Are Mortality Rates Random Walk? Panel Unit-root Tests with the Evidences from Micro Data*

Shijun Gu[ψ]

University of Notre Dame

April 19, 2013

Abstract

This study investigates the relationship between economic conditions and health. Previous studies have estimated that they have a significantly negative correlation. However, there is a concern that mortality rates are non-stationary series, with which a chance of spurious correlation exhibits. By taking first difference on regressors and conducting unit-root tests for panel data, it shows some evidences that the unit-root concern is reasonable and the association between health and economic shocks is exaggerated. An accompanying analysis of micro data indicates that the influence of risky behaviors on mortality rate in response to economic conditions cannot match the extent to which the basic fixed-effect model predicted.

* I am extremely grateful to Professor William Evans for his constant guidance and support. All errors are mine.
ψ Department of Economics, University of Notre Dame, IN 46556. Email: sgu1@nd.edu

The analysis provides strong evidence that the negative correlation between health and economic condition is exaggerated. When taking a one-period difference for both state mortality and unemployment rate respectively, the regression result shows a more than 80% shrinking of the coefficient, though it is still significant. Consistent with this result, the Fisher-Type test shows that the state mortality rate fails to pass the unit-root test, despite that the unemployment rate is not a random walk.

In addition, micro data from the *Behavioral Risk Factor Surveillance System* (BRFSS) are used to provide some evidences for potential problem of unit root by showing the negative coefficient between mortality and unemployment rates cannot be explained by some related risky behaviors. Ruhm (2000) indicates that the mortality rates are procyclical by decomposing the variation in mortality into several components, including tobacco use, drinking, physical activity, diet and medical care. Furthermore, Sparks, Cooper, Fried, and Shirom (1997) argue that a rising workload has a negative effect on people's health status by using meta-analysis to examine the relationship between the length of the working week and health symptoms. White and Beswick (2003), and Siegrist and Rodel (2006) draw the same conclusion. Nonetheless, I show none of these can lead to such a sharp increase in mortality rate in the expansion era with data analysis and intuitive induction.

Fixed-effect models are estimated using panel data for the smoking rate for 1996-2010 period and alcohol-related mortality for 1984-1992 period. The results reveal that both smoking and drinking related deaths are significantly increasing during the expansion era. However, the coefficients are far smaller relative to the total mortality rate. Aguiar, Hurst and Karabarbounis

state characteristics, α_t accounts for nationwide time effects and γ captures the impact of within-state deviations in economic conditions. The effect of national business cycle is also obtained by estimating

$$H_{jt} = \alpha_t + X_{jt}\beta + E_{jt}\gamma + S_j + \epsilon_{jt} \quad (2)$$

where E_t indicates national economic conditions and the time effects are excluded.

2.2 Descriptive statistics

Summary statistics, weighted by the total resident population in each state by year, are displayed in Table I and are largely self-explanatory. The death rate refers to all-caused deaths per 10000 persons. The state and unemployment rates are the weighted average of period 1984-2010 by state. The per capital personal income is the weighted average of nominal dollar of the same period.

TABLE I
VARIABLES USED IN ANALYSIS OF STATE AGGREGATE DATA

Variable	Mean	Standard deviation
Death rate per 10000 people	84.63	13.26
State unemployment rate in %	5.97	1.89
National unemployment rate in %	5.96	1.38
Per capita personal income (in thousands)	36.86	10.84

All variables are weighed by state populations. The data of mortality rates are from CDC WONDER. The unemployment rates are provided by Bureau of Labor Statistics, Local Area Unemployment Statistics (LAUS) program. Income data are constructed using the data from U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements. Population statistics are provided by Population Division, U.S. Census Bureau.

Figure I displays national total mortality and unemployment rates in each year. The variables normalized by subtracting mean of variable. The result shows some evidences of inverse relationship between economic conditions and fatality rates. However, unlike Ruhm

rate (per100,000 persons). Table II summarizes the results of a variety of specifications, all of which control for state fixed-effects, and use state or national unemployment rates to proxy macroeconomic conditions. Some specifications also include year dummy variables, and some hold constant personal incomes.

As Table II shows, the negative relationship between unemployment rate and mortality rate is even larger than previous predictions. One percentage increase of state unemployment rates is associated with 1.2 percentage decrease of mortality rates. With the control of personal income, the result holds. If the year dummy is excluded, a little bit weaker relationship is observed. This contradicts to the result from Ruhm (2000), which states that the negative relationship is stronger by dropping the year dummy. If the independent estimator is the national mortality rate, the relationship is even weaker, but still very significant. One percentage increase of national unemployment rate leads to 0.6 decline of mortality rate.

The middle and bottom panel of Table II presents separate estimates for the 1984-1997 and 1998-2010 periods, the ten highest and lowest income city based on the income in 2010. Splitting the sample into shorter time period is likely to reduce the influence of within-state changes in omitted factors that are correlated with unemployment rate. The rationale for singling the states with highest and lowest income is that if the negative heath effect of economic expansion is due to migration, a difference may be observed for those to specifications.

variables. Many literatures (Romero-Ávila and Usabiaga, 2007; Schwert 1987) have already shown that we do not have to worry about a random walk for some important economic indicators, including unemployment rates. However, few researches focus on whether the mortality rates are random walk. The rationale is that for individuals, we can separate the causes of death to two classifications. One is the internal causes of death and the other is external causes of death. The latter one is triggered by some risky behaviors associated with the change of economic condition, which likely to be cyclical. However, independent from unhealthy behaviors, the time of death is very random. The amount of fatalities possibly is heterogeneous across years. That gives another potential cyclical of mortality rate which barely has a correlation with economic shocks. If the internal causes are dominant, we probably can observe a negative relationship between mortality and unemployment rate. However, economic expansion and recession cannot be applied to explain the correlation. In turn, the results I got in Section 2 are exaggerated.

3.1 Model

3.1.1 Difference on difference test

I use the subscripts j and t to index the state and year. The difference on difference regression equation is

$$\Delta H_{jt} = \alpha_t + x_{jt}\beta + \Delta E_{jt}\gamma + \varepsilon_{jt} \quad (3)$$

for ΔH_{jt} is the first difference of natural log of the mortality rate, ΔE_{jt} is the proxies of the first difference of economic conditions, X a vector of supplementary regressors, and ε the error term, α_t accounts for nationwide time effects.

exhibit a unit-root. The null hypothesis is that all the panels have unit roots and the alternative hypothesis is that at least one panel does not have unit roots or some panels do not have unit roots. This routine provides 4 different unit-root test methods as proposed by Choi (2001).

3.2 Result

3.2.1 Difference on difference test

The way in which I interpret the Table III is analogous to the Section 2 while the numbers are significantly different. By difference on difference test, one percentage increase of state unemployment rate is associated to 0.26% decline of mortality rate. The coefficient is still significant but has shrunk about 5/6 compared to the basic regression. Adding year dummy or not, controlling personal income or not and estimating by state or national economic predictors give similar observations.

TABLE III
FIRST DIFFERENCE TEST OF DETERMINANTS OF MORTALITY RATE

	Basic specification				
Full sample estimates	(a)	(b)	(c)	(d)	(e)
State unemployment rate	-0.0026	-0.0024	-0.0035		
	(0.0009)	(0.0011)	(0.0006)		
U.S. unemployment rate				-0.0037	-0.0027
				(0.0006)	(0.0007)
Personal income		-0.0186			-0.0102
		(0.0090)			(0.0024)
Year effect	Yes	Yes	No	No	No

The dependent variable is the natural logarithm of the total mortality rate per 10,000 populations. State dummy here is excluded for avoiding bias. Year dummy variables are controlled for, except models (c), (d) and (e). Standard errors are in parentheses. The sample in the top panel includes annual observations for the 50 states and the District of Columbia covering the period 1985–2010.

The test draws a conclusion that by converting the non-stationary series into stationary, the updated results show evidences that the basic regression exaggerates the correlation

As Figure II shows, the red line represents the unemployment rate; dot line indicates the external mortality rate, which is responsive to the economic shocks; dashed line shows the internal mortality rate, which is determined by people's own health status rather than risky behavior; and cross line exhibits the aggregate mortality rate, which is an additive combination of internal and external mortality rate.

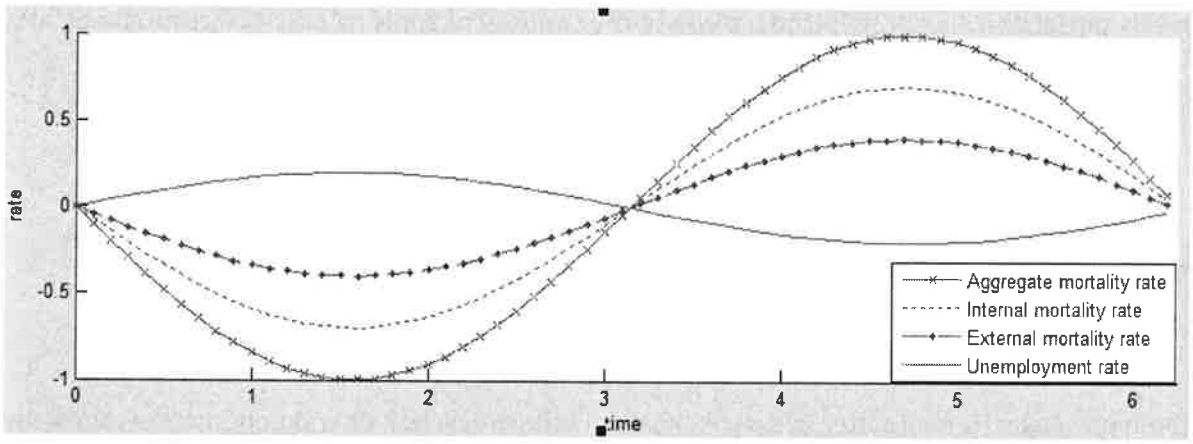

Figure II
Schematic Diagram of Separation of Mortality Rates

The reason why I cast doubt on the method given by Ruhm (2000) is that he actually regresses the red line (unemployment rate) on the cross line (aggregate mortality rate). However, only external mortality is responsive to the economic shocks while the internal one is probably a random cycle. Therefore, an exaggerated result is inevitable because some non-economic reason is mistakenly attributed.

My fisher-type test shows the aggregate mortality rate is a random walk, which implies that the internal death-caused reasons are dominant. The difference on difference test indicates a significant but small correlation between health and economic condition. That

It is true that some behavioral responses to the change of economic condition significantly influence people's health status. However, obviously none of these factors leads people's death immediately except drunk driving, which is not statistically significant when varying unemployment rate. For instance, one can drastically increase his/her tobacco use during a good economic state. But he/she is almost unlike to die during the period of one business state. Especially when taking the age factor into account, this intuition is more reasonable. Apparently, Young people's behaviors are more sensitive to the economic condition. But only after decades their mortalities can be recorded into data. Their life expectancies were shortened by the unhealthy behaviors during good states. However to what extent one's life expectancy is altered is highly heterogeneous and unable to be measured. Possibly, in a random year, there is an explosion of mortality rate. However, this is irrelevant to the current economic condition but related to a collective behavior changes due to good economic condition a few decades ago. Thus, it reminds me that if a random walk can explain the change of mortality rate because of the heterogeneous effects of behavioral change on people's life expectancy.

4.2 Model

Econometric estimates of the determinants of smoking and drinking are summarized in Table VII. The basic econometric specification is

$$H_{ijt} = \alpha_t + x_{ijt}\beta + E_{jt}\gamma + S_j + \varepsilon_{ijt} \quad (6)$$

where i indicates the individual, H the health input, and other variables are as defined above. The linear probability model can estimate how state smoking rates respond to the economic shocks. For drinking-related mortality, I use the same model as Section 2 shows.

Smoking rate has a significantly negative relationship with state unemployment rate. One percentage increases in unemployment rate leads to 0.16 percentage decrease in smoking rate. However, does it enough to show that the increasing consumption of smoking can largely explain the deteriorated health condition during economic expansion?

To show this, I run another regression to find the relationship between smoking rate and mortality rate. The result exhibits that the smoking rate and mortality rate has a significant positive relationship and one percentage rise in smoking rate is associated with 0.18 percentage increase in mortality rate. Then by using simple algebra I can conclude that if unemployment rate goes up by 1%, the mortality rate driven solely by rising tobacco consumption decreases about 0.03% (0.16*0.18). If compared with 1.2% decrease in total mortality rate, this number is quite small.

What about drinking? By intuition we know that the death caused by drinking during economic expansion is more noticeable than smoking. This is because of drunk driving. During 1984-1992, the annual alcohol-related driving fatalities are 22500 on average. Drunk driving, unlike smoking even binge drinking, probably leads to death in next minute. Thus, even though Ruhm (2000) argues that the drinking rate is not very procyclical, some treatment is still needed.

The regression result shows that one percentage increase in state unemployment rate leads to 1.7% decrease in drinking death rate. The result is significant and quite big. In addition, as the Figure III shows, during the period of 1984-1992, the alcohol-related death shares a same pattern as total mortality rate, both of which is procyclical. Nevertheless I still have to do some adjustment on the number. By calculation I get among all people who died during 1984-1992, 5%

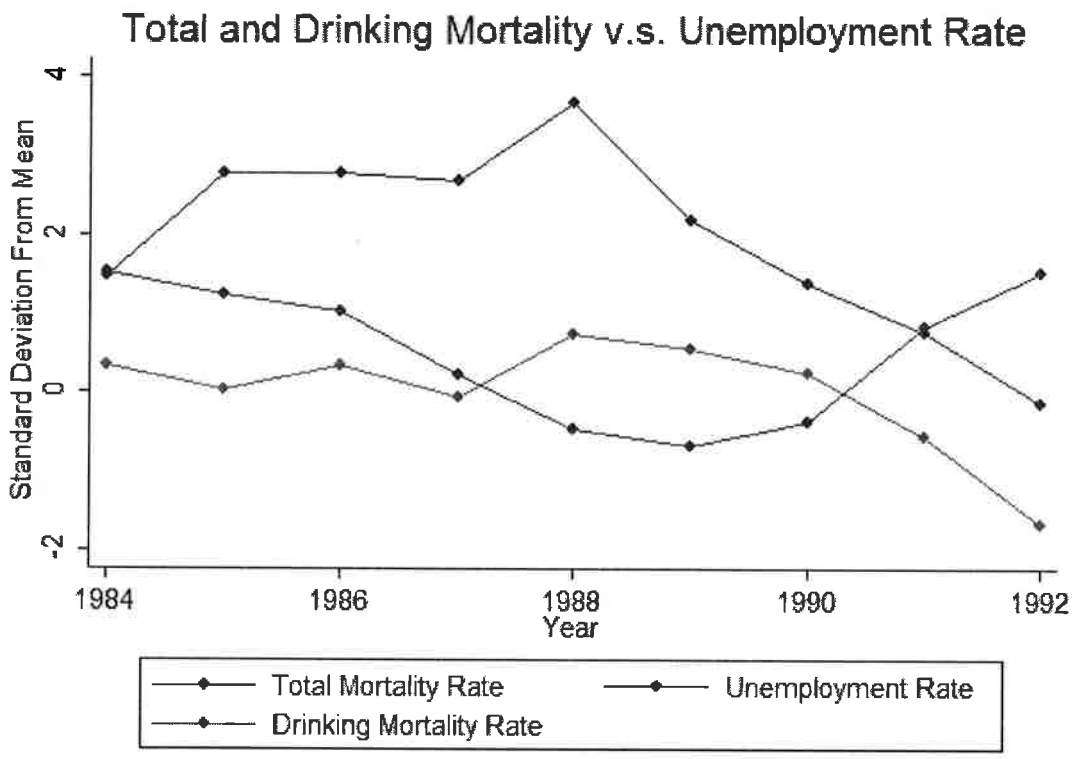

Figure III
Comparison between Total Mortality Rate and Alcohol-Related Death

B. Workload

If the behavioral change on smoking or drinking patterns cannot explain the large negative figure, what about stress? An increase of working hours during economic expansion exerts more responsibilities for workers. This in turn deteriorates people's health. Conversely, during recessions, people tend to have less workload, which subsequently reduce their stress. In practice, Sparks, Cooper, Fried, and Shirom (1997) argue that a rising workload has a negative effect on people's health status by using meta-analysis to examine the relationship between

business cycle of 2003-2010. We focus on the most recent great recession. During the period of 2008-2010, the aggregate unemployment rate was rising from around 5.8% to around 9.6%. The data shows that the market work hours fell by 7%. This is consistent with the statistics given by the Bureau of Labor Statistics (BLS). A simple calculation shows that one percentage increase of unemployment rate is associated with a 1.84% decrease in working hours. This means that a representative worker who is working about 40 hours per week has extra 44 minutes leisure hours during a recession when the unemployment rate increases by 1 percent. I do not have empirical result to show how this 44-minute difference per week alters people's health condition. However, this is obviously a small number in practice.

Moreover, this number could be shrinking if we take how people allocate the extra hours during a recession into account. Aguiar, Hurst and Karabarbounis (2011) shows that roughly 30% of the foregone market working hours are reallocated to non-market production (excluding child care), about 32% of foregone work hours are allocated to some regular housework, including cooking, cleaning, shopping, and child care. People cannot feel much more relaxed if a very large fraction of forgone working time is allocated like this. Comparably speaking, sleeping only account for 20% and health care and civic activities is even less.

C. Diet, physical activities and medical care

Among all behavioral changes in response to the economic shocks, I choose smoking and drinking to do further research. This is because a drastic increase in consumption of them may significantly deteriorate people's health. Diet, for instance, do help people keep good health indicators (blood pressure, blood sugar, etc.). However, they are long-term determinants of

relationship. Stress may be another assumption to interpret the procyclical nature of the mortality rate. However, some related researched have already shown the average saving working hours are not influential enough to alter people's health status. Even if people have less working responsibilities in recession era, they tend to allocate a large fraction of the saving hours to non-market production and housework, which consume energy as well.

Are recessions good for your health? Maybe the answer appears to be yes. However, the effect is far less than previously predicted. Further research may find more evidences by focusing more on age distribution and some specific causes of death.

Reference

[1] Aguiar, Hurst, Karabarbounis (2011) "Time use during recessions."

[2] Breitung J (2000) "The local power of some unit root tests for panel data." In B.Baltagi (ed.), Nonstationary Panels, Panel Cointegration, and Dynamic Panels, *Advances in Econometrics*, 15. JAI: Amsterdam, 161-178

[3] Berniell (2012) "The effects of working hours on health status and health behaviors."

[4] Cho, Cooley (1994), "Employment and hours over the business cycle", *Journal of Economic Dynamics and Control* 18 (1994) 411-432.

[5] Choi In (2001) "Unit root tests for panel data." *Journal of International Money and Finance* 20: 249 – 272.