Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____ _____

Sangsoo Shin Date

The impact of the unemployment rate on infant mortality rate in the US, 2000-2016: the system Generalized Method of Moments approach.

By

Sangsoo Shin
Master of Public Health

Department of Epidemiology

_____

Carolyn Drews-Botsch, MPH, PhD
Committee Chair

The impact of the unemployment rate on infant mortality rate in the US, 2000-2016: the system Generalized Method of Moments approach.

By

Sangsoo Shin

Bachelor of Arts
Chung-Ang University
2008

Thesis Committee Chair: Carolyn Drews-Botsch, MPH, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology
2019

Abstract

The impact of the unemployment rate on infant mortality rate in the US, 2000-2016: the system Generalized Method of Moments approach.

By Sangsoo Shin

Introduction: Infant mortality rate has been known to be an indicator of quality of healthcare in a nation and a proxy for overall population health. Infant mortality rate in the US has decreased over time but remains higher than infant mortality rate in developed countries. The unemployment rate has been considered as risk factor for mortality rate. But the effect of unemployment rate on infant mortality rate in the US has not been assessed. Our study tried to identify immediate association between the unemployment rate and Infant mortality rate in the US over recent time periods.

Methods: Infant mortality rates at state-level were extracted from the linked data of death and birth certificate at Center for Disease Control and Prevention. Linked data of 446,426 deaths with 69,158,041 births are collapsed to total 867 observations of 51 states in the US from 2000 to 2016 to create infant mortality rate by year and state. Annual unemployment rate at state-level was collected from Bureau of Labor Statistics. As covariates, annual state-level data of urbanization rate, the percentage of bachelor's degree or higher and percentage of Black and African American were obtained from American Community Survey or Surveillance, Epidemiology, and End Results Program. The system Generalized method of moments analysis was used to evaluate the effect of the unemployment rate with dataset merged by year and state.

Results: The overall infant mortality rate in the United States decreased from 6.89 per 1,000 in 2000 to 5.87 in 2016, while the unemployment rate showed fluctuated trajectory. In unadjusted model, One percent point increase in the unemployment rate was associated with 0.019 increase in infant mortality rate (95% CI: -0.030, 0.068). After adjusting for other covariates, the strength of the association was halved, but increases in the unemployment rate continued to be associated with a small reduction in the IMR (0.101, 95% CI: -0.118, -0.085).

Conclusion: We found counterintuitive evidence that short-term economic downturns, measured as increases in the unemployment rate, were associated with increases in the IMR. The reasons for this paradox should be investigated in future analyses.

The impact of the unemployment rate on infant mortality rate in the US, 2000-2016: the system Generalized Method of Moments approach.

By

Sangsoo Shin

Bachelor of Arts
Chung-Ang University
2008

Thesis Committee Chair: Carolyn Drews-Botsch, MPH, PhD

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology
2019

Table of Contents

Introduction

Background

Infant mortality rate (IMR) is defined as the number of deaths of liveborn infants under one year of age per 1,000 live births. The infant mortality rate has been considered as a pithy measure of population health(1) and as a suitable indicator of availability and quality of medical technology and availability of health services in a population. Infant mortality rate across the world, overall, has been decreasing for twenty centuries. The reasons for this observed trend in infant mortality rate has been widely discussed with a focus on improvements in socioeconomic indicators such as Gross National Income per capita, Gini index and poverty as a key explanation for both the overall reductions in IMR(2).

Similar to the pattern worldwide, the infant mortality rate in the United States has declined substantially during the past century from a rate of 47.0 per infant deaths per 1,000 live birth in 1940 to 5.87 in 2015(3) but has remained higher than infant mortalities of other developed countries(4). Due to the importance and pressing issue, Healthy people 2020 developed by U.S. Department of Health and Health Services, a multiyear plan to eliminate or reduce illness, disability, and premature death among individuals and communities(5), adopted infant mortality rate as one of the health indicators to monitor and improve.

National Bureau of Economic Research (NBER) defines a recession as a a significant decline in economic activity spread across the economy, lasting more than a few months. Recessions can normally be seen as reductions in real GDP, real income, industrial production, and wholesale-retail sales(6). Since 2000, there have been two economic recessions in the United States, which have impacted the lives of individuals and societal culture. First of these recessions occurred between March 2001 and November 2001; the second began in December 2007 and lasted eighteen months, until June 2009. The first recession, in 2001, followed the dot-com bubble while the second was triggered by a subprime mortgage collapse. Compared to

short term of recession 2001, Recession of 2008, also known as “the Great Recession,” has had profound economic consequences for many countries and has had a significant impact on the global economy and household over a more extended period. International Labor Organization (ILO) announced that the estimated number of jobless worldwide reached about 212 million in 2009(7).

The economic crisis has been associated with various health indicators at population-level, mainly to negative direction(8). There was a significant relationship between economic downturn and psychopathology, onset or exacerbation of mood disorders, and distress(9) There was an estimated excessive suicide in 2009 compared with the number expected based on previous trends(10). Inequalities in health-related quality of life were observed in developed countries during economic recession(11). Women were more negatively affected by unemployment in relation to health and mental status than men. These analyses have reported two main associations between the economic downturn and population health outcomes. Cross-sectional analyses have typically reported that the health of residents living in economically disadvantaged environments is worse than that of residents living in the better-off environment. Interpretation of cross-sectional study appears to be similar to the mechanism explaining longitudinal model; worsening economic condition results in the serious health condition (12).

However, more recent analyses of the association between economic condition and health at ecological level has reported opposite findings or null association. Premature mortality rates from several causes of death, except from cancer, reported downward trends during the recession in Spain (13) and the recession lowered mortality rates in Germany (14). There is little evidence to suggest that the Great Recession caused additional suicide(15). Increase in mortality was observed during economic expansions in the United States(16).

One of the reasons for recent inconsistent results is that the economic crisis has a dual effect on health moderated by some factors. Without a doubt, the economic crisis placed increased burdens on households, businesses, and governments, which resulted in fewer

financial resources for health care(17). The economic crisis also affects the allocation of budget about social policy at the national level(17). However, change in economic condition at macro level leads to changes in health-related behavior at the individual level in the positive direction such as cessation of smoking and likelihood of relapse(18), fall in alcohol consumption(19) and change in fertility behavior(20).

Another reason for this variability in results is due to the heterogeneity of research design for identifying the relation. There are various estimations of the economic condition at regional-level depending on data availability, the type of methods used to measure, different level of geographical aggregation. Also, different range of study period, geography return different research output.

The unemployment rate is frequently used as a proxy for macroeconomic conditions in the field of health research(21) as well as a widely used indicator of economic transition. The unemployment rate is typically collected by the government in a regular time base and without change in definition of employment over time. Also, surveying status of employment is less exposed to information bias than reporting income level that could be an proxy variable affected by economic transition at ecological level. Previous literature that evaluated the relationship between the unemployment rate and infant mortality rate but only included limited geographical area(22) or shorter term that only included the Great Recession(23).

To identify the association between change in the unemployment rate and infant mortality rate, our study further considered adjustment of covariates that would affect the outcome; urbanization rate, rate of higher education completion, and percent of black and African American.

In short, there is less convergence regarding the association between the unemployment rate and infant mortality rate in the United States. Also, there is little study to identify the impact of the unemployment rate on infant mortality rate, in particular.

The present study used ecologic approach, which denotes that interpretation is limited to

the association at population-level. Ecological studies are potentially susceptible to “ecological fallacy.”(24) The result from ecologic approach does not provide meaningful interpretation of the relation between being unemployment of individual and risk of infant mortality. Nevertheless, ecological analysis is valuable in that factor such as the unemployment rate is only available at the population level. Also, the repeated cross-sectional study allows control for unmeasured confounders at the ecological level through the inclusion of state-level fixed effects in the statistical model(25).

Research Aims

Even though most of studies evaluate the association between economic recession and health indicators including mortality, there is lack of evidence of the association on infant mortality rate in the United States. This study aims to refine the association between the fluctuation in the unemployment rate and infant mortality rate at state-level. We aimed, therefore, following a goal by using 17-year state-level observations to test rather immediate effect of the unemployment rate on infant mortality rate.

Methods

Study Design

We will investigate the association between fluctuations in state-specific economic indicators over time and state-specific trends in IMR between 2000 and 2016. This ecologic investigation takes advantage of the fact that the economic downturns impacted different states differently. All variables including covariates for this study were extracted from de-identified publicly-available datasets. Therefore, institutional review board approval was not needed.

Study Variables

This study used yearly state-level variables. State-level data produce a small number of observations and is more stable on observations either between states or between years compared to lower-level data such as county-level or zip code unit. Therefore, state-level is much reliable ecological data and thus suitable for period, while the value extracted from smaller samples at lower-level area would be more imprecise, and, in turn, much variable over time.

The outcome variable of our interest is the infant mortality rate for all causes at the state level, which is the number of deaths of children under one year of age per 1,000 live births. Data on state- and year-specific infant mortality were obtained from CDC WONDER (https://wonder.cdc.gov/lbd.html), developed by the Center for Disease and Control and Prevention. CDC WONDER uses linked infant birth and death certificates to develop counts and rates for deaths among liveborn infants less than one year of age by state of birth and state of death. The normality assumption of panel regression was met for infant mortality rate, determined through the skewness (>2) and kurtosis (>2) of the outcome measure. Any further transformation was not required.

Independent variable is the unemployment rate at state-level for each year between 2000 and 2016. The unemployment rate was obtained from the Bureau of Labor Statistics.

Confounders in this study were considered as % of Black and African American population, % of bachelor or higher degree and urbanization rate at the state level, respectively.

Considering that substantial race and ethnic disparities in infant mortality in the United States(26), the overall-, statewide percentage of Black an African American population was extracted from Surveillance, Epidemiology, and End Results Program (SEER) managed by National Institutes of Health. Household median income was extracted from the Current Population Survey conducted by the U.S. Census Bureau and ACS that is collected by the Census Bureau provides vital information every year basis regarding social, economic, housing, and demographic characteristics. ACS sampled approximately two million housing unit annually stateside since 2005 and the full implementation of the ACS data collection began in 2006. Census Bureau provided averaged value of these observations by states by years.

We adjusted for urbanization rate and proportion of Black and African American. The urban area has fundamentally easy access to a health care facility and health-related information. Past research indicated that infant mortality rates vary by urbanization level(27, 28). The continued and parallel progress in absolute inequality in infant mortality rate between black and white infant has been observed at the national level(29). Therefore, the proportion of specific indicators would be one factor for infant mortality rate at the state level.

We further considered GINI index extracted from ACS as a confounder for the first time, but the GINI index was excluded from the final model in that provided GINI index was only available for 2007 to 2016. The median household income and the percent of the uninsured at state-level excluded in that those variables share similar meaning with the unemployment rate as a proxy variable at state-level.

Statistical Methods

SAS 9.4 (Copyright © 2000-2012 by SAS Institute INC., Cary, NC, USA.) was used to implement survey methods and panel modeling to estimate the association the unemployment rate with infant mortality rate.

At first, we plotted trends in the unemployment rates and other covariates and infant mortality rate over time at national-level and state-level with spaghetti plots and compared trajectories of each variable [supplement 1].

Secondly, we run the unadjusted model and state and time fixed analysis, so-called two fixed model. Estimating equation with the ordinary least square regression without a panel set can be problematic since OLS ignore the state-specific fixed effect. The equation to be estimated is as follows:

$$IMR_{i,t} = \beta_0 + \beta_1(Unemployment\ rate_{i,t}) + \ \beta_2(Education\ level_{i,t}) + \beta_3\left(Rate\ of\ Black\ and\ African\ American\ _{i,t}\right) + \beta_5\left(Urbanization\ rate_{i,t}\right) + \ \alpha_i + \delta_t + \varepsilon_{i,t} \quad \ldots\ldots (1)$$

Where the subscript i indexes each state and t indexes year with t = 1, 2, …, 10; Z_{it} is a vector denoting confounder variables; α_i denotes unobserved state-specific effects; δ_t denotes unobserved time-specific effect; $\varepsilon_{i,t}$ captures the error term which is assumed to be independently and identically distributed with a zero mean and variance σ^2 for all i and t; β_j (j = 0, 1, 2, 3, 4) and γ are estimated coefficients and an estimated coefficient vector, respectively.

We checked whether our data are appropriate to use a random model or fixed model with the Hausman test for random effect for each weight group dataset. If the null hypothesis for the Hausman test is rejected, it means that state-level effects are not random and are correlated with the effect of each other so the fixed effect should be used for analysis. As results of the Hausman test for a random effect, we decided to set to fixed effect model. Fixed-effects models allow identifying the causes of change in infant mortality rate within a state adjusting for all time-

invariant factors between states.

Lastly, we ran the full model adjusting for fixed state effect and time effect by the system Generalized Method of Moment (SYS-GMM). There is a possibility of serial correlation and endogeneity of all the regressor in the dynamic OLS regression(30). To cope with endogeneity, the model was first differenced. First differencing removes any possible unobserved heterogeneity among the countries or states.

$$\Delta IMR_{i,t} = \beta_0 + \beta_1(\Delta IMR_{i,t-1}) + \beta_2(\Delta Unemployment\ rate_{i,t}) + \beta_3(\Delta Educaltion\ level_{i,t}) + \beta_4(\Delta Rate\ of\ Black\ and\ African\ American_{i,t}) + \beta_5(\Delta Urbanization\ rate_{i,t}) + \Delta e_{i,t} \quad \ldots\ldots (2)$$

Where Δ indicates the first difference operator ($\Delta IMR_{i,t} = IMR_{i,t} - IMR_{i,t-1}$, $\Delta IMR_{i,t-1} = IMR_{i,t-1} - IMR_{i,t-2}$, $etc.$). IMR_{t-1} is infant mortality rate of previous year, serves as instruments. The new error term, $\Delta e_{ij} = e_{i,t} - e_{i,t-1}$, is correlated with the lagged outcome variable $\Delta IMR_{i,t} = IMR_{i,t} - IMR_{i,t-1}$. Other indicators in function (2) are almost same with indicators in function (1). If the $e_{i,t}$ are the serially uncorrelated, the residuals in the first-differenced model is only first-order correlated but should not be correlated with second-order(31, 32).

The system GMM returns more exact result both when the numbers of periods available are small and the time series is highly persistent(33), which aligns with our dataset. The system of GMM modifies both autocorrelation and heteroscedasticity(34). There is a growing body of the literature using system GMM to identify risk factor of researchers' interest in mortality rates(30, 35). We suggested 95% confidence intervals using estimation and standard error.

Results

Descriptive analysis

Table 1 highlights general population information of data extracted from the CDC WONDER. The national level infant mortality rate is the value of the infant death divided by total birth, while state level infant mortality rate is averaged infant mortality rate of each estimation of states. After total infant deaths and total birth peaked in 2007, both indicators decreased. Total infant death decreased by 20.0% over 17 years, while total births only decreased by 2.7% during the same period.

Table 1. Demographic characteristics of the study population, 2000-2016, United States

Year	Death	Total Birth	IMR in US	Mean of IMRs at State-level	Economic crisis
2000	28,960	4,058,882	6.89	7.18	
2001	27,523	4,026,036	6.84	7.12	Dot.com bubble
2002	27,970	4,021,825	6.95	7.12	
2003	27,995	4,090,007	6.84	6.96	
2004	27,860	4,112,055	6.78	6.96	
2005	28,384	4,138,573	6.86	7.11	
2006	28,509	4,265,593	6.68	6.92	
2007	29,153	4,316,233	6.75	7.06	the Great Recession
2008	28,075	4,247,726	6.61	6.75	
2009	26,498	4,130,665	6.39	6.58	
2010	24,572	3,999,386	6.14	6.24	
2011	24,001	3,953,590	6.07	6.21	
2012	23,654	3,952,841	5.98	6.20	
2013	23,446	3,932,181	5.96	6.12	
2014	23,211	3,988,076	5.82	5.97	
2015	23,458	3,978,497	5.90	6.17	
2016	23,157	3,945,875	5.87	6.06	

There were different trajectories of total infant deaths and total births between post dot-com bubble and post the Great Recession. During and after the Great Recession, total infant deaths and total birth have decreased while post dot-com bubble shows a slight increase in both

the total numbers of infant death and total births by 2007.

Both infant mortality rates in the United States and at state-level showed similar patterns over time. Two types of infant mortality rates show an overall decrease over time; 6.89 in 2000 to 5.87 in 2016 at infant mortality rate in the United States, 7.18 in 2000 to 6.06 in 2016 at infant mortality rate at the state level. Also, there are heterogenous trajectories of infant mortality rate during the Great recession. For instance, infant mortality rate in Alabama recorded 8.98 in 2006, increased to 9.47 in 2008 then decreased to 8.28 in 2009. Infant mortality rate in California showed similar pattern with that of Alabama: 5.04 in 2006, 5.11 in 2008, then fall to 4.91 in 2009. Infant mortality rate in Georgia, however, showed overall fall during the same period: 8.07 in 2006, 7.99 in 2008, and 7.33 in 2009.

Table 2. The trend of the unemployment rate and covariates over time at state-level, 2000-2016, United States

Year	Unemployment rate	% of high education	Urbanization rate	% of Black or AA
2000	3.94	25.19	74.71	11.45
2001	4.59	25.68	74.92	11.53
2002	5.39	26.36	75.05	11.59
2003	5.65	26.71	75.15	11.64
2004	5.25	27.61	75.27	11.70
2005	4.93	27.36	75.38	11.75
2006	4.48	27.61	75.46	11.80
2007	4.37	27.15	75.58	11.86
2008	5.34	27.36	75.70	11.92
2009	8.54	27.59	75.82	11.98
2010	8.85	27.93	75.88	12.02
2011	8.24	28.34	76.01	12.10
2012	7.40	28.93	76.14	12.17
2013	6.81	29.40	76.27	12.25
2014	5.83	29.74	76.39	12.31
2015	5.07	30.33	76.49	12.38
2016	4.70	31.01	76.61	12.45

Note: Shading cell; Dot-com bubble in 2001 and the Great recession in 2007-2009.

Table 2 indicates the overall trajectory of the mean unemployment rate and other

covariates at state-level over time, 2000 to 2016 [Figure 1 to 8 in Supplement 1]. The lowest value of the unemployment rate was 2.2 percent in Virginia, 2000 across the state and year. Virginia showed 2.2 percent of the unemployment rate in 2000(lowest in Virginia), 3.1 percent in 2006 and 2007, 4.0 percent in 2008, 6.6 percent in 2009, 7.5 percent in 2010(highest), 6.5 percent in 2011, and 4.1 percent in 2016. The highest value of the unemployment rate was 14.4 percent in Nevada, 2010 across the state and year. Nevada recorded 4.1 percent of the unemployment rate in 2000 and 2006(lowest in Nevada), 4.6 percent in 2007, 6.1 percent in 2008, 11.3 percent in 2009, 14.4 percent in 2010(highest), 13.1 percent in 2011 and 5.9 percent in 2016.

Both in state and national data there are two peaks in the unemployment rate: one in 2003 the year after the dot.com bubble and a second in 2010, two years after the great recession.

For the unemployment rate, there are substantial fluctuations that record bimodal peaks; 5.65 in 2003, subsequent year of the dot-com bubble, and 8.54 in 2010, year right after the Great Recession. The rapid decrease in the unemployment rate was observed after 2010, and the unemployment records 4.7% in 2016, the latest year available.

Unadjusted analysis

Table 3 conveyed the result from the unadjusted model. One percent point increase in the unemployment rate was associated with 0.19 increase in infant mortality rate(95% CI -0.03, 0.068).

Table 3. The effect of unemployment rate on Infant mortality rate, unadjusted model

Variable	Coefficient	Standard Error	95% CI
Unemployment rate	0.019	0.025	-0.030, 0.068
Education rate	-0.075	0.008	-0.091, -0.059
Urbanization rate	-0.002	0.003	-0.007, 0.003
Black and AA rate	0.087	0.003	0.081, 0.094

Two fixed model

Table 4 indicates the result of the adjusted two-fixed model, adjusting for state and year effect. One percent point increase in the unemployment rate was associated with decrease by 0.032 of infant mortality rate (95% CI: -0.082, 0.018).

Table 4. The effect of unemployment rate on Infant mortality rate, two fixed model

Variable	Coefficient	Standard Error	95% CI
Unemployment rate	-0.032	0.025	-0.082, 0.018
Education rate	-0.032	0.020	-0.071, 0.006
Urbanization rate	0.010	0.037	-0.062, 0.082
Black and AA rate	0.249	0.030	0.190, 0.307

The system of Generalized method at moments

Table 5 indicates the result from the fully adjusted model with the system generalized method of the moment. One percent point increase in the unemployment rate decreased by 0.101 of infant mortality rate (95% CI: -0.118, -0.085).

Table 5. The effect of unemployment rate on Infant mortality rate, SYS-GMM

Variable	Coefficient	Standard Error	95% CI
Infant mortality rate $_{t-1}$	-0.018	0.025	-0.067, 0.032
Unemployment rate	-0.101	0.009	-0.118, -0.085
Education rate	-0.156	0.026	-0.207, -0.105
Urbanization rate	0.027	0.204	-0.373, 0.426
Black and AA rate	-0.764	0.221	-1.198, -0.329

Discussion

The purpose of this study was to look trends of infant mortality rate, the unemployment rate, and other covariates by states, 2000 to 2016 in the United States and then to identify the influence of the unemployment rate as a proxy variable for the economic crisis on infant mortality rate. Supposing that the unemployment rate is a compatible proxy for explaining economic ups and downs through the literature review about past pieces of literature, our study performed the first systematic investigation of the association between the unemployment rate and Infant mortality rate using 867 observations for 17 years at state-level in the United States.

Findings

Overall, these data suggest that there has been an improvement in infant mortality rates in the United States between 2000 and 2016. Total infant death decreased by 20.0% over 17 years, while total births only reduced by 2.7% during the corresponding period in the United States resulting in a 14.8% decrease in the infant mortality rate. Since 2000, the infant mortality rate in the United States peaked in 2002, then continued to decrease over time.

There were heterogeneous decreasing trends in infant mortality rate by state. For instance, in California, total number of infant deaths decreased by 28.4 percent over 17 years while total birth decreased by 8.1 percent, 5.4 to 4.2, which explained 22.1 percent decline in infant mortality rate. In Alabama, total number of infant deaths decreased by 11.3 percent, while total birth only decreased by 6.6 percent over corresponding period, which produced only 5.1 percent decrease of infant mortality rate, 9.5 to 9.0. The heterogeneous decrease in infant mortality rate might imply that there would be possibility of social selection discussed later part.

The mean of infant mortality rate at state level remained at higher levels than infant mortality rate in the United States. Infant mortality rate in the United States is calculated with weighted value of each state using population size. However, the mean of infant mortality rate at

state level assumes all states have equal weight on infant mortality rate regardless of population size at each state. The infant mortality rate at California, where the index is below the average, and total number of birth is large, and infant mortality rate at Alabama, where the index is above the average, and total number of birth is relatively small, had the same weight to produce the mean of infant mortality rate at the state level. The mean of infant mortality rate at state level peaked in 2000 but showed the slight fluctuation of the index in an overall downward trend over time. This suggests infant mortality rate at the state level might be more sensitive and might be corresponding to other macro indicators beyond the secular trend.

Through the first descriptive plotting two trends, the unemployment rate and infant mortality rate appears to have a weak positive or none significant relationship. In particular, since 2010 when the Great Recession almost ends officially, fall in the unemployment rate has align with a decrease in infant mortality rate. Infant mortality rates exhibit a steady decrease over time contrary to a huge fluctuation in the unemployment rate during the corresponding period. The rapid drop in the total number of infant deaths compared to a mild decrease in total births imply the qualitative change not being able to explain the phenomenon with the quantitative feature given by now.

In the unadjusted model, not adjusting for common factor in a state or a time, the result returned the direction corresponding to the hypothesis that bad economic environment incurs worse health outcome. Compared to the unadjusted model, two fixed model showed a quite different estimation. For the association between the unemployment rate and infant mortality rate, two fixed model and the system Generalized Method at Moments showed the same direction but different significance. Considering overall decrease in infant mortality rate over time observed in Figure 2, negative estimates of change in infant mortality rate of previous year suggests that the SYS-GMM equation controlled for secular decline in infant mortality rate.

The most interesting result was observed in negative relationship between the unemployment rate and the infant mortality rate, adjusting for other covariates and using the

SYS-GMM. We did not find evidence that the unemployment rate was associated with infant mortality in two-fixed model adjusting for state and year effect, but there is association between two indicators in the system GMM adjusting for secular trends. Two fixed model does not consider overall linear trajectory of infant mortality rate over time and variation of outcome in this method is saturated too much to state and year dummy variables. As a result, effect of the unemployment rate and other covariates were quite mitigated. However, the system GMM returns more exact result both when the numbers of periods available are small and the time series is highly persistent by using first differenced value(33), which is similar conditions with our dataset.

According to previous literature evaluating the relationship between the recession and mortality, the effect of the recession on mortality would be mixed. The result of this study provided the negative correlation between the unemployment rate and infant mortality rate. Among literature treating mortality, the strong belief that the harmful effect of the economic downturn affects suicide negatively(36, 37) has been suspected from more recent research(38).

Furthermore, a decrease in some harmful health behaviors such as smoking and obesity had been shown when the economy strengthens at the individual level(39). The evidence that the infant mortality rate declined when the economic condition falters is consistent with other research in the United States(40). When it comes to economic condition at ecological level, the typical mechanism asserts that mortality and the unemployment rate is procyclical; rising when the economic condition improves and falling when they deteriorate(21). The infant mortality rate appears to align with the same mechanism discussed recently in overall mortality.

In addition to the general mechanism discussed, for change in infant mortality rate by economic condition, the social selection of being pregnant and its differential impact on infant mortality rate by socio-economic condition can be considered as well. As part of possible explanations, women`s reported pregnancy intentions, with many women indicating that because of the economic burden, they are likely to delay pregnancy(41). Thus, cost of being

pregnant during economic downturn would be higher than another period, and this burden would be critical to economically disadvantaged population. Countries in European Union that were hit hard by the recession showed reduced fertility, especially at younger age, during the Great Recession(42). There is a positive relationship between younger pregnancy and worse socioeconomic condition, even though that would be bi-directional association(43). Among infant mortality, the post neonatal mortality disadvantage was driven by poor birth outcome among lower socioeconomic individuals(4).

Not only mechanism that explains putting off low-income individuals' pregnancy, we also assume broader context to explain the association on general population. During economic recession, rising enrollment in higher education leads to declining marriage rates(20), which in turn might result in mild decrease in birth from younger adult.

Summarizing two mechanisms, the fact that distribution of gestational age at birth and improvements in survival after birth during 2007-2013 were improved(44) suggests that healthier mother or mother durable to economic hardship were likely to hold the intention to be pregnant during that time than someone else, which, in turn, would lead to improvement in infant mortality rate over economic downturn.

Limitation and Strength

Although the period of economic recession was included in our analysis, our data set might not permit effect by the degree to long-term fluctuation or the long-term effect of the unemployment rate on infant mortality. Also, the results could be biased by the migration effect of the pregnancy. Healthy individuals are more likely to move than are those in worse health(45). The fact that while changes in two phenomena, the unemployment rate, and infant mortality rate, may be highly correlated at a population level, but they may not be at an individual level. Again, such aggregate analyses cannot translate into risk indices for individuals. Multi-level analysis with longitudinal data would be desirable to separate the effect of covariate

at the individual level and the regional level. Other potential covariates for infant mortality rate has not been controlled. Several potential sources of bias in the mortality related to numerator/denominator lie in the analysis because two indicators do not exact matched in terms of data selection. Further work will be needed to evaluate lag effect of economic crisis not for socio-economic reasons but for biological reason. It usually takes 40 weeks to give birth so time lag between exposure to economic crisis and infant mortality might exist, considering only the relationship between two. Thus, analyses considering time lag effect might produce reliable estimation. Lastly, further work needs to assess the association between infant mortality rate and unemployment rate at smaller unites. Heterogenous environments in a state were oversimplified to one value in this study due to lack of data about smaller geographical unit. analyses using data at smaller unit would provide more exact relationship.

Nonetheless, the analysis indicates reasonably strong evidence that the protective effect of economic downturns on infant mortality with medium term. Our study is the first longitudinal evaluation we are aware of to render the unemployment rate. This ecological study avoids the problem of recall bias differed by bringing all administrative data confirmed and is likely to prevent the same source bias by collecting data from diverse sources. Panel regressions using two fixed model and the system GMM have been estimated by fixed effects to investigate the association between the unemployment rate and infant mortality rate. This method allows avoiding estimation biases due to the uncontrolled influence of time-invariant state-specific omitted variables(46). While various individual factors that directly impact the intention to pregnancy and adverse birth outcome should always be considered, paying attention to state-level factors can help to begin to grasp why some of the states still struggle with high infant mortality rate even though powerful intervention at the individual level was tried.

Conclusion and Public Health Implication

The current finding demonstrates that the worsening unemployment rate may be still

associated with better infant mortality rate after adjusting for covariates. The simple positive association between two indicators would be the result affected by confounders; Negative effect of improved unemployment rate during economic boom on infant mortality rate would be offset by the positive effect of improvement in other socio-economic indicators and change in health policy during the corresponding period.

Recently, mass communication and economic analysts start to warn economic depression in the United States and global. If the same predictions become the reality, various economic indicators would oscillate again; particularly the unemployment rate. We further need to understand the context of being maternity, and by doing so we can grasp essential function and mechanism of economic crisis for infant mortality.

List of Reference

1. Reidpath DD, Allotey PJJoE, Health C. Infant mortality rate as an indicator of population health. 2003;57(5):344-6.
2. Schell CO, Reilly M, Rosling H, et al. Socioeconomic determinants of infant mortality: a worldwide study of 152 low-, middle-, and high-income countries. *Scand J Public Health* 2007;35(3):288-97.
3. Xu J, Murphy SL, Kochanek KD, et al. Deaths: Final Data for 2016. *Natl Vital Stat Rep* 2018;67(5):1-76.
4. Chen A, Oster E, Williams H. Why is infant mortality higher in the United States than in Europe? *American Economic Journal: Economic Policy* 2016;8(2):89-124.
5. Koh HK, Piotrowski JJ, Kumanyika S, et al. Healthy people: a 2020 vision for the social determinants approach. *Health Educ Behav* 2011;38(6):551-7.
6. Lusardi A, Schneider DJ, Tufano P. The economic crisis and medical care usage. National Bureau of Economic Research, 2010.
7. Office IL. *Global Employment Trends for Youth: August 2010: Special Issue on the Impact of the Global Economic Crisis on Youth*. International Labour Office Geneva; 2010.
8. Drydakis N. The effect of unemployment on self-reported health and mental health in Greece from 2008 to 2013: a longitudinal study before and during the financial crisis. *Social Science & Medicine* 2015;128:43-51.
9. Zivin K, Paczkowski M, Galea S. Economic downturns and population mental health: research findings, gaps, challenges and priorities. *Psychological medicine* 2011;41(7):1343-8.
10. Chang S-S, Stuckler D, Yip P, et al. Impact of 2008 global economic crisis on suicide: time trend study in 54 countries. *Bmj* 2013;347:f5239.

11. Rajmil L, de Sanmamed M-J, Choonara I, et al. Impact of the 2008 economic and financial crisis on child health: a systematic review. *International journal of environmental research and public health* 2014;11(6):6528-46.
12. Zavras D, Tsiantou V, Pavi E, et al. Impact of economic crisis and other demographic and socio-economic factors on self-rated health in Greece. *Eur J Public Health* 2013;23(2):206-10.
13. Regidor E, Barrio G, Bravo MJ, et al. Has health in Spain been declining since the economic crisis? *J Epidemiol Community Health* 2014;68(3):280-2.
14. Neumayer E. Recessions lower (some) mortality rates:: evidence from Germany. *Social science & medicine* 2004;58(6):1037-47.
15. Harper S, Bruckner TA. Did the Great Recession increase suicides in the USA? Evidence from an interrupted time-series analysis. *Annals of epidemiology* 2017;27(7):409-14. e6.
16. Tapia Granados JA. Increasing mortality during the expansions of the US economy, 1900-1996. *Int J Epidemiol* 2005;34(6):1194-202.
17. Martin A, Lassman D, Whittle L, et al. Recession contributes to slowest annual rate of increase in health spending in five decades. *Health Aff (Millwood)* 2011;30(1):11-22.
18. McClure CB, Valdimarsdottir UA, Hauksdottir A, et al. Economic crisis and smoking behaviour: prospective cohort study in Iceland. *BMJ Open* 2012;2(5).
19. Harhay MO, Bor J, Basu S, et al. Differential impact of the economic recession on alcohol use among white British adults, 2004-2010. *Eur J Public Health* 2014;24(3):410-5.
20. Sobotka T, Skirbekk V, Philipov D. Economic recession and fertility in the developed world. *Popul Dev Rev* 2011;37(2):267-306.
21. Ruhm CJ. Health Effects of Economic Crises. *Health Econ* 2016;25 Suppl 2:6-24.
22. Aquino R, De Oliveira NF, Barreto ML. Impact of the family health program on infant

mortality in Brazilian municipalities. *American journal of public health* 2009;99(1):87-93.

23. Dallolio L, Di Gregori V, Lenzi J, et al. Socio-economic factors associated with infant mortality in Italy: an ecological study. *Int J Equity Health* 2012;11:45.
24. Loney T, Nagelkerke NJ. The individualistic fallacy, ecological studies and instrumental variables: a causal interpretation. *Emerging themes in epidemiology* 2014;11(1):18.
25. Hsiao C. *Analysis of panel data*. Cambridge ; New York: Cambridge University Press; 1986.
26. MacDorman MF. Race and ethnic disparities in fetal mortality, preterm birth, and infant mortality in the United States: an overview. *Semin Perinatol* 2011;35(4):200-8.
27. Singh GK, Siahpush M. Widening rural-urban disparities in all-cause mortality and mortality from major causes of death in the USA, 1969-2009. *J Urban Health* 2014;91(2):272-92.
28. Hogue CJ, Vasquez C. Toward a strategic approach for reducing disparities in infant mortality. *Am J Public Health* 2002;92(4):552-6.
29. Riddell CA, Harper S, Kaufman JS. Trends in Differences in US Mortality Rates Between Black and White Infants. *JAMA Pediatr* 2017;171(9):911-3.
30. Agboola MO. Impact of food availability on child mortality: a cross country comparative analysis. *Agricultural Economics* 2017;63(6):283-97.
31. Arellano M, Bond S. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies* 1991;58(2):277-97.
32. Blundell R, Bond S. Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics* 1998;87(1):115-43.
33. Favara G. An empirical reassessment of the relationship between finance and growth. 2003.
34. Roodman D. How to do xtabond2: An introduction to difference and system GMM in

Stata. *The Stata Journal* 2009;9(1):86-136.

35. Aakvik A, Holmas TH. Access to primary health care and health outcomes: the relationships between GP characteristics and mortality rates. *J Health Econ* 2006;25(6):1139-53.

36. Reeves A, Stuckler D, McKee M, et al. Increase in state suicide rates in the USA during economic recession. *Lancet* 2012;380(9856):1813-4.

37. Barr B, Taylor-Robinson D, Scott-Samuel A, et al. Suicides associated with the 2008-10 economic recession in England: time trend analysis. *BMJ* 2012;345:e5142.

38. Harper S, Bruckner TA. Did the Great Recession increase suicides in the USA? Evidence from an interrupted time-series analysis. *Ann Epidemiol* 2017;27(7):409-14 e6.

39. Ruhm CJ. Economic conditions and health behaviors: are recessions good for your health? *N C Med J* 2009;70(4):328-9.

40. Ruhm C. Are recessions good for your health? *The Quarterly journal of economics* 2000;115(2):617-50.

41. Gold R, Nash E, Cohen SA, et al. A real-time look at the impact of the recession on women's family planning and pregnancy decisions. *New York: Guttmacher Institute* 2009.

42. Goldstein J, Kreyenfeld M, Jasilioniene A, et al. Fertility reactions to the" Great Recession" in Europe: Recent evidence from order-specific data. *Demographic Research* 2013;29:85-104.

43. Markovitz BP, Cook R, Flick LH, et al. Socioeconomic factors and adolescent pregnancy outcomes: distinctions between neonatal and post-neonatal deaths? *BMC Public Health* 2005;5(1):79.

44. Callaghan WM, MacDorman MF, Shapiro-Mendoza CK, et al. Explaining the recent decrease in US infant mortality rate, 2007-2013. *Am J Obstet Gynecol* 2017;216(1):73 e1- e8.

45. Halliday TJ. Business cycles, migration and health. *Soc Sci Med* 2007;64(7):1420-4.

46. Noh Y-H. Does unemployment increase suicide rates? The OECD panel evidence. *Journal of Economic Psychology* 2009;30(4):575-82.

Supplement 1. Trends in each variable over time

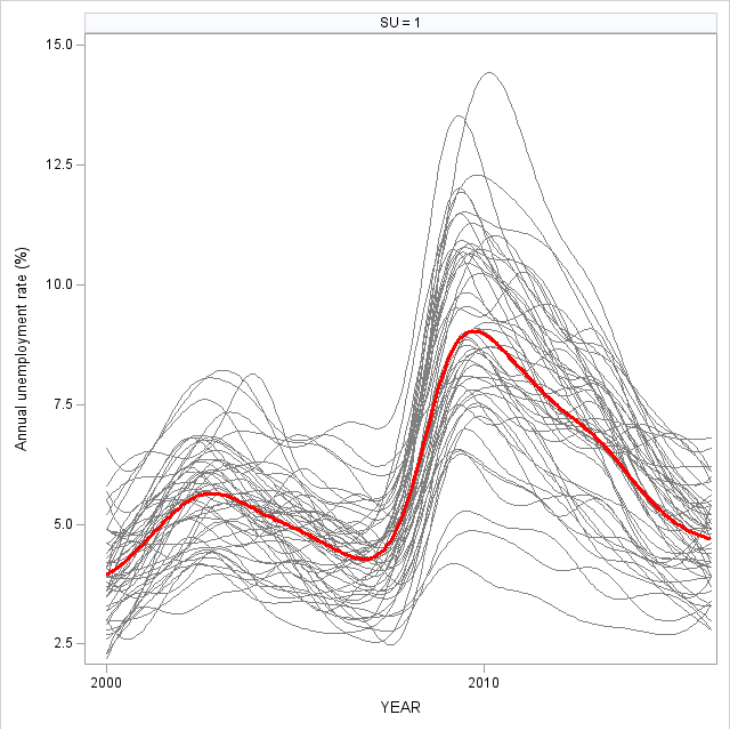

Figure 1 The unemployment rate in the United states, 2000-2016

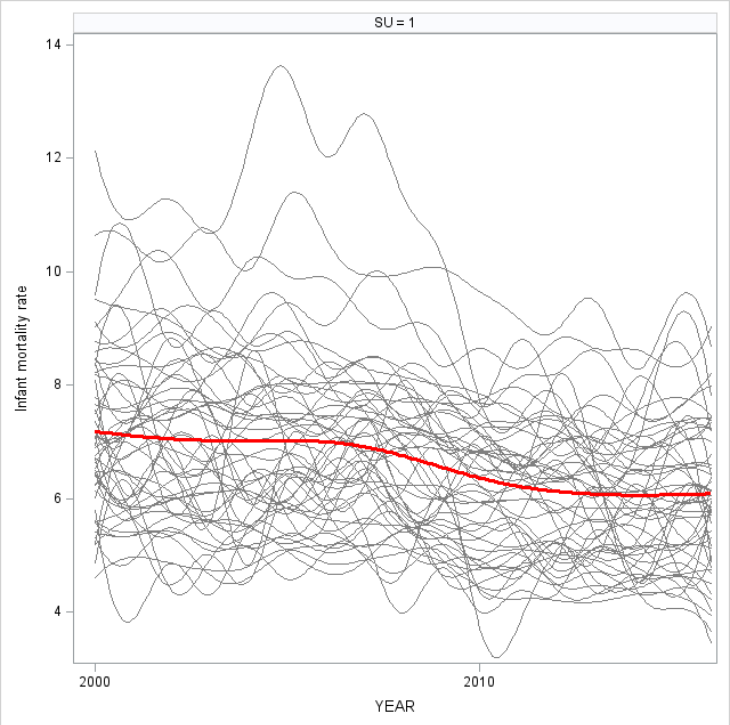

Figure 2 Infant mortality rate in the United States, 2000-2016

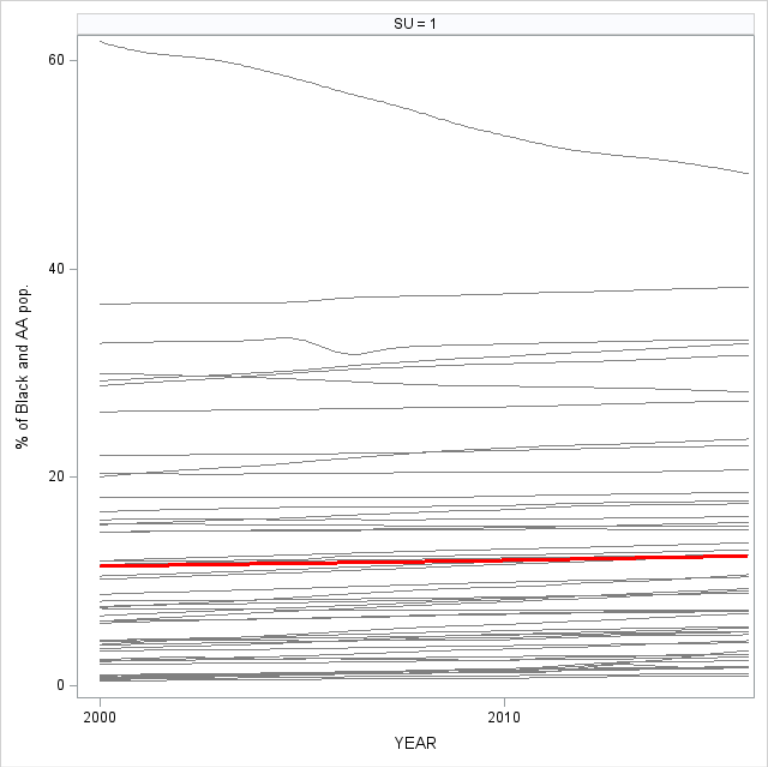

Figure 3 % of Black and African American, 2000-2016

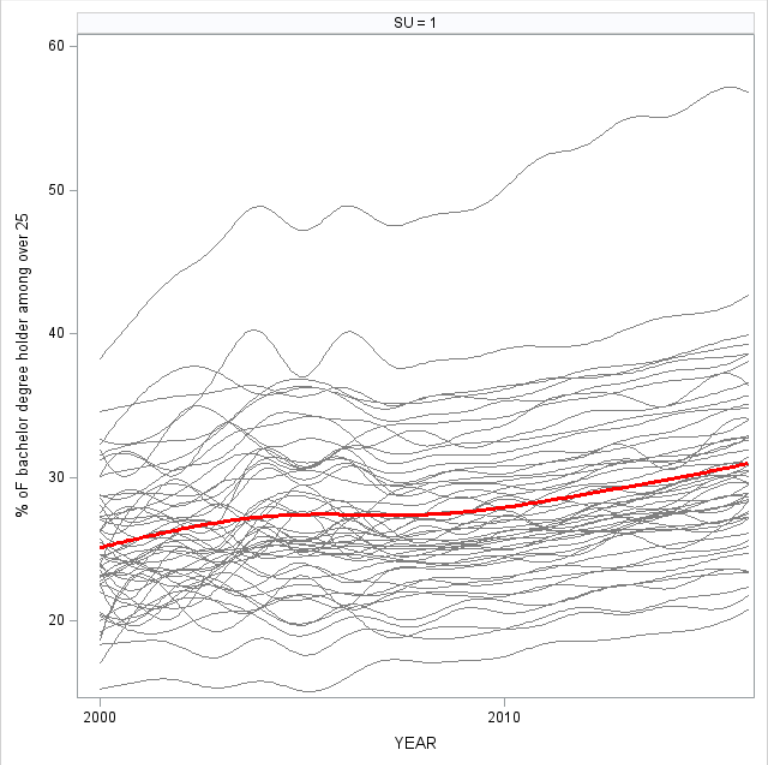

Figure 4 % of bachelor's degree or above among over 25 in the United States, 2000-2016

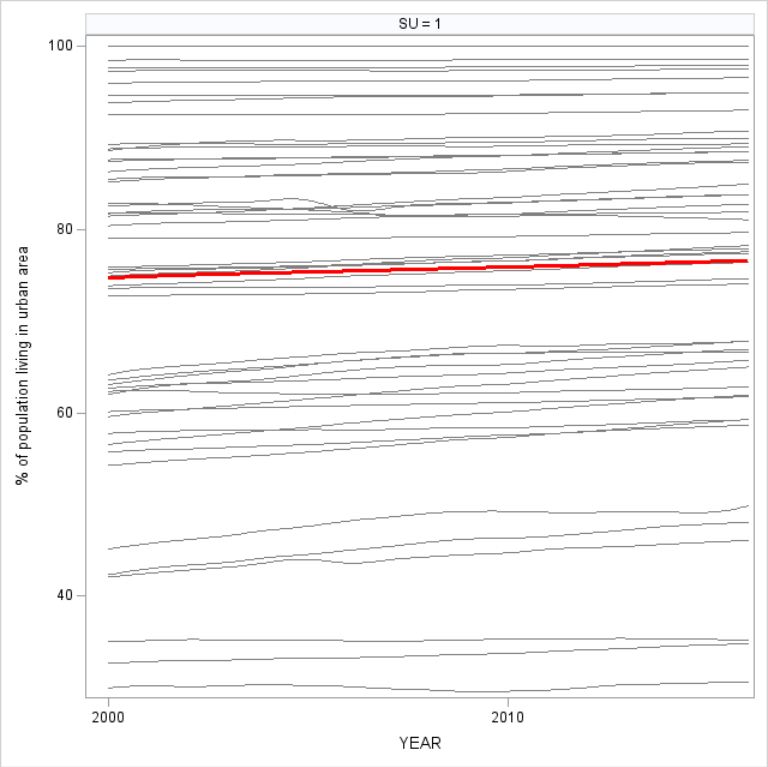

Figure 5 Urbanization Rate in the United States, 2000-2016

Supplement 2. DAG in the model

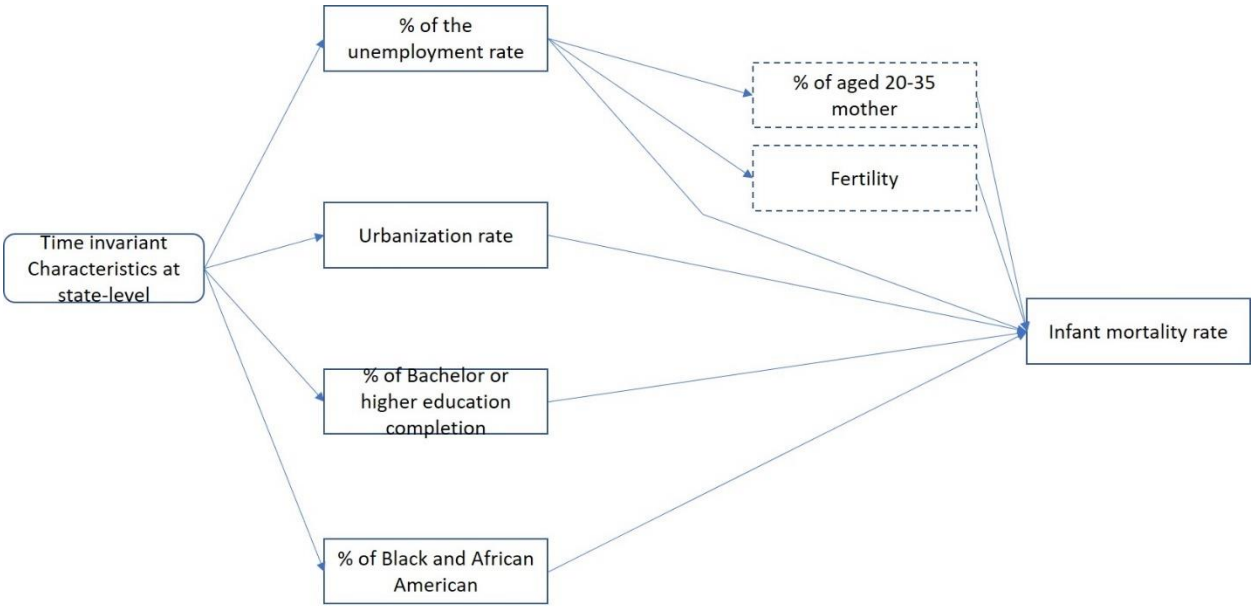

Figure 6 Effect of the unemployment rate on infant mortality rate

Variables in spotted box were not added in the final model because current SYS-GMM does not provide estimation of mediation modeling. The research used mediated routes by those factors only when interpreting significant association in the discussion session.