can capture a low probability event like migration (National Research Council 2013). The Conteo and Census contain modules on international migration that ask households to list the members who have migrated abroad in the past five years and their age at migration. These questions allow us to see not only migrants who left Mexico and returned, but also those who left and remain abroad.[18] For example, the 1995 Conteo covers migration incidents that occurred from 1990 to 1995– a time period when the first cohorts to receive the vaccine as infants (1973 and beyond) reach an age when they can decide to migrate as adults. [19] Meanwhile, in the ENE, ENEU and ENOE households are

[16]We cannot use the 2005 Intercensal count, as it does not include state of birth

[17]For income we use the highest value over the time they are in the panel.

[18]To ensure no double counting of international migrants we only count those who appear in the separate migration module. We do not use the migration questions that appear in the main questionnaire.

[19]The 2005 intercensal survey does not include state of birth

asked if any members listed in the first survey are absent because they moved abroad. These datasets therefore capture exactly who leaves from which Mexican location and how they compare to those who remain. We note that migration incidence differs across the Conteo and Census and the ENE, ENEU and ENOE, as the former capture stocks while the latter capture flows. In other words, the Conteo and Census capture the total number of men who have left in the previous five years, while the ENE, ENOE and ENEU capture the number of people who leave in one specific year. This means the migration numbers are larger for the Conteo and Census than for the other datasets.[20]

To capture the population that is most likely to work we use men ages 18 to 65. For wages we use real, monthly wage income, adjusting all income values so that they are in Q42004 pesos using the Index of National Consumer Prices, obtained through INEGI. For education, in addition to total years of schooling we also consider educational attainment, determined using data on the highest level of education reached plus the number of years at that level. We code three levels of attainment: primary school or less (0-8 years of education); lower secondary school (9 to 10 years of education); and upper secondary school and above (11 years of education or more).[21] The distribution of years of education by dataset are presented in Figure 4. They show that the three attainment categories approximately capture the lower, middle and upper ends of the education distribution. At the upper end, the relative scarcity of workers with upper secondary and college education should lead to higher wages for those who obtain these levels of educational attainment. Meanwhile, the middle of the distribution is of interest because several papers document that Mexican migrants to the U.S. largely are

[20]Researchers have shown that the migration flows in the ENOE match those from other representative datasets in Mexico, including the ENADID and the EMIF (Conover et al. 2022). Meanwhile other datasets used to examine migration in Mexico, principally the Mexican Family Life Survey and the Mexican Migration Project, are not representative at the state level nor are they very large. They do not have sufficient geographic and age cohort variation to capture the effect of the measles vaccination program.

[21]In the appendix we also consider less than primary (0-5 years) and primary (6 to 8 years of education) separately. For the datasets that do not have a code for educational attainment we follow INEGI and code this based on the highest level of schooling one reaches plus the years completed at that level. For example, someone who reached lower secondary school but only completed one year would not have finished this level of schooling. They are coded as having completed just a primary education. More details are available upon request.

drawn from here (Chiquiar and Hanson 2005, Fernández-Huertas Moraga 2011, Rendall and Parker 2014). This means individuals with lower secondary education levels are more likely to compare labor market outcomes at home to those abroad.

Summary statistics from all five datasets are in Table 1, and show a high degree of similarity across the samples in terms of average age and employment status. Where we see differences is in wage income and education, which are higher in the ENEU than the other datasets. This reflects differences in rural and urban incomes and educational attainment, and the fact that the ENEU is entirely urban.

For international migration we present a graph of flows by year or quarter-year from all five datasets in Appendix Figure A2. The datasets cover time periods of large increases in outmigration (1990 to 2000), steady rates of outmigration (2000 to 2004) and declines in outmigration (2005 to 2008). To capture the geographic variation in migration intensity we present a map of migration rates by state from the ENE in Figure A3. The ENE covers a period of high out-migration, and the categorization of high and low sending states coincides with those found by other authors (Hanson 2007).

4 Empirical Model

4.1 Disease Incidence

The difference-in-differences research design exploits variation across states based on pre-vaccine measles incidence rates and variation across cohorts based on cohort specific years of exposure to the measles vaccine. The primary identifying assumption for our study design is that in the absence of the mass measles vaccination program in Mexico the difference in outcomes across birth cohorts would have evolved similarly in higher- and lower-measles incidence rate states.

Several features of measles help support the parallel trends assumption. First, measles is a highly contagious disease in all contexts, and in the absence of a vaccine 95- to 98-

percent of children will contract it by age 16. Prior to the availability of the vaccine, the majority of measles cases occur when those who previously have not had measles (mostly children who have not previously contracted measles) congregate and spread the disease to other susceptible members of the population. The universality of measles means that environmental factors which explain the incidence of mosquito borne diseases like malaria do little to explain the pre-vaccine incidence of measles. We provide some evidence of this in Figure 3, which illustrates the variation across Mexican states in measles incidence rates prior to the National Immunization Program of 1973. The map highlights the absence of any clear geographic trend in pre-vaccine measles rate. For example, rates are not uniformly higher among states that border the U.S., Guatemala, the Gulf of Mexico or the Pacific. In Table 2 we show the correlation between measles rates and geographic features in 1970 of the capital city of the state, including average temperature, days of significant rain, and annual precipitation. The results confirm there is no correlation between any of the measures and average, pre-vaccine measles rates. [22]

The nature of measles also means there should be a low correlation between pre vaccine incidence and the income or wealth in a state (although there would be a correlation to morbidity and mortality from the disease). We see some evidence of this if we look at the ranking of states by pre-vaccine measles incidence, (shown in Appendix Table A1), as wealthier and poorer states are equally represented in the high and low incidence groups. We also explicitly test for a correlation between average wage monthly wage income, employment and literacy rates in the 1970 census and the average pre-vaccine measles rate across states. The results in Table 3 show no correlation for all variables.[23]

Ideally, we also would test the relationship between measles incidence rates pre-program and the susceptible population density (those who have never had the measles) within geographic areas smaller than the state level. We are limited by data on both metrics to be

[22] All variables from the 1970 *Anuario Estadístico de los Estados Unidos Mexicanos.*

[23] We also find no correlation with changes in employment or literacy rates between the 1960 and 1970 census. Results available upon request

able to effectively test this relationship. First, yearly state level measles incidence data is the smallest geographic unit reported. Second, the age distribution of the measles incidence at the state level is not reported and we must proxy for the susceptible population density using the population. Therefore measuring this relationship at the state level is a crude approximation, as population density is not uniform across a state and other factors such as social networks and number of members in a household impact the susceptible population density. These likely are the reasons why we find no statistically significant relationship between pre-vaccine measles incidence and for either the general population density or the density of children aged 0 to 5 in a state (as shown in Table 3.[24].

Finally, the absence of measles treatment and the high effectiveness of the vaccine means that the mass measles vaccination campaign in 1973 was successful in reducing the measles burden in Mexico (as illustrated by Figure 1), but it is unlikely any intervention other than the measles vaccine would lead to a sharp and permanent decline in measles rates. Furthermore, given the universality of the measles and measles induced "immune amnesia", it is unlikely any other intervention at this time led to the same improvements in childhood health.

We conduct an event study analysis to provide more direct evidence supporting the parallel trends assumption. Following (Atwood 2022, Goodman-Bacon 2017, and Jacobson et al. 1993) we use a standard event study model for state s where pre- and post-treatment are defined by indicators variables that measure time to and time from Mexico's mass measles vaccination initiative in 1973, and treatment and control groups are represented by the continuous variable of the pre-vaccination measles rate in a state.

[24]To establish the relationship between the susceptible population and measles incidence rates monthly level data on births, deaths, and case counts by age is needed for small geographic areas. Using these data from Baltimore over a time period from 1897 to 1927 Hedrich finds that measles case counts fluctuate with the susceptible population in a narrowly defined community and that outbreaks are more likely to occur in areas with a higher susceptible population density (Hedrich 1930). This illustrates why within a city pockets of outbreaks can occur.

$$Y_{st} = \beta_0 + M^{pre}_{1965-1972_s}[\sum_{y=-8}^{-2} \alpha_y(t - t* = y) + \sum_{y=0}^{6} \lambda_y(t - t* = y)] + \delta_s + \delta_t + \gamma * X_{st} + \epsilon_{st} \quad (1)$$

$M^{pre}_{1965-1972}$ is measured as an unweighted eight-year average of a state's measles incidence rate per 100,000 population. We average over all the years of pre-vaccine data due to the 2- to 3- year cycle of measles epidemics, meaning that previous years measles outbreaks influence the current year susceptible population and number of cases. The time period used in the event study is from 1965 to 1978. We include state fixed effects to control for time invariant state level characteristics such as climate and unchanging infrastructure. The reference period is set to the year before the measles vaccine was licensed in Mexico and the government instituted a mass measles vaccination campaign. We include the time varying state population as a covariate. Standard errors are clustered at the state level.

The coefficients of interest are α_y and λ_y. These coefficients measure the covariate adjusted relationship between the incidence rate of measles and the unweighted average-8-year pre-vaccine measles incidence rate in the 8 years leading up to the mass vaccination initiative and the 6 years after. The indicator of the year prior to the vaccination campaign (1972) is omitted, which normalizes estimates of α_y and λ_y to zero in that event year. The α_y are falsification tests that capture the relationship between the pre-vaccine average measles rates and outcomes before the vaccine was available. Their pattern and statistical significance are a direct test of of the common trends assumption. The λ_y are intention-to-treat effects of an additional 1 per 100,000 rate increase in the pre-vaccine measles incidence rate on the post-vaccine incidence of a disease. The estimates will equal zero if the measles vaccine affected morbidity equally across all states. If the pre-measles vaccine incidence rate is completely eliminated across states as suggested by Figure 2, the estimates will equal negative one.

Figure 5 presents the α_y and λ_y estimates from Equation 1 and illustrates that the incidence of measles was impacted by the arrival of the measles vaccine. The α_y coefficients provide evidence in support of the common trends assumption holding as there is no statistical difference for state measles rates during the pre-period. The λ_y coefficients show that after the mass vaccination campaign in 1973, there is a sharp and immediate decreases in measles incidence rates. The year estimates are negative with the majority having a coefficient of negative one, indicating a one-for-one negative impact on subsequent measles cases by pre-vaccine incidence rate.[25] This indicates that sates with higher pre-vaccine measles incidence rates experienced a greater benefit from the measles vaccine than those with lower incidence rates.

A principal concern is that the divergence in trends in measles rates across high and low incidence states is due to other factors that changed in 1973 instead of the measles vaccine. For example, the National Immunization Program could have been combined with other efforts to improve public health, such as expansions of health clinics, expansions of public health insurance, or sanitation improvements. These efforts could have been more intense in states with high measles incidence than low measles incidence. While we have not seen evidence in the reports that any of these public health investments occurred in tandem with the NIP, we conduct falsification tests to see if the program affected other diseases. If our measure captures general improvements in public health and not just the rollout of the measles vaccine we should see a similar divergence for diseases that are unrelated to measles but would be affected by improved access to health providers or clean water.

To perform falsification tests using Equation 1 we use diseases that are not a focus of the program, nor are preventable from the measles vaccine.[26] We start by examining syphilis and gonorrhoea, two sexually transmitted diseases which are overwhelmingly diagnosed in adults (thus negligible incidence in the age range where measles occurs), have more than

[25]During 1976-1977 there were worldwide epidemics of swine flu and measles. This coincides with the two years of smaller estimates where the estimate is not statistically different from zero. The sign for each of these estimates is negative and the confidence intervals include negative one.

[26]Data on these diseases come from the 1965 to 1978 annual epidemiological bulletins published in the *Salud Pública de México*.

10,000 reported cases in a year, and exhibit variation in the reported number of cases across states. If the measles vaccine was accompanied by expansion of health clinics, we would expect the incidence of these diseases should be reduced. However, as shown in the first row of Figure 6 we find coefficients that are not statistically significantly different from zero in either the pre- or post-program period.

We next examine if there are differential changes to dysentery cases that are related to measles vaccination. Poor sanitary conditions spread dysentery as it is passed in the feces of an infected person and often spread through drinking contaminated water. Therefore, if states made investments in sanitation that coincided with the timing of the National Immunization Program and their pre-vaccine measles incidence rates, then states that benefited more from the measles vaccine would also demonstrate reductions in dysentery that corresponded to their reduction in measles incidence. The second row in Figure 6 shows no evidence of this. There is no difference in the periods prior to the National Immunization Program or the periods after.

We continue with the incidence rates of three other vaccine preventable infectious diseases - polio, diphtheria, and tuberculosis. The vaccines for all three were developed and had mass vaccination campaigns in Mexico well before the measles vaccine became available and the National Immunization Program was launched. Specifically, the oral polio virus vaccine became available in 1959 in Mexico and was introduced as an anti-epidemic measure with mass vaccination efforts, while a massive DPT (combined vaccine for diphtheria, pertussis, tetanus) vaccination program was instituted in 1960.[27] Meanwhile the tuberculous' BCG vaccine began being produced in Mexico in 1931. These vaccines therefore predate that of the measles by at least 10 years. Therefore previous mass vaccination campaigns and availability of these other vaccines in Mexico meant that these diseases exhibited low incidence at the start of the National Immunization Program and ensured children continued to receive these vaccinations on the regular schedule (See Appendix Table A1). As shown in the second

[27] Ideally we would also include event study figures for pertussis and tetanus; but they are not included in the infectious disease reports.

and third rows of Figure 6 none of these three diseases indicate a change in incidence that is related to the National Immunization Program and a state's pre-campaign measles incidence rate. This coupled with the fact none of these diseases are culprits to suffer from measles related "immune amnesia" provides additional support for access to the measles vaccine as the driver for improved childhood health.

Finally, we use the *Anuario Estadístico de los Estados Unidos Mexicanos* to test for changes in adult mortality from causes other than infectious diseases in the years leading up to and after mass vaccination. If the National Immunization Program only targets children for vaccinations then we do not expect to see impacts on adult health outcomes at the same time. We do this for this mortality from childbirth and mortality from accidents, poisoning and homicides. These two types of cause-specific mortality are unrelated to infectious disease in adults, but could be affected by improvements in public health infrastructure.[28] As shown in Figure 7 there is no significant change in trend in mortality from either cause following the launch of the NIP.

In sum, the eight event studies on diseases and adult mortality that should not be affected by the measles vaccine indicate the health affects for children from the National Immunization Program are coming through the measles vaccination channel and not through other public investments in health.

4.2 Long Term Outcomes

Following Atwood 2022 , our main model compares both across states and across cohorts - taking advantage of variation in pre-vaccine incidence rates and differential exposure to the vaccine because of one's age - using a difference-in-differences specification [29]:

[28] They also have consistent codes over time. The coding system for mortality causes changed in 1970.

[29] A standard difference-in-differences model assumes that the measles vaccine is limited to the year of birth. This is not the case because individuals can contract measles throughout childhood. The majority of cases are contracted between the ages of 5 and 9. Therefore our preferred specification allows for differential exposure to the measles vaccine.

$$Y_{icst} = \beta_0 + \beta_1 (M^{pre}_{1965-1972} * Exposure)_{cs} + \delta_c + \delta_s + \delta_t + \gamma * X_{icst} + \epsilon_{icst} \quad (2)$$

where we are looking at outcomes for individual i in birth cohort c at time t in Mexican state s. $M^{pre}_{1965-1972}$ is measured as an unweighted eight-year average of a state's measles incidence rate per 100,000 population. [30] Chuard et al. 2022, provides strong support for the use of reduced-form approaches that focus on the severity of the disease environment when measuring the long-term benefits of disease reductions. The average measles incidence before the vaccine and the incidence change due to the vaccine are equivalent as illustrated in Figure 2, therefore using either will yield the same results. We match adult individuals to the pre-vaccine measles incidence rate of their state of birth. [31].

M^{pre} is interacted with *Exposure* to allow for cross-cohort comparisons. Exposure to the vaccine is 16 for those born in 1973 or later, and decreases linearly for those born in the 16 years prior, and is zero for the older cohorts.[32] β_1 provides the reduced form estimate of the differences in gains based on pre-vaccine measles rates for outcome $_{icst}$ for person i, born in state s, in cohort c, at year t. If measles adversely affects labor market and schooling outcomes, then cohorts with more exposure to the vaccine should experience better outcomes than those with less exposure to the vaccine in the same state.

The model also includes cohort fixed effects (δ_c), which control for characteristics consistent across the birth year cohort, and state-of-birth fixed effects (δ_s), which control for time invariant state characteristics. For the ENE, ENEU, and ENOE we also include survey year fixed effects (δ_t) to control for national level characteristics of a given year. $\gamma * X_{icst}$ are individual level controls, including marital and urban status. Standard errors are clustered

[30] Appendix Tables A9 and A8 present the estimates for Equation 2 using different numbers of years in M^{pre} for employment and log income.

[31] Matching this way can be important when examining later life outcomes, since migration within country is more likely over the long term. In the Appendix we will present regressions using state of residence as an adult.

[32] We use a maximum of 16 years of exposure as measles incidence is negligible after the age of 16.

at the state-of-birth-cohort level. Our analysis focuses on males between the ages of 18 and 65, as they significantly are more likely to be in the labor force and to migrate abroad than females.

5 Results

5.1 Labor Market Outcomes

We start by examining the impact of the measles vaccine on the incidence of employment and log real wage income. Table 4, presents the estimates of Equation 2 for labor market outcomes for men age 18 to 65. The data set used in the regressions appear in the top row of the table. The table also includes the years of the data available for analysis from each source, the age of the first fully exposed cohort in those years (those born in 1973), the number of observations, and the outcome mean. Table 4 shows evidence of the positive effect of the measles vaccination through the National Immunization Program on adult male employment and earnings. Calculating the impact of the coefficient for someone with full exposure (16 years) to the vaccination program and being born in a state with the average 8-year pre-vaccine measles incidence rate (1.33 per 1000) is useful for interpreting the effect of the measles vaccine and we do so below when discussing the results.

Exposure to the measles vaccine shows a positive impact on the likelihood of employment as presented in Panel A. Estimates from the 1995 Conteo (2.2 percentage points), 2000 Census (1.0 percentage points) ENE (0.3 percentage points), ENEU (2 percentage points), and ENOE (0.2 percentage points) demonstrate a statistically significant increase of between 1.1 and 3.5-percent in employment attributable to the measles vaccine. These increases are statistically significant in three out of the five datasets. Panel B shows the measles vaccine had a positive and significant impact on income, with wages increasing 2.2 and 12.6 percent (the 1995 Conteo (13.2-percent), 2000 Census (6.9 percent), ENE (7.3-percent), and ENEU (6.7-percent). For the ENOE wages rise 7.8 percent, but this increase is insignificant.

Our employment and earnings estimates are of the same sign and significance as those estimated for the United States. However, the impact of measles vaccination in Mexico is of greater magnitude. Atwood (2022) finds an employment increase of 0.3 percent (0.3 percentage point increase with mean employment at 0.96) and an increase in the natural log of income of 1.7-percent and Chuard et al. (2022) finds a 2.7 percent increase in the log of total family income. Our results of a 3-percent increase in the likelihood of employment and a 2.5- to 12-percent increase in income are significantly larger. This is not unexpected. Mexico has a higher infectious disease burden than the United States, so when children receive the measles vaccine and are protected from the "immune amnesia" effects of measles the measles vaccine provides a greater protective effect in a more infectious location (Mexico) than a less infectious location (United States).[33] Additionally, recent work on the long-run impacts of measles vaccination in India find a 13.8 percent increase in weekly wages (Summan et al. 2022) which is in line with our income estimates.

5.2 Education

A key channel through which labor market improvements may have occurred is through education, and we turn to this in Table 4. Panel A presents results for changes in the number of years of education, which show a positive increase attributable to access to the measles vaccine. The average impact of the the estimates is consistent across all data sets, with the increase in years of schooling ranging from 0.57 years for the 2000 Census, 0.65 years for the ENE, 0.67 for the ENEU, 0.70 for the ENOE and and 0.8 years in the 1995 Conteo. These represent increases between 6.7 to 9.7 percent from the mean years of schooling in each data set.

The increase in years of education are non-trivial, and might be sufficient to push individuals into higher levels of educational attainment. These results of these estimations are shown in Table 5, and include primary education or less (Panel B), lower secondary

[33] In Bleakley's 2010 paper examining the impact of malaria eradication campaigns in the United States, Mexico, Brazil, and Columbia, larger effects on income are found in Mexico, Brazil, and Columbia compared to the U.S. These are attributed to the greater benefit provided by eradication in locations with higher infectious disease burdens.

education (Panel C), and upper secondary education or more (Panel D). Given that mean years of education range between eight and eleven, we expect to see the largest gains in the attainment of lower (9 years) and upper secondary (12 years) school.

The results confirm this expectation, showing the measles vaccine leads to a shift out of primary education or less and a shift into lower and upper secondary education. Specifically, those born in states with higher pre-vaccine incidence rates and with exposure to the measles vaccine are 5-7 percentage points less likely to have attained a primary education or less, 1.4 to 3.1 percentage points more likely to have attained a lower secondary education and 2.4-5 percentage points more likely to have attained an upper secondary education. For primary education this represents a 21 to 32 percent decline relative to the mean, while for lower and upper secondary this represents increases between 8 and 15 percent of the mean.[34] Thus we find fairly large changes in education attainment among the most exposed cohorts. These results support the hypothesis that children that are healthier may learn more effectively and not need to increase the number of years of schooling to see positive labor market returns.

Other work has shown positive effects on education due to measles vaccination. In a study using similar difference-in-differences methodology to ours, Chuard et al. (2022) find a 0.85 percentage point increase in the likelihood of graduating high school in the US. Two other studies that do not utilize disease severity also find positive education effects. An increase in boys school enrollment in found in Bangladesh utilizing the staggered roll-out of a measles vaccination campaign for identification (Driessen et al. 2015) and a mother fixed effects method paper found measles vaccination increased school grade attainment in rural South Africa (Anekwe et al. 2015).

The educational impacts for men we find are striking because the literature has found minimal educational effects on men of the eradication of other diseases. Bleakely (2007) finds the hookworm eradication campaigns in the American South showed a positive impact

[34] In Appendix Table A2 we estimate less than primary and primary as separate categories of educational attainment. We find significant declines in less than primary (less than six years of schooling) and smaller and insignificant changes in primary education. Thus we we do not find strong evidence that the increased years of schooling is coming from the completion of primary school.

on earnings but no statistically significant impact on educational attainment. There is substantial evidence that malaria eradication campaigns have impacts on income and household consumption but no evidence of impact on educational attainment for men across multiple settings, including the U.S., Mexico, Brazil, Columbia, and India (Bleakley 2010; Cutler et al. 2010; Venkataramani 2012). [35] [36] Our findings of increased educational attainment are plausible because measles is distinct from malaria and hookworm in that it is a universal childhood disease and your location does not determine whether or not you are exposed to (and will contract) measles during childhood. This makes it more likely that we would be able to detect positive educational attainment effects. Additionally, in the U.S. context where infectious disease morbidity is lower than Mexico and educational attainment is higher it is less likely that sickness in childhood due to "immune amnesia" would lead individuals to drop out of school. However, the same is not the case for a middle income country like Mexico, where the larger improvements in childhood health due to mass measles vaccination appear to have pushed boys to stay in school longer.

Finally, the increase in educational attainment may explain why we find an increase in employment and wages following what can only be an increase in labor supply. In the absence of an increase in labor demand, wages should fall in response. The fact that they do not means labor demand must have increased, and rising educational attainment, particularly at the upper end of the education distribution, may explain why.

5.3 Migration Abroad

Table 6 presents evidence of a nuanced story for how the measles vaccine impacted outmigration. As shown in Panel A the coefficients have mixed signs and are insignificant all five datasets. This is surprising, as the datasets we use cover a time period when migration rates are high. Furthermore, previous work by Hanson and McIntosh (2010) find that migration increased

[35] Lucas 2010 finds positive educational attainment for malaria eradication in Paraguay and Sri Lanka, but only for women.

[36] Venkataramani 2012 finds positive impacts of malaria eradication on cognitive test scores and on-time educational attainment but no effect on the years of schooling attained.

among the age cohorts we study as a result of rising cohort size and labor supply. Thus one might expect improved health from the vaccine to lead to increased out migration.

On the other hand, we find that labor market outcomes improve for the most affected cohorts, and this likely dampened the incentives to migrate. This argument is in line with several papers which find migration to the U.S. declines when wages in Mexico rise (Lessem 2018) and rises when labor market conditions in Mexico worsen (Orrenius and Zavodny 2005, Monras 2020). Overall, however, the picture from our main results is unclear, and may hide a more nuanced story about the impact of the measles vaccine on outmigration.

Specifically, the improvements in labor market outcomes in Mexico would reduce outmigration only if they decreased the expected return of migrating to the U.S. relative to staying in Mexico. These expectations comprise two pieces: expected outcomes in Mexico, which are easier to view, and expected outcomes in the U.S, which are harder to view and depend on migration networks. Thus the calculation of changes to the relative returns to migration should vary depending on the strength of one's migration network. We, of course, do not know this for individuals in any of the datasets we use. Instead we proxy for the extent of migration networks using an index of migration intensity in an individual's municipality. Mexico's National Population Council (Consejo Nacional de Población, or CONAPO) This constructed this index using the percentage of households with an out, circular and return migrant and the percentage of households that receive remittances in the year 2000 Census. We take the top 20% of municipalities, classified as high or very high migration areas. As shown in Appendix Table A3 the migration measures are two the twenty times higher in municipalities categorized as high migration areas than in those categorized as having low levels of migration. For example, the average number of households that report receiving remittances in high migration municipalities is 18.6%, while the percentage who report an outmigrant is 16.8%. This compares to values of 3.5 and 3.7%, respectively, for low migration areas.[37]

[37]We also defined migration networks using measures of historical access to train travel to the U.S. Specifically, following (Chiquiar et al., 2012) we use the sum of distance to the closest train station and

We then estimate a triple difference model, interacting the pre-vaccine measles rate and years of exposure with a binary variable for living in a high migration municipality. One complication of using municipalities is that we only have this information for the current residence, not the residence of birth. We therefore must use state and municipality of residence, instead of birth, in the model. This leads to concerns over sample selection bias, if the propensity to move abroad and internally are correlated. To gauge the extent of this we restrict Equation 2 to men that reside as adults in their state of birth (70- to 80-percent of the analysis sample). Panel B of Table 6 shows that the estimates for migration abroad after restricting the sample are consistent with the main results. The results of the triple interaction are shown in Panel C of Table 6. Here we find that migration increased significantly, but only in high migration municipalities. This confirms that among the cohorts most affected by the vaccine, only individuals with better information about labor market conditions in the U.S. become more likely to migrate abroad.

6 Robustness Checks

To further support our findings we conduct convergence and specification checks.

6.1 Convergence Checks

Convergence is a concern if states experienced different trends in labor market outcomes prior to the National Immunization Program. In this case the gains in education, employment, income, and migration abroad could have occurred in the the absence of the vaccine. We test this by examining whether the estimates remain consistent after allowing for cohort effects to vary regionally. Our main specification, Equation 2, assumes common trends across states in the factors affecting different birth cohorts. If states experienced differential changes during

distance from that station to the U.S. border in 1920, or direct distance to the U.S. border, whichever is smaller. Measures based on the railroad system in 1920 have been used by numerous authors (Woodruff, Hanson and McIntosh (2010), Chiquiar et al. (2012)) and rests on the argument that migration to the U.S. was facilitated and later intensified by railroad access, and that these early networks became established and persisted over time. The results are presented in Appendix Table A10 this period, such as health care quality improvements or the expansion of access to health care, this assumption may fail to hold. To test for differential trends, we allow year of birth effects to vary across regions (Stephens and Yang 2014). If the estimates remain consistent with the inclusion of Census Region by year-of-birth fixed effects included in Equation 2, this provides support that our results are not being driven by differences between Census Regions as opposed to variation within Census Regions over time.

Panel A in Table 7 shows that including region by birth year fixed effects in the model does not change our estimates for employment, suggesting that the results form the baseline model are not driven by variation between regions rather than by changes within states over time.[38] The magnitude of the coefficients is slightly larger with the inclusion of the region by birth year fixed effects, but remain within one standard deviation of our main results, indicating that we are not overestimating the impact of measles vaccination with our main model. Additionally, the consistency of our estimates occurs across all data sets we use in our analysis. These findings support our main model assumption that between-region differences are not an important source of variation need to identify the model and support of the common trends assumption being valid for our preferred main model - Equation 2.

6.2 Specification Checks

In our main specification we model the potential impact of the vaccine as linear in years of access prior to age 16. For example, a person born in 1971 was two years old when the vaccine was introduced in 1973, giving them 14 potential years of access. Meanwhile, someone born in 1961 was 12 when the vaccine was introduced, giving them only 4 potential years of access. In this section we consider other ways to model potential vaccine exposure. We start by limiting the potential exposure to years of access to the vaccine prior to the age of six instead of sixteen. We stop at six because the vaccines were targeted at ages zero

[38]Appendix Table 7 present estimates for including the region-by-year-of-birth fixed effects in the models with income, education and migration as the outcome variables of interest. The estimates remain consistent with our main results for all outcomes of interest and across all data sets used for analysis.

to five , and in Mexico, over 60% of cases were among children ages 0-5 (de Castro 1983). We extend the period by one year to include when most children start primary school. The results are presented in Appendix Table A4, and show the effects of the measles vaccine are larger for the group most targeted by the program. The coefficients are approximately two times larger than with our original specification, with the largest differences seen in years of education, lower and upper secondary attainment.

Next we limit the analysis sample of cohorts included. We begin by limiting the analysis sample to only those with no exposure (exposure=0) or a full life time of exposure (exposure=16) to the measles vaccine. This version of the model therefore models potential benefits of the vaccine as nonlinear. The results for are shown in Appendix Table A5. We find the coefficients of interest exhibit the same patterns across all of our outcomes when compared to our main results.

We continue by limiting the range of cohorts to those born between 1948 to 1978. This truncates the sample such that there are fewer observations with the extreme values of zero or sixteen years of exposure. The results, presented in Appendix table A6, again show coefficients consistent with our main results. These findings, along with the previous two, show our findings do not depend on modeling exposure to the vaccine in one, particular way.

We next limit the sample to men in urban areas, since the vaccine rollout began by targeting urban areas, making the initial waves of the program more intense than in rural areas (de Castro 1983). We therefore anticipate larger estimated effects of the vaccine among the urban sample. This expectation is confirmed in Appendix Table A7, which shows slightly larger coefficients for most outcomes in the urban sub-sample than the complete one.

Finally we comment on concerns related to Progresa and Seguro Popular, two large scale and well known government programs that provided conditional cash transfers and health insurance, respectively, to poor households. A large literature shows these programs had positive impacts on education and health outcomes, but they were implemented in 1997 (Progresa) and 2003 (Seguro Popular), which are 24 to 30 years after the NIP. Since the datasets we use cover adults age 18 to 65 in the years 1994 to 2008, the labor force, education and migration decisions of very few people in our sample should be affected by these programs.

7 Conclusion

We find that mass measles vaccination in Mexico leads to improved long-run adult labor market outcomes. The National Immunization Program in 1973 is a plausibly exogenous introduction of mass measles vaccination in Mexico. Being a universal childhood disease, individuals are only able to avoid contracting the measles through herd immunity, which is achieved through mass vaccination. Not contracting measles improves childhood health because children no longer experience "immune amnesia" caused by measles. Cohorts of male children born after the launch of the National Immunization Program are more likely to be employed and earn a higher income as an adult. We find that these cohorts are also more likely to have attained a higher level of education at both the lower- and upper-secondary school level. We do not find that a healthier childhood due to measles vaccination impacts migration abroad, and that this result is robust to controlling for migration network.

The measles vaccine has been hailed as one of the most influential public health interventions of all time. After more than 50 years since the original measles vaccine licensing in 1963 (in the United States) it has shown time and time again that it is a successful and cost effective public health intervention. The vast majority of the impact of the measles vaccine research focuses on short term outcomes focusing on primary measles reduction. There is a growing body of work in economics, public health, and medicine examining the spillover effects of the measles vaccine and its long run outcomes. We add to this literature by documenting that the measles vaccine improved long-run labor market outcomes for Mexicans, and provide additional evidence that these long-run outcomes are greater for countries with higher infectious disease burdens.

Measles is highly contagious with a R_0 of 16-18.[39] To put this in context chicken pox has a R_0 of 10-12, and R_0s for COVID variants range from 2.5 in the original strain, to 7 in delta, and omicron having a R_0 of 10. Given measles high reproduction rate, high vaccination rates are needed to protect from community spread. To achieve herd immunity for measles 95-percent of the population needs to be vaccinated. During the global COVID pandemic the world has witnessed the largest increase in unvaccinated children in the past two decades, threatening the progress made towards measles eradication.[40] 19 countries measles vaccination campaigns are still on hold from the start of the pandemic as of April 2022, putting more than 73 million children at risk for measles. Measles cases have also significantly increased with 21 large disruptive measles outbreaks in the past year as well as a 79 percent increase in reported measles cases globally from January and February 2022 compared to January and February 2021 (UNICEF 2022). Considering the magnitude of the gains in adult earnings and that these impacts are greater for those in higher infectious disease environments, there is a case to be made to to support efforts that offset/catch up measles vaccination for children that missed out due to the COVID pandemic.

[39] R_0 (the reproduction number) is the number of cases, on average, an infected person will cause during their infectious period. The basic reproduction number represents the maximum epidemic potential of a pathogen. It describes what would happen if an infectious person were to enter a fully susceptible community.

[40] https://www.who.int/news/item/10-11-2021-global-progress-against-measles-threatened-amidst-covid-19-pandemic

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Tables

Table 1: Summary Statistics

	Dataset				
	(1) 1995 Count	(2) 2000 Census	(3) ENE	(4) ENEU	(5) ENOE
Age	34.81	35.05	35.59	34.55	36.32
	(12.69)	(12.58)	(12.74)	(12.30)	(12.84)
Years Vaccine Exposure	6.82	8.82	9.22	8.54	10.41
	(6.58)	(6.80)	(6.82)	(6.77)	(6.60)
Employed	0.86	0.84	0.86	0.85	0.86
	(0.35)	(0.36)	(0.35)	(0.36)	(0.35)
Income (2004 pesos)	3.64	4.67	5.76	23.93	6.07
	(7.51)	(25.15)	(7.81)	(87.73)	(7.92)
Migrates abroad	0.04	0.04	0.02	0.01	0.01
	(0.20)	(0.20)	(0.14)	(0.09)	(0.12)
Years of education	8.21	8.25	8.97	10.09	8.97
	(4.44)	(4.76)	(4.10)	(4.10)	(4.62)
Educational Attainment					
Primary or below	0.54	0.48	0.44	0.33	0.40
	(0.50)	(0.50)	(0.50)	(0.47)	(0.49)
Lower secondary	0.22	0.22	0.25	0.26	0.31
	(0.41)	(0.41)	(0.43)	(0.44)	(0.46)
Upper secondary or more	0.25	0.30	0.30	0.41	0.29
	(0.43)	(0.46)	(0.46)	(0.49)	(0.46)
Observations	87,755	2,664,170	819,822	1,230,411	530,219
Years	1995	2000	2000-2004	1994-2004	2005-2009

Note: Sample limited to men age 18 to 65. Population weights are used.
Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Table 2: Pre 1973 Measles Rates and State Geographic Measures

	In Capital City, 1970		
	(1)	(2)	(3)
	Average Temperature	Days of Rain	Total Precipitation (milimeters)
PANEL A: 1965-1972			
Average 8 yr Measles Rate	0.0140	0.0052	0.0065
	(0.0117)	(0.1031)	(1.3437)
Observations	32	32	32
Mean Outcome	20.49	72.50	762.30

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1972 Statistical Annual and Salud Pública de México

Note: The outcomes are average values by state for those 18 and older in the 1970 Mexican Census. The measles rates vary by the number of years prior to 1973 included in the averages, where the longest time range is 8 years. As shown in Panel A, this averages the measles rates from 1965 to 1972. The other panels include shorter time horizons before 1973, and the number of years and the specific ones includes in the averages are listed.

Table 3: Pre 1973 Measles Rates and 1970 State Averages

	1970 Census Values						
	(1) Average Monthly Income (Pesos)	(2) Employment Rates	(3) Literacy Rates	(4) Population Density	(5) Children 0-5 to Pop.	(6) Urbanization Rate	(7) Percent Workers Manufacturing
PANEL A: 1965-1972							
Average 8 yr Measles Rate	-3.6207	-0.0000	0.0001	-2.2714	-0.0000	-0.0001	-0.0002
	(7.5800)	(0.0001)	(0.0003)	(2.0315)	(0.0000)	(0.0005)	(0.0002)
PANEL B: 1966-1972							
Average 7 year Measles Rate	-4.8636	-0.0000	0.0002	-2.3972	-0.0000	-0.0001	-0.0002
	(7.1889)	(0.0001)	(0.0003)	(1.9248)	(0.0000)	(0.0004)	(0.0002)
PANEL C: 1967-1972							
Average 6 year Measles Rate	-8.4973	-0.0000	0.0002	-2.7624	0.0000	-0.0002	-0.0002
	(7.6740)	(0.0001)	(0.0003)	(2.0731)	(0.0000)	(0.0005)	(0.0002)
Observations	32	32	32	32	32	32	32
Mean Outcome	5,107.10	0.49	0.72	180.17	0.21	0.54	0.12

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1970 Census and Salud Pública de México

Note: The outcomes are average values by state for those 18 and older in the 1970 Mexican Census. The measles rates vary by the number of years prior to 1973 included in the averages, where the longest time range is 8 years. As shown in Panel A, this averages the measles rates from 1965 to 1972. The other panels include shorter time horizons before 1973, and the number of years and the specific ones includes in the averages are listed.

Table 4: Employment and Wages

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employed					
Measles Rate*Exposure	0.00106*	0.00068**	0.00013	0.00095***	0.00011
	(0.00063)	(0.00030)	(0.00027)	(0.00026)	(0.00028)
Observations	82,808	2,517,138	815,757	1,113,677	527,582
Mean Outcome	0.8612	0.8421	0.8581	0.8511	0.8586
PANEL B: Log Income					
Measles Rate*Exposure	0.00620***	0.00393***	0.00289***	0.00098*	0.00214***
	(0.00219)	(0.00060)	(0.00067)	(0.00053)	(0.00056)
Observations	59,983	1,704,142	708,963	991,205	448,506
Mean Value Outcome	0.70	1.10	1.40	2.34	1.48
Years in Sample	1995	2000	2000-2004	1994-2004	2005-2008
Age 1973 Cohort	22	27	27-31	21-31	32-35

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. The coefficients on years of exposure to the measles vaccine times pre-vaccine, state level rates are shown. Population weights are used and standard errors are clustered at the level of year and state of birth. Controls include marital status, urban residency status, birth-year cohort fixed effects, and state-of-birth fixed effects. For the ENE, ENEU, and ENOE survey year fixed effects also are included. In Panel A the outcome is employment and in Panel B the outcome is income.

Table 5: Education: Years and Level Attained

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Years					
Measles Rate*Exposure	0.03758***	0.02665***	0.03062***	0.03140***	0.03284***
	(0.00688)	(0.00382)	(0.00391)	(0.00291)	(0.00446)
Mean Outcome	8.2111	8.2493	8.9663	10.0918	8.9744
PANEL B:<= Primary					
Measles Rate*Exposure	-0.00296***	-0.00234***	-0.00305***	-0.00299***	-0.00336***
	(0.00061)	(0.00025)	(0.00035)	(0.00028)	(0.00036)
Mean Outcome	0.5371	0.4820	0.4422	0.3311	0.4000
PANEL C: Lower Sec.					
Measles Rate*Exposure	0.00149***	0.00120***	0.00101***	0.00069***	0.00132***
	(0.00050)	(0.00015)	(0.00023)	(0.00020)	(0.00023)
Mean Outcome	0.2172	0.2158	0.2488	0.2630	0.3068
PANEL D: >= Upper Sec.					
Measles Rate*Exposure	0.00147***	0.00113***	0.00194***	0.00230***	0.00206***
	(0.00054)	(0.00018)	(0.00027)	(0.00025)	(0.00031)
Observations	82,358	2,456,028	815,608	1,112,769	527,175
Mean Value Outcome	0.2457	0.3022	0.2994	0.4059	0.2928
Years in Sample	1995	2000	2000-2004	1994-2004	2005-2008
Age 1973 Cohort	22	27	27-31	21-31	32-35

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. The coefficients on years of exposure to the measles vaccine times pre-vaccine, state level rates are shown. Population weights are used and standard errors are clustered at the level of year and state of birth. Controls include marital status, urban residency status, birth-year cohort fixed effects, and state-of-birth fixed effects. For the ENE, ENEU, and ENOE survey year fixed effects also are included. In Panel A the outcome is total years of schooling, while in Panels B, C, and D the outcome is educational attainment at the level listed.

Table 6: Migration Abroad

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Birth State					
Measles Rate*Exposure	0.00021	-0.00003	0.00005	-0.00002	-0.00004
	(0.00026)	(0.00015)	(0.00006)	(0.00003)	(0.00005)
Observations	87,399	2,652,986	815,888	1,113,734	527,640
Mean Value Outcome	0.0434	0.0413	0.0189	0.0088	0.0139
Years in Sample	1990-1995	1995-2000	2000-2004	1994-2004	2005-2008
PANEL B: Residence State					
Measles Rate*Exposure	0.00014	-0.00017	0.00002	-0.00003	-0.00000
	(0.00027)	(0.00015)	(0.00006)	(0.00003)	(0.00006)
Observations	69,094	2,174,664	609,463	794,471	404,854
Mean Value Outcome	0.0562	0.0523	0.0214	0.0096	0.0159
PANEL C: Municipality					
Measles Rate*Exposure	-0.00017	-0.00040***	-0.00004	-0.00003	-0.00003
	(0.00023)	(0.00010)	(0.00006)	(0.00003)	(0.00005)
Measles Rate*Exposure High Migration	0.00971***	0.00909***	0.00320***	-0.00003	0.00184***
	(0.00070)	(0.00027)	(0.00033)	(0.00174)	(0.00022)
Observations	69,094	2,174,664	609,455	794,438	404,835
Mean High Mig. Mun.	0.0380	0.0380	0.0152	0.0096	0.0127
Mean Low Mig. Mun.	0.1906	0.1762	0.0819	0.0759	0.0526

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. The coefficients on years of exposure to the measles vaccine times pre-vaccine, state level rates are shown. Population weights are used and standard errors are clustered at the level of year and state of birth. Controls include marital status, urban residency status, birth-year cohort fixed effects, and state-of-birth fixed effects. For the ENE, ENEU, and ENOE survey year fixed effects also are included. In all Panels the outcome is migration abroad. Panel A links individuals to their state of birth, while Panels B and C link them to their state of residence. Panel C also includes a control for being in a high migration municipality.

Table 7: Robustness: Region-Birth Year Fixed Effects

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employment					
Measles Rate*Exposure	0.00167***	0.00135***	0.00081***	0.00136***	0.00037
	(0.00054)	(0.00026)	(0.00023)	(0.00019)	(0.00025)
PANEL B: Log Income					
Measles Rate*Exposure	0.00652***	0.00460***	0.00260***	0.00144***	0.00225***
	(0.00207)	(0.00051)	(0.00059)	(0.00046)	(0.00055)
PANEL C: Years Educ.					
Measles Rate*Exposure	0.04249***	0.03075***	0.03422***	0.03073***	0.03565***
	(0.00641)	(0.00353)	(0.00337)	(0.00236)	(0.00424)
PANEL C: <= Primary					
Measles Rate*Exposure	0.00038	0.00048*	-0.00019	-0.00001	-0.00057*
	(0.00058)	(0.00026)	(0.00027)	(0.00019)	(0.00030)
PANEL E: Lower Sec.					
Measles Rate*Exposure	0.00201***	0.00185***	0.00180***	0.00137***	0.00186***
	(0.00049)	(0.00014)	(0.00021)	(0.00017)	(0.00023)
PANEL F: >= Upper Sec.					
Measles Rate*Exposure	0.00169***	0.00116***	0.00174***	0.00184***	0.00207***
	(0.00054)	(0.00017)	(0.00026)	(0.00022)	(0.00030)
PANEL G: Migration					
Measles Rate*Exposure	0.00045*	0.00014	-0.00001	-0.00005*	-0.00007
	(0.00025)	(0.00016)	(0.00006)	(0.00003)	(0.00005)

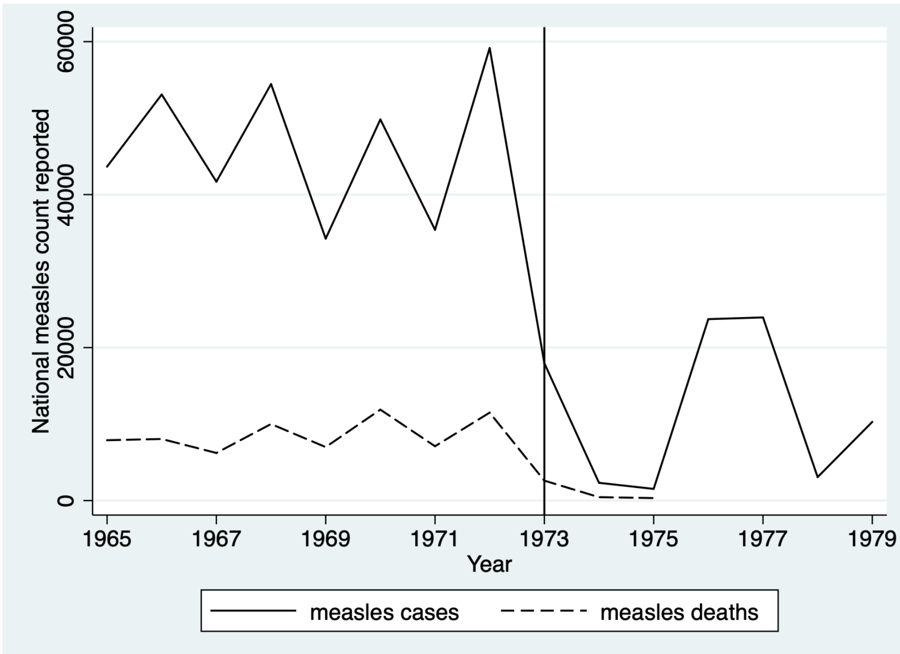
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. The coefficients on years of exposure to the measles vaccine times pre-vaccine, state level measures rates are shown. Population weights are used and standard errors are clustered at the level of year and state of birth. Controls include marital status, urban residency status, birth-year cohort fixed effects, and state-of-birth fixed effects and add region by birth-year fixed effects. For the ENE, ENEU, and ENOE survey year fixed effects also are included.

Figures

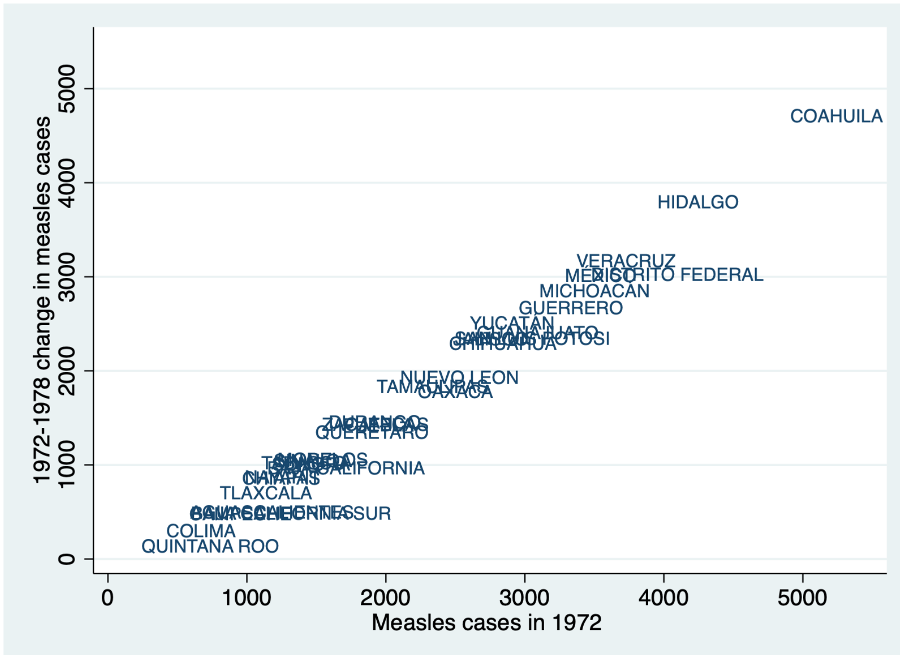
Figure 1: National Incidence of Measles Morbidity and Mortality



Notes: Data come from the annual epidemiology bulletins published in and Salud Pública de México. The solid line shows the national measles incidence rate by year and the dashed line shows the number of measles deaths in the nation by year. The vertical line denotes 1973, the year Mexico launched its National Immunization Program. There is a sharp reduction in both measles morbidity and mortality that corresponds to the National Immunization Program. Mortality data is only available from 1965 to 1975 in the reports. A worldwide measles epidemic occurs in 1976, which accounts for the increase in cases in 1976 and 1977.

Figure 2: National Incidence of Infectious Disease in Mexico

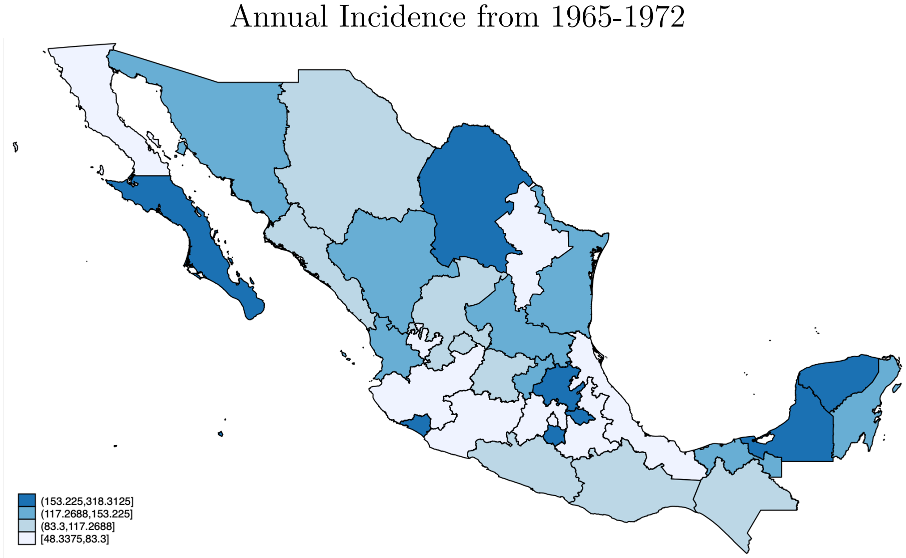
Annual Incidence from 1965-1979



Source: Salud Pública de México - publishing of annual epidemiology bulletins.

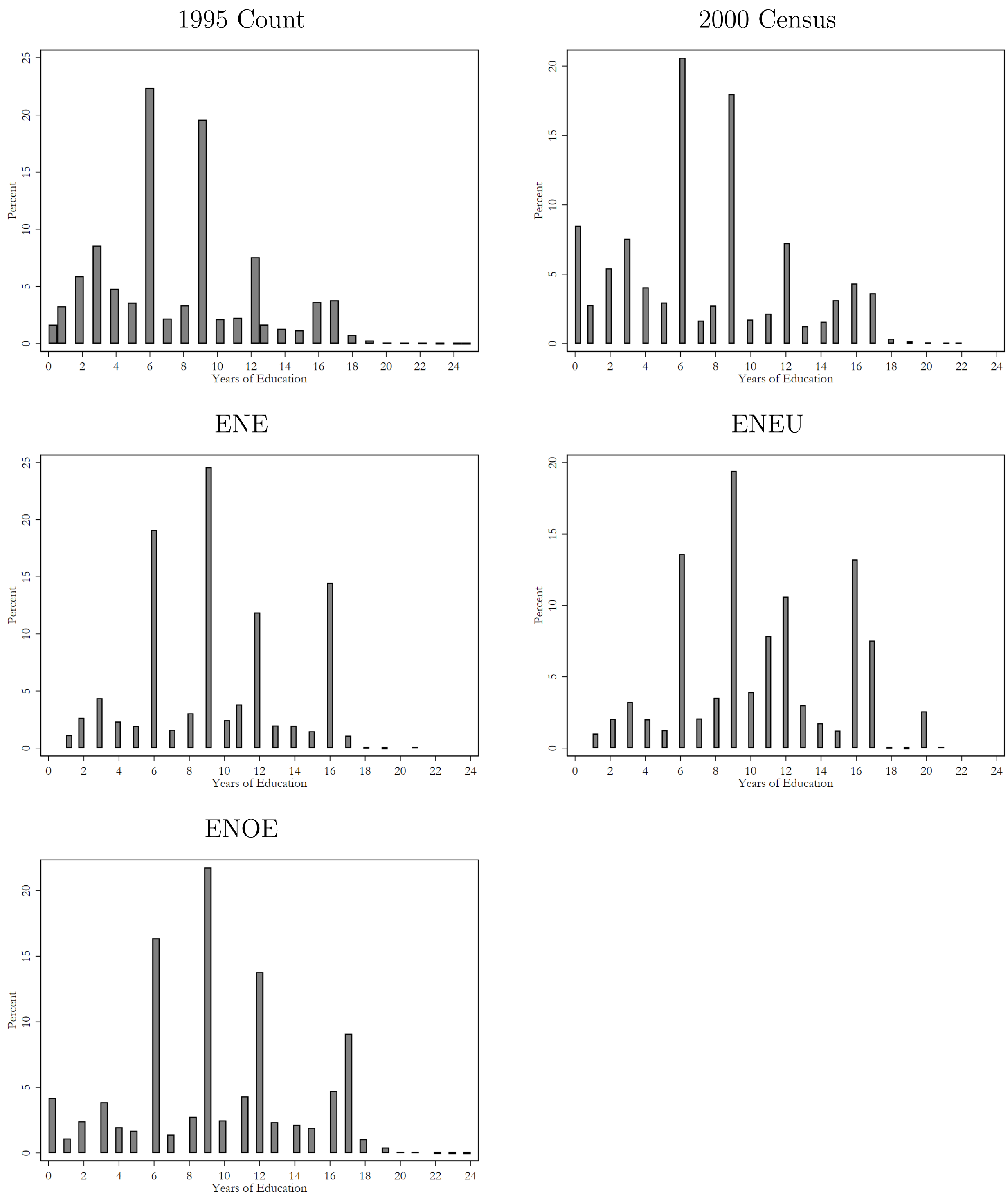
Figure 3: Map of Pre-Vaccine Incidence Rates in Mexico

Annual Incidence from 1965-1972



Source: Salud Pública de México - publishing of annual epidemiology bulletins.

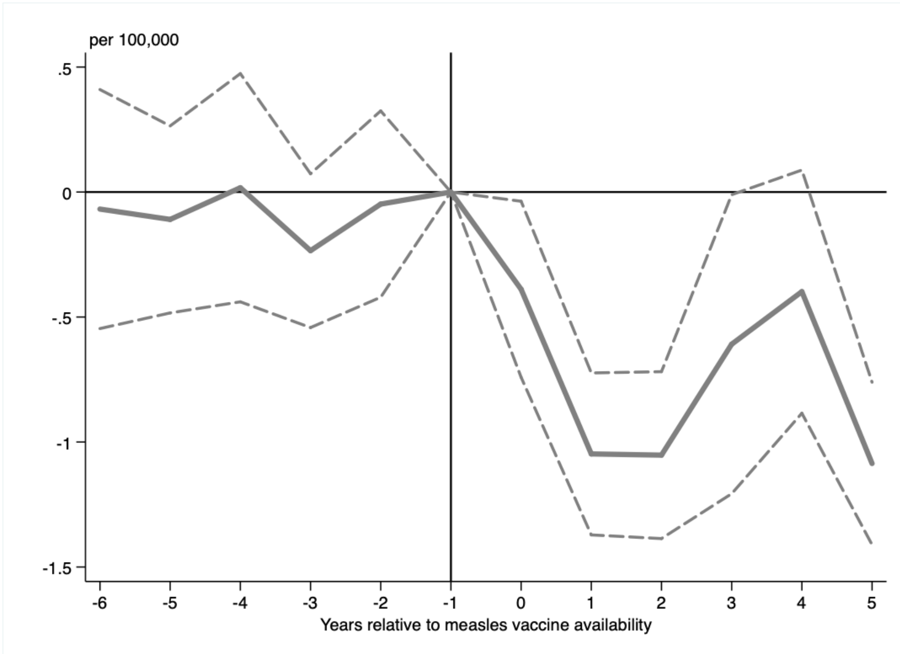
Figure 4: Years of Education Distribution by Dataset



Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE.

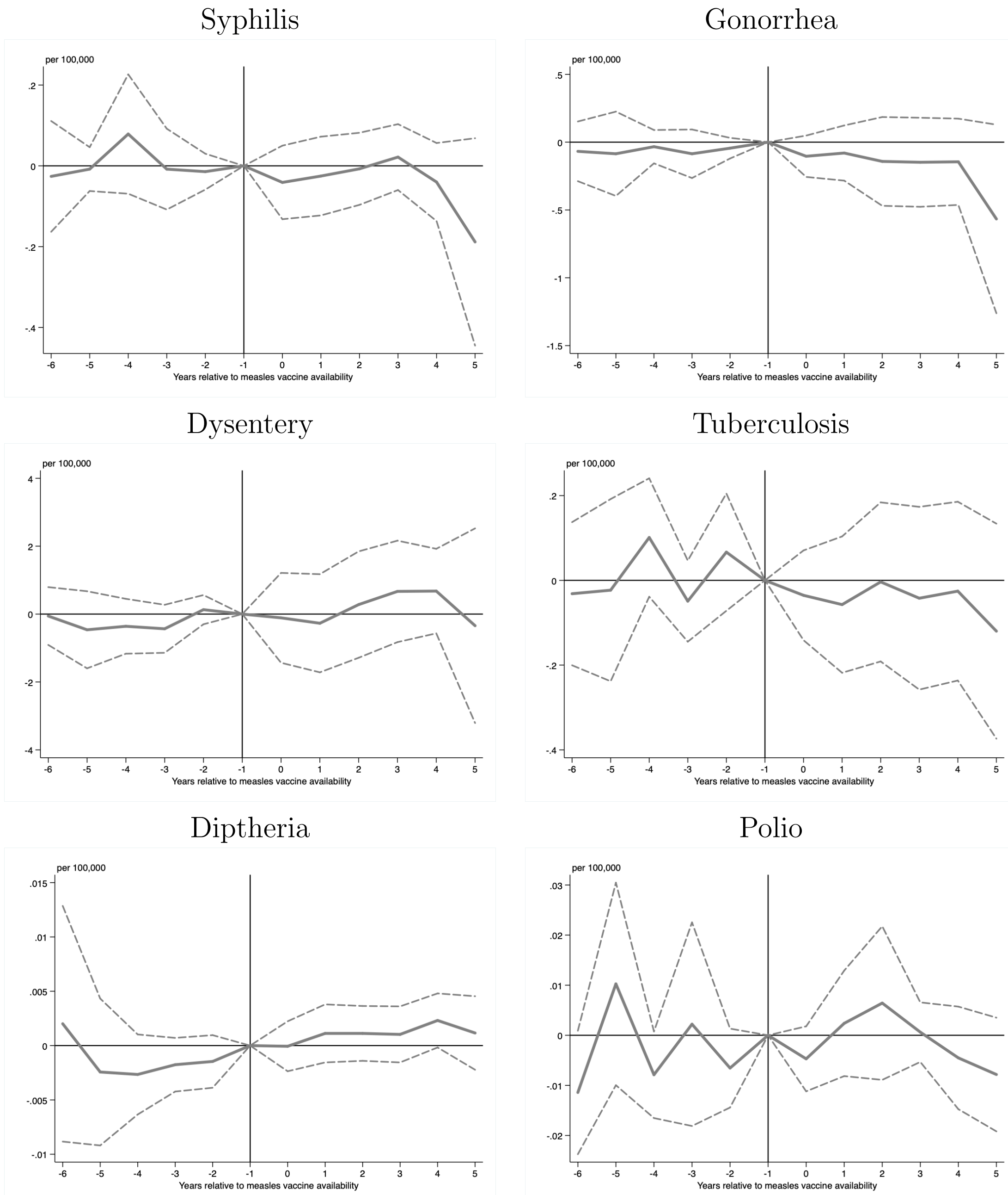
Figure 5: Event Study Figures of Measles in Mexico

Panel A: Measles 1967-1978



Notes: The figure shows regression adjusted estimates of the National Immunization Program's intention-to-treat effect on measles. The dependent variable is the incidence rate per 100,000 population for a state in a year. The solid line plots the estimated coefficients from Equation 1 on interactions between the time to vaccination program dummies and the average eight-year pre-program measles incidence rate. The year prior to the program is omitted. The model includes state fixed effects and controls for the state population. The dashed lines are point-wise 95-percent confidence intervals based on standard errors clustered at the state level. The data come from the annual epidemiology bulletins published in and Salud Pública de México.

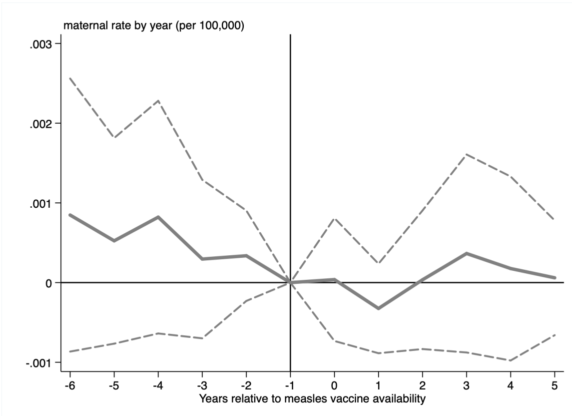
Figure 6: Event Study Figures of Infectious Disease in Mexico 1967-1978



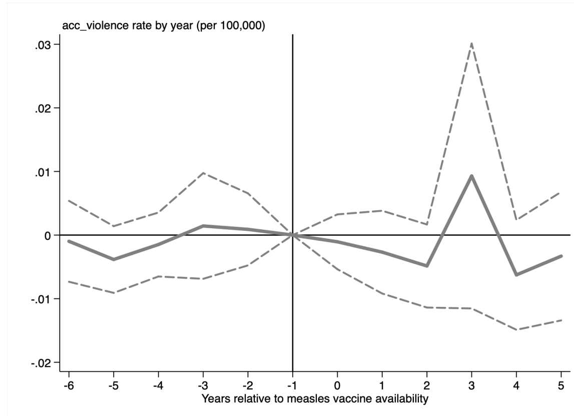
Note: The figure shows regression adjusted estimates of the National Immunization Program's intention-to-treat effect on disease incidence. The dependent variable is the incidence rate per 100,000 population for a state in a year. The solid line plots the estimated coefficients from Equation 1 on interactions between the time to vaccination program dummies and the average eight-year pre-program measles incidence rate. The year prior to the program is omitted. The model includes state fixed effects and controls for the state population. The dashed lines are point-wise 95-percent confidence intervals based on standard errors clustered at the state level.
Source: Salud Pública de México.

Figure 7: Event Study Figures of Other Cause Mortality 1967-1978

Maternal



Accidents/Homicides



Note: The figure shows regression adjusted estimates of the National Immunization Program's intention-to-treat effect on mortality from maternity or accidents/poisoning/homicides. The dependent variable is the incidence rate per 100,000 population for a state in a year. The solid line plots the estimated coefficients from Equation 1 on interactions between the time to vaccination program dummies and the average eight-year pre-program measles incidence rate. The year prior to the program is omitted. The model includes state fixed effects and controls for the state population. The dashed lines are point-wise 95-percent confidence intervals based on standard errors clustered at the state level.
Source: Salud Pública de México and Anuario Estadístico, multiple years

Appendix

Table A1: Pre Vaccine Measles Rates, State Ranking

State	Average 8 year Measles Rate	Average Income 1970 (pesos)	Population 1970 (Thousands)
Baja California	48	12,795.24	870.00
Distrito Federal	59	5,948.79	6,874.00
Puebla	61	3,212.24	2,508.00
Jalisco	63	4,534.40	3,297.00
Mexico	67	2,910.24	3,833.00
Veracruz	74	3,242.91	3,815.00
Nuevo Leon	74	3,291.66	1,695.00
Michoacan	79	4,339.18	2,324.00
Chiapas	88	8,225.11	1,569.00
Chihuahua	88	3,987.87	1,613.00
Aguascalientes	94	1,058.88	338.00
Oaxaca	96	4,196.05	2,015.00
Sinaloa	101	7,526.22	1,267.00
Zacatecas	102	8,659.25	952.00
Guerrero	109	4,400.21	1,597.00
Guanajuato	114	3,816.40	2,270.00
San Luis Potosi	120	3,976.50	1,282.00
Sonora	122	6,244.38	1,099.00
Tamaulipas	124	7,995.44	1,457.00
Nayarit	133	5,570.35	544.00
Tabasco	142	2,006.21	768.00
Durango	149	5,014.64	939.00
Queretaro	151	800.50	486.00
Quintana Roo	151	591.23	88.00
Colima	155	5,627.42	241.00
Morelos	160	11,916.34	616.00
Hidalgo	173	6,920.20	1,194.00
Tlaxcala	234	6,239.00	421.00
Campeche	245	9,522.01	252.00
Coahuila	250	2,979.84	1,115.00
Baja California Sur	317	2,113.47	128.00
Yucatan	318	3,765.09	768.00

Source: Salud Pública de México and 1970 Mexican Census.

Table A2: Robustness: Less than Primary and Primary Education

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: < Primary					
Measles Rate*Exposure	-0.00389***	-0.00297***	-0.00289***	-0.00293***	-0.00303***
	(0.00066)	(0.00039)	(0.00044)	(0.00030)	(0.00044)
Mean Outcome	0.2882	0.2435	0.2089	0.1146	0.1794
PANEL B: Primary					
Measles Rate*Exposure	0.00093	0.00064**	-0.00016	-0.00007	-0.00034
	(0.00060)	(0.00026)	(0.00030)	(0.00019)	(0.00031)
Mean Outcome	0.2489	0.2385	0.2333	0.2165	0.2206

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A3: Summary Statistics, Migration Intensity

Variable	(1) Low Migration	(2) High Migration	(3) Difference
% HHs receive remittances	3.470	18.637	15.167***
	(3.655)	(7.620)	(0.238)
% HHs with an out migrant	3.702	16.811	13.108***
	(3.873)	(5.996)	(0.221)
% HHs with a circular migrant	0.573	3.776	3.203***
	(0.823)	(3.460)	(0.087)
% HHs with a return migrant	0.509	3.764	3.255***
	(0.729)	(2.229)	(0.060)
Migration intensity index	-0.382	1.681	2.063***
	(0.436)	(0.813)	(0.027)
Observations	1,951	492	2,443

Note: Means by municipality, using the year 2000 Mexican Census. High migration municipalities are those categorized as having intensity of high or very high (top 20%). Low migration municipalities are all others. Source: CONAPO.

Table A4: Robustness: Years of Exposure Capped at 6

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employment					
Measles Rate*Exposure	0.00238	0.00202**	0.00087	0.00296***	0.00052
	(0.00198)	(0.00086)	(0.00071)	(0.00071)	(0.00070)
PANEL B: Log Income					
Measles Rate*Exposure	0.01072*	0.00864***	0.00561***	0.00166	0.00318**
	(0.00598)	(0.00155)	(0.00159)	(0.00128)	(0.00125)
PANEL C: Yrs. Educ.					
Measles Rate*Exposure	0.07785***	0.05798***	0.06363***	0.06378***	0.06840***
	(0.01815)	(0.00954)	(0.00903)	(0.00683)	(0.00971)
PANEL D: <= Primary					
Measles Rate*Exposure	0.00099	0.00111*	-0.00066	-0.00040	-0.00103
	(0.00155)	(0.00060)	(0.00065)	(0.00044)	(0.00063)
PANEL E: Lower Sec.					
Measles Rate*Exposure	0.00291**	0.00309***	0.00209***	0.00170***	0.00260***
	(0.00142)	(0.00036)	(0.00058)	(0.00051)	(0.00054)
PANEL F: >= Upper Sec.					
Measles Rate*Exposure	0.00363**	0.00221***	0.00399***	0.00457***	0.00454***
	(0.00150)	(0.00047)	(0.00067)	(0.00061)	(0.00073)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A5: Robustness: Full or Zero Exposure to Measles Vaccine

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employment					
Measles Rate*Exposure	0.00091	0.00066**	0.00008	0.00093***	0.00007
	(0.00081)	(0.00031)	(0.00028)	(0.00028)	(0.00030)
PANEL B: Log Income					
Measles Rate*Exposure	0.00647**	0.00460***	0.00304***	0.00120**	0.00262***
	(0.00275)	(0.00069)	(0.00078)	(0.00061)	(0.00067)
PANEL C: Yrs. Educ.					
Measles Rate*Exposure	0.03882***	0.02898***	0.03424***	0.03429***	0.03498***
	(0.00914)	(0.00437)	(0.00455)	(0.00337)	(0.00540)
PANEL D: <= Primary					
Measles Rate*Exposure	0.00100	0.00057*	-0.00012	-0.00000	-0.00029
	(0.00079)	(0.00030)	(0.00033)	(0.00022)	(0.00036)
PANEL E: Lower Sec.					
Measles Rate*Exposure	0.00099*	0.00116***	0.00108***	0.00055**	0.00135***
	(0.00058)	(0.00016)	(0.00025)	(0.00022)	(0.00025)
PANEL F: >= Upper Sec.					
Measles Rate*Exposure	0.00187***	0.00135***	0.00214***	0.00259***	0.00211***
	(0.00069)	(0.00019)	(0.00030)	(0.00028)	(0.00035)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65 born either before 1957 (0 years exposure) or after 1973 (16 years of exposure). Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A6: Robustness: 1948 to 1978 Birth Cohorts Only

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employment					
Measles Rate*Exposure	0.00095	0.00048**	0.00009	0.00112***	-0.00005
	(0.00069)	(0.00021)	(0.00022)	(0.00028)	(0.00017)
PANEL B: Log Income					
Measles Rate*Exposure	0.00488**	0.00332***	0.00248***	0.00047	0.00202***
	(0.00238)	(0.00063)	(0.00067)	(0.00061)	(0.00055)
PANEL C: Yrs. Educ.					
Measles Rate*Exposure	0.03568***	0.02454***	0.02294***	0.02651***	0.02818***
	(0.00786)	(0.00397)	(0.00406)	(0.00315)	(0.00441)
PANEL D: <= Primary					
Measles Rate*Exposure	0.00012	0.00081***	-0.00001	-0.00023	0.00015
	(0.00067)	(0.00030)	(0.00036)	(0.00022)	(0.00038)
PANEL E: Lower Sec.					
Measles Rate*Exposure	0.00147**	0.00103***	0.00104***	0.00062**	0.00141***
	(0.00059)	(0.00017)	(0.00031)	(0.00025)	(0.00031)
PANEL F: >= Upper Sec.					
Measles Rate*Exposure	0.00163**	0.00099***	0.00130***	0.00196***	0.00211***
	(0.00063)	(0.00019)	(0.00030)	(0.00029)	(0.00035)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65 born between 1948 and 1978. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A7: Robustness: Urban Only Sample

	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Employed					
Measles Rate*Exposure	0.00065	0.00097***	0.00069**	0.00091***	0.00036
	(0.00066)	(0.00028)	(0.00028)	(0.00029)	(0.00028)
PANEL B: Log Income					
Measles Rate*Exposure	0.00441**	0.00443***	0.00359***	0.00140**	0.00198***
	(0.00210)	(0.00053)	(0.00064)	(0.00058)	(0.00053)
PANEL C: Years Education					
Measles Rate*Exposure	0.03685***	0.02453***	0.03233***	0.03584***	0.02886***
	(0.00690)	(0.00346)	(0.00376)	(0.00298)	(0.00411)
PANEL D: <= Primary					
Measles Rate*Exposure	-0.00004	0.00012	-0.00044	-0.00082***	-0.00032
	(0.00069)	(0.00022)	(0.00029)	(0.00020)	(0.00031)
PANEL E: Lower Secondary					
Measles Rate*Exposure	0.00137**	0.00093***	0.00076***	0.00049**	0.00089***
	(0.00058)	(0.00017)	(0.00027)	(0.00023)	(0.00027)
PANEL F: >= Upper Secondary					
Measles Rate*Exposure	0.00195***	0.00129***	0.00217***	0.00302***	0.00198***
	(0.00068)	(0.00022)	(0.00035)	(0.00029)	(0.00037)

* p < 0.1, ** p < 0.05, *** p < 0.01. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65 in urban locations who reside in their state of birth. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A8: Robustness: Employment Alternate Pre-Period Years

	Pre Period Years			
	(1)	(2)	(3)	(4)
	4 Years	5 Years	6 Years	7 Years
PANEL A: Conteo 1995				
Measles Rate*Exposure	0.00122*	0.00144**	0.00138*	0.00110*
	(0.00066)	(0.00069)	(0.00072)	(0.00060)
PANEL B: Census 2000				
Measles Rate*Exposure	0.00091***	0.00103***	0.00101***	0.00082***
	(0.00032)	(0.00035)	(0.00036)	(0.00029)
PANEL C: ENE				
Measles Rate*Exposure	0.00054*	0.00062**	0.00053*	0.00039
	(0.00028)	(0.00030)	(0.00031)	(0.00026)
PANEL D: ENEU				
Measles Rate*Exposure	0.00135***	0.00143***	0.00137***	0.00111***
	(0.00026)	(0.00028)	(0.00029)	(0.00025)
PANEL E: ENOE				
Measles Rate*Exposure	0.00028	0.00035	0.00028	0.00023
	(0.00030)	(0.00032)	(0.00033)	(0.00027)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A9: Robustness: Log Income Alternate Pre-Period Years

	Pre Period Years			
	(1)	(2)	(3)	(4)
	4	5	6	7
PANEL A: Conteo 1995				
Measles Rate*Exposure	0.00527**	0.00568**	0.00651***	0.00506**
	(0.00219)	(0.00230)	(0.00237)	(0.00206)
PANEL B: Census 2000				
Measles Rate*Exposure	0.00379***	0.00412***	0.00452***	0.00359***
	(0.00065)	(0.00069)	(0.00071)	(0.00059)
PANEL C: ENE				
Measles Rate*Exposure	0.00287***	0.00304***	0.00349***	0.00248***
	(0.00071)	(0.00075)	(0.00077)	(0.00065)
PANEL D: ENEU				
Measles Rate*Exposure	0.00070	0.00100**	0.00098**	0.00060
	(0.00046)	(0.00048)	(0.00050)	(0.00043)
PANEL E: ENOE				
Measles Rate*Exposure	0.00180***	0.00184***	0.00218***	0.00156***
	(0.00059)	(0.00062)	(0.00063)	(0.00054)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

Note: Sample limited to men age 18 to 65. Population weights are used and standard errors are clustered at the level of year and state of birth.

Table A10: Robustness: Outmigration

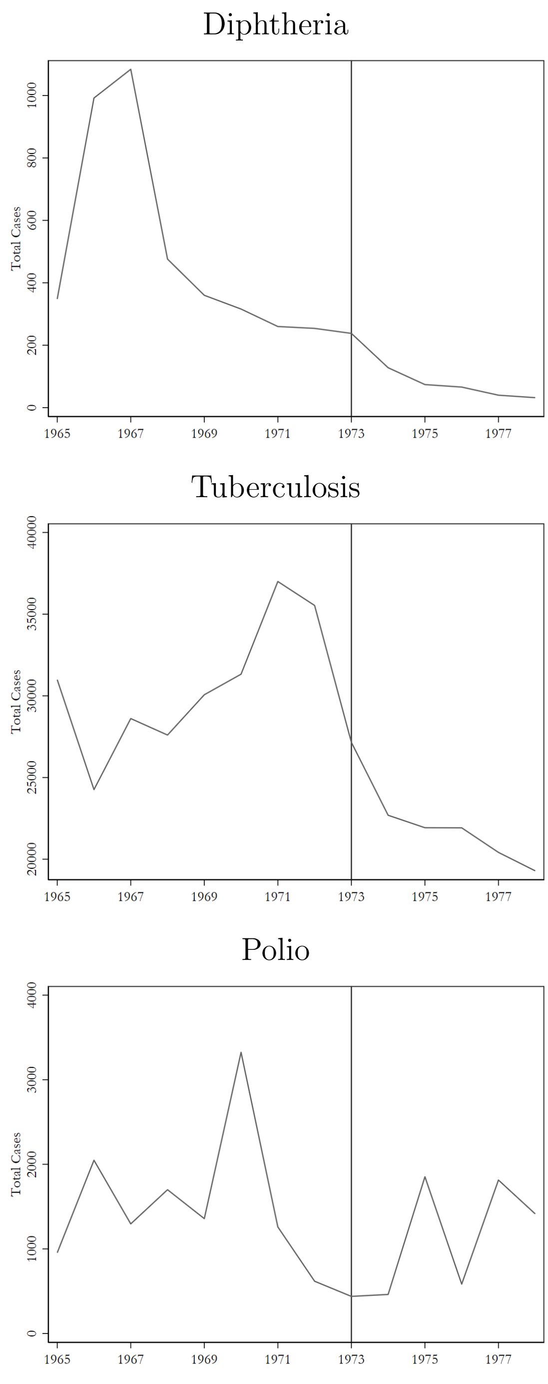
	Dataset				
	(1)	(2)	(3)	(4)	(5)
	1995 Count	2000 Census	ENE	ENEU	ENOE
PANEL A: Birth State					
Measles Rate*Exposure	0.00039	0.00011	0.00005	-0.00008*	-0.00017
	(0.00034)	(0.00027)	(0.00012)	(0.00005)	(0.00019)
Observations	60,628	1,819,229	553,156	785,149	341,574
Mean Value Outcome	0.0539	0.0531	0.0227	0.0100	0.0175
Years in Sample	1990-1995	1995-2000	2000-2004	1994-2004	2005-2008
PANEL B: Residence State					
Measles Rate*Exposure	0.00034	-0.00009	0.00004	-0.00008*	-0.00021
	(0.00036)	(0.00027)	(0.00015)	(0.00004)	(0.00024)
Observations	48,976	1,518,306	424,596	578,018	269,148
Mean Value Outcome	0.0680	0.0653	0.0254	0.0108	0.0198
PANEL C: Residence State					
Measles Rate*Exposure* Distance	-0.0000004	-0.0000001	0.0000001**	-0.0000000	0.0000000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Observations	69,094	2,174,664	609,455	794,438	404,835

* p < 0.1, ** p < 0.05, *** p < 0.01. Standard errors in parentheses.

Source: Mexican 1995 Conteo, Mexican 2000 Census, ENEU, ENE, ENOE and Salud Pública de México

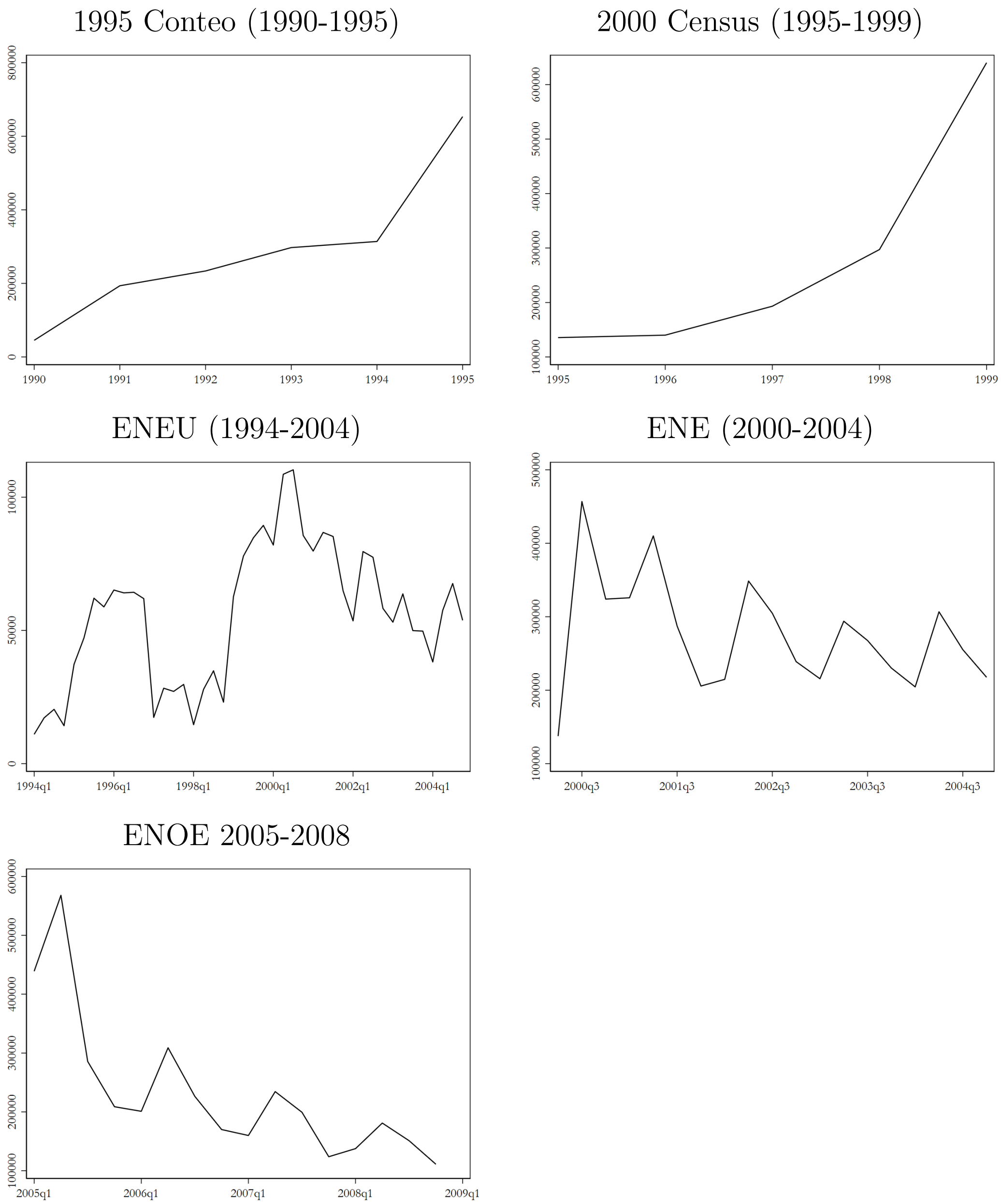
Note: In Panel A and B the sample is limited to men age 18 to 40. In Panel C the sample is limited to men age 18 to 65. Population weights are used and standard errors are clustered at the level of year and state of birth (Panel A) or residence (Panels B and C).

Figure A1: Incidence, Other Diseases



Source: Salud Publica de Mexico

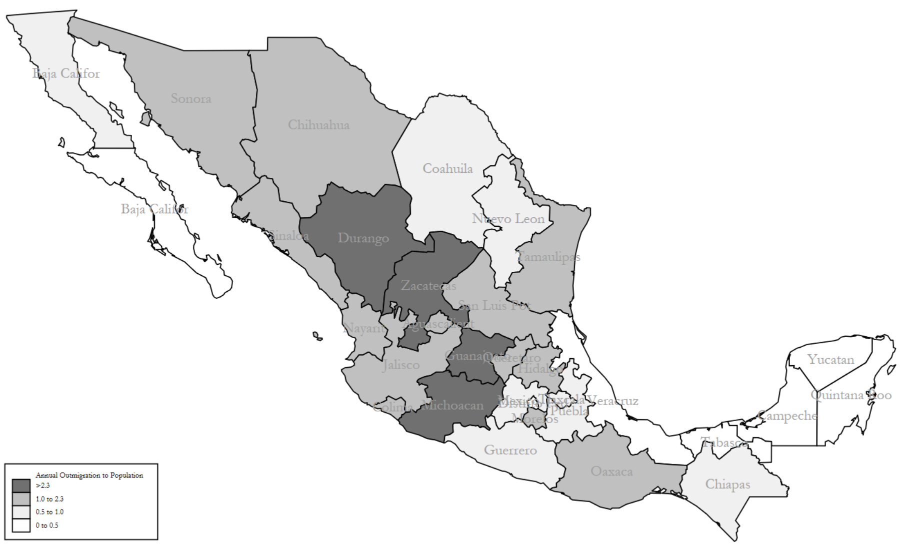
Figure A2: Out Migration



Source: 1995 Conteo, 2000 Census, ENEU, ENE and ENOE

Figure A3: Geographic Variation in Outmigration

Panel A: Annual Rates from 2000-2004



Source: ENE. Includes urban and rural areas