Panel Co-integration Analysis of Cigarette Taxes and Health: The Case of Respiratory Cancers

Echu Liu[1]

Southern Illinois University Carbondale

Wei-Choun Yu[2]

Winona State University

Hsin-Ling Hsieh[3]

Northern Michigan University

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Abstract

Using a panel of state data for the years 1954 to 2005, this study investigates the long-run relationship between the excise taxes on cigarettes and the mortalities of cancers of respiratory system. Statistical tests show that real cigarette excise tax and mortalities of respiratory cancers are non-stationary and co-integrated. The estimates of co-integrating vector indicated that in the long run a 10% increase in real cigarette excise tax leads to 2.5% reduction in mortalities of respiratory cancers, and this effect is statistically significant at 1% level. This result implies that cigarette tax serves as an effective means toward improving public health.

Keywords: Cigarette Tax; Panel Co-integration; Panel unit roots

JEL classification: I10; I18; F31

[1] Corresponding Author: School of Allied Health, Southern Illinois University at Carbondale, Mail Code 6615, Carbondale, IL 62901, USA. Email: echuliu@siu.edu. Tel:+1-618-453-8883.

[2] Department of Economics, Winona State University, Somsen 319E, Winona, MN 55987, USA. Email: wyu@winona.edu. Tel: +1-507-457-2982.

[3] Department of Economics, Northern Michigan University, 1401 Presque Isle Avenue, Marquette, MI 49855, USA. Email: hhsieh@nmu.edu. Tel: +1-906-227-1214.

1. Introduction

Since the issuance of first Surgeon General's report on the health hazards of smoking in 1964, various levels of government have consistently implemented tobacco control policies to promote the reduction in tobacco use. According to US Department of Health and Human Services (2000), the most important economic policy device for promoting the reduction in tobacco use is the increased taxation on tobacco products. The governments, especially the state governments, have vigorously used cigarette excise taxes as a principal tool to discourage smoking in recent years. By approving various acts, voters in many states also showed their supports for the governments' initiatives to increase the state excise taxes on cigarette as part of the tobacco control campaigns.

Imposing higher cigarette taxes on cigarette is primarily based on the following justifications. First, since consumers may be addicted to smoking, cigarette tax is an effortless way for government to raise revenues.[4] Second, increased excise taxes, which result in higher prices on cigarettes, would reduce smoking prevalence and cigarette consumption. Third, since the health benefits of smoking cessation have been proven by many medical studies to be significant,[5] tax-induced increases in the prices of cigarette would have remarkable potential to improve public health outcomes, and consequently trim down the health care cost from the smoking-related diseases.[6]

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[4] The increased revenues are often used to fund public health care programs and finance antismoking campaign. For example, on February 4, 2009, President Obama singed a bill into law to increase the federal excise tax on a pack of cigarettes from $0.39 to historically high level of $1.01, which was effective on April 1, 2009. The increased tax revenues from this big hike in the federal tax rate would be used to finance the State Children's Health Insurance Plan (SCHIP).

[5] Many clinical researches provide evidence about the benefits of smoking cessation, including, for example, the reduction in the risk of cardiovascular diseases. Ockene and Miller (1997) summarize these findings.

[6] As pointed out by 2004 Surgeon General's report, smoking is the main preventable cause of illness and death in

The dollar amount of government revenues generated by cigarette taxes has increased considerably in nominal terms since 1965. The federal tobacco tax revenues increased from $2.1 billion to nearly $7.4 billion in 2007, and state and local tobacco tax revenues increased from $1.2 billion to almost $14 billion in 2007. Using panel data from 46 American states for the period 1963 to 1988, Baltagi and Levin (1992) estimated the elasticity of cigarette tax revenue with respect to the cigarette tax rate and found it is positive in the short and long runs for each state. These statistics and empirical evidence provide solid support for the first rationale of using cigarette excise tax as a policy tool for tobacco control.

Using different data and methods, many empirical studies, including Baltagi and Goel (1987), Baltagi and Levin (1992), Chaloupka (1991), Chaloupka and Wechsler (1997), Grossman (1989), Lewit et al. (1981), Lewit and Coate (1982), Lewit et al. (1997), Meier and Licari (1997), Peterson et al. (1992), Sung et al. (1994), and Wasserman et al. (1991), showed that increased cigarette taxation significantly reduced cigarette smoking by discouraging young people from initiating smoking, increasing smoking cessations among grown-ups, and decreasing the average cigarette consumption among ongoing smokers. These empirical findings offer support for the second rationale of using cigarette taxation as a policy to combat smoking.

Although many statistics and empirical findings support the first and second rationales of raising cigarette tax, relatively few studies have directly examined the effects of cigarette taxation on public health. This type of research, however, is of great importance and particular interest to many public health advocates and health policy makers.[7]

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the US, leading to 440,000 deaths every year and costing the nation around $157 billon in medical expenses and lost productivity annually.

[7] As pointed out by Warner (1986), the ultimate importance of tax-induced changes in cigarette consumption lies in their health consequences.

To the best of our knowledge, there are only three researches using econometric methods to provide empirical evidence of health benefits produced by higher cigarette taxes. Moore (1996) used a panel of state data for the years 1954-1988 to analyze the effect of tobacco excise tax changes on smoking-related mortality, and found that tax increases lead to statistically significant decreases in smoking-related mortality. Evans and Ringel (1999) used data from 1989-1992 Natality Detail files to show that raising cigarette tax leads to advantageous impact on mean birth weight. Liu et al. (2008) used a panel of state data for the years 1970-2000 to estimate the effect of tobacco excise tax changes on smoking-related morbidity, and found that tax increases lead to small and statistically insignificant decreases in the incidence of many smoking-attributable illnesses.

This research extends the study of Moore (1996) by examining the effectiveness of state and federal cigarette taxes in reducing mortality of cancers of respiratory system, the diseases that are among the top smoking-related negative health outcomes and causes of deaths and disability in the US. Our research extension introduces several innovations. First, we explicitly consider the non-stationarity of data to avoid making incorrect inference[8]. Second, we perform a co-integration analysis of non-stationary data, and hence are able to estimate the long-term effect of cigarette taxation on the prevalence of a leading smoking-attributable disease. In the context of public health, this estimate will validate the use of cigarette excise tax as a tool in campaigns to reduce cigarette smoking. Third, our analysis covers the period from 1954 through 2005, a longer and more up-to-date time span.

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[8] Granger and Newbold (1974) pointed out that ignoring the non-stationarity of dependent and independent variables may lead to spurious inferences.

The rest of this article is organized as follows. Section 2 describes the sources of the data. Section 3 outlines the estimation methods and presents the results. Section 4 concludes.

2. Data

Our data cover the years 1954-2005 for 50 states in the United States and the District of Columbia. The mortality of respiratory cancers (ICD8 160-164, ICD9 160-165 and ICD10 C30-C39) is from the *Vital Statistics of the United States*, *Annual Summary* and the WONDER Database of The Centers for Disease Control and Prevention (CDC). The nominal state and federal cigarette excise tax rates were taken from Orzechowski and Walker (2007). The real cigarette excise tax is defined as the sum of nominal state and federal cigarette excise tax rates (in cents) per pack deflated by Consumer Price Index with the value of 100 in 1983. The summary statistics of the mortality and real cigarette tax rates are reported in Table 1.

3. The Method and Estimations

In order to analyze the relationship between the cigarette tax and the mortality of respiratory cancers, the standard approaches, such as fixed effect models, can be applied. However, as indicated by Entfor (1997), the spurious regression problem could exist by doing so if both independent and dependent variables contain unit roots.[9] A co-integration analysis is more appropriate for non-stationary panel data. Before conducting panel co-integration tests, it is necessary to confirm that the panel has unit root. We use the panel unit root tests proposed by Levin, Lin and Chu (2002) (LLC), Im, Pesaran and Shin (2003) (IPS), and Hadri (2000). Based

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[9] In this case, fixed effect models will produce consistent coefficient estimates, but inconsistent standard errors, meaning the associated *t*-tests are not valid. This is the famous "spurious regression" problem, which was first discussed in Granger and Newbold (1974).

on augmented Dickey-Fuller (1981) test, the LLC test allows the degree of persistence in regression error, the intercept, and trend coefficient to differ across individuals. The IPS test extends LLC framework by averaging individual unit root test statistics in the alternative hypothesis. The LLC and IPS tests are based on the following equation

$$\Delta y_{it} = \alpha_i + \gamma_i t + \delta_i y_{it-1} + \sum_{L=1}^{Pi} \phi_{ij} \Delta y_{it-L} + \varepsilon_{it} \qquad (1)$$

for $i = 1, 2, ..., N$, $N = 51$ and $t = 1, 2, ..., T$, $T = 52$, where y_{it} is the log real excise tax rate on cigarette per pack in 1983 dollar and the log mortalities of respiratory cancers for state *i* in year *t*[10]; α_i denotes the state-specific fixed effects, t denotes deterministic trends[11], and $\delta = \rho - 1$ where ρ is the autoregressive coefficient. Δ is the lag operator, and ε_{it} is the error term. Under the null hypothesis of $\delta = 0$, all series are non-stationary processes for both LLC and IPS tests. However, under the alternative hypothesis, the LLC assumes all series are stationary while the IPS assumes a fraction of series is stationary. The number of lags (P_i) is selected based on the Schwarz Information Criterion (SIC). Bartlett kernel is used for spectral estimation, and Newey-West (1994) was used to choose the bandwidth.

Several time series literature, such as DeJong and Whiteman (1991) and Kwiatkowski et al. (1992), noted that the conventional unit root tests have low power and suggested testing null hypothesis of stationarity against the alternative of a unit root. In order to provide solutions to this problem, Hadri (2000) proposed a residual-based Lagrange multiplier test with a null hypothesis of stationarity for panel data.

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[10] We also conducted all the tests for real excise tax rate and mortalities of respiratory cancers. The main results are the same as the logarithmic data.

[11] There is no obvious deterministic trend in states cigarette tax data while we find evident upward sloping trend in cancers of respiratory system. We perform the panel unit root tests accordingly.

The results of panel unit root tests are presented in Table 2. For both LLC and IPS tests, we fail to reject the null hypothesis for both panels (the log real excise tax rate on cigarette per pack in 1983 dollar and the log mortalities of respiratory cancers). For Hadri's *Z*-test, we reject the null hypothesis for both panels. In other words, we find that both panels have unit roots.

The next step is to test if these two panels have co-integration relationship. If so, we could suggest that there is a long-run association between the log real cigarette excise tax and the log mortality of respiratory cancers. In general, the panel co-integration test provides higher power than traditional time-series based co-integration test originally proposed by Engle and Granger (1987). In this study, the panel co-integration tests developed by Pedroni (1999, 2004) and Kao (1999) are applied.

Pedroni (1999, 2004) proposed the residual-based tests for the null of no co-integration for dynamic panels in which both the short-term dynamic and long-term slope coefficients are allowed to be heterogeneous across individuals. The tests of Pedroni (1999, 2004) are based on the residual estimation of the following equation, which permits the heterogeneous fixed effect and trend terms,

$$y_{it} = \alpha_i + \gamma_i t + \beta_i x_{it} + \varepsilon_{it} \tag{2}$$

where y_{it} is the log mortality of respiratory cancers for state *i* in year *t* and x_{it} is the log real cigarette excise tax for state *i* in year *t*. Pedroni (1999, 2004) suggested the use of seven residual-based panel co-integration statistics, four based on pooling the autoregressive coefficients across the different states for the unit root tests on the estimated residuals (called "panel co-integration statistics"), and three are based on the average of individual estimated autoregressive coefficients for each state (called "group mean co-integration statistics"). Under the null hypothesis, these two types of tests have the same implications. However, under the alternative hypothesis, these tests have different implications. For the panel tests, the alternative assumes that the stationary autoregressive parameter is homogenous, while for the group tests, it is assumed to be heterogeneous.

The results of Pedroni (1999, 2004) panel co-integration tests are reported in Table 3. All seven statistics show the evidence that the null hypothesis of no co-integration should be rejected. For the robustness check, we also perform the Kao (1999) ADF test, which is based on the assumption of strict endogenous regressors. The results shown in Table 3 also provide the same conclusion of rejecting the null hypothesis.

Now that we have established the two series are co-integrated, we use Fully Modified Ordinary Least Square (FMOLS) technique proposed by Pedroni (2000) to estimate the long-run co-integrating vector between the log mortality of respiratory cancers and log cigarette tax. FMOLS was designed for non-stationary panels, and accounts for the endogeneity of the independent variables and the correlation and heteroscedasticity of the error terms, which are possibly present in the long-run economic relationship.

The results of FMOLS are displayed in Table 4. Individual FMOLS estimates and *t*-statistics are reported in the first 51 entries, and the panel estimate is reported at the bottom. The majority of the individual coefficients have the expected signs, and the corresponding *t*-statistics are statistically significant. Based on the panel group FMOLS results, we can conclude that in the long run a 10% increase in real cigarette excise tax leads to 2.5% reduction in mortality of the cancers of the respiratory system, and this effect is statistically significant at 1% level.

4. Conclusion

Cigarette excise taxes have long been used to raise revenue, curtail smoking, and support tobacco prevention and smoking termination programs in the US. Many empirical studies have shown that raising taxes on cigarettes is an effective tool of increasing governments' revenues and reducing the prevalence of smoking and average cigarette consumption. However, fewer studies address the health benefits of tax increases on cigarette. Using state data for the years 1954-2005, this study tries to fill this gap by examining the long-term association between mortality rates of respiratory cancers and cigarette taxes. It was found these two panels are non-stationary and co-integrated series, and the estimated co-integrated vector shows that in the long run a 10% increase in real cigarette excise tax leads to 2.5% reduction in mortality. This effect is statistically significant at 1% level. Thus, cigarette tax serves as an effective means toward improving public health, as well as a potent tool for devising health policy.

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Table 1: Descriptive Characteristics and Variable Definitions

Variables	Mean	Standard Deviation	Description
Mortality of respiratory cancers	42.522	18.040	Death rate of cancers of the respiratory system per 100,000 persons.
Logarithm of mortality of respiratory cancers	3.639	0.503	Logarithm of death rate of cancers of the respiratory system per 100,000 persons.
Cigarette tax (in cents) per pack	39.488	14.839	Real state and federal excise tax in 1983 dollars (deflated using CPI) per pack of cigarettes.
Logarithm of cigarette tax per pack	3.614	0.349	Logarithm of real state and federal excise tax in 1983 dollars (deflated using CPI) per pack of cigarettes.

Table 2: Tests of Panel Unit Roots for the Logarithms of Mortality and Real Cigarette Tax, 1954-2005

Variables	Levin, Lin, and Chu (2002)		Im, Pesaran, and Shin (2003)		Hadri (2000)	
	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value
Logarithm of mortality of respiratory cancers	4.179	1.000	10.642	1.000	28.769	0.000
Logarithm of cigarette tax per pack	5.221	1.000	4.785	1.000	10.781	0.000

Notes: 1. The null hypothesis in Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003) is that all individual series have unit roots. 2. The null hypothesis in Hadri (2000) is that that all individual series are stationary.

Table 3: Panel Co-integration Tests: 1954-2005

Pedroni (1999, 2004) Tests		Kao (1999) Test	
Panel *ν*-statistic	1.468 (0.071)	ADF-Test	19.963 (0.000)
Panel ρ-statistic	-7.271 (0.000)		
Panel *t*-statistic (non-parametric)	-16.317 (0.000)		
Panel *t*-statistic (parametric)	-16.309 (0.000)		
Group ρ-statistic	-2.061 (0.020)		
Group *t*-statistic (non-parametric)	-7.828 (0.000)		
Group *t*-statistic (parametric)	-7.401 (0.000)		

Notes: 1. The null hypotheses in Pedroni (1999, 2004) and Kao (1999) is that two panels are not co-integrated. 2. *p*-values are in parenthesis. 3. To choose the appropriate lags, we use the automatic selection method to minimize the Schwarz information criteria (SIC): 2(L/T)+klog(T)/T, where L is the selected Newey-West (1994) bandwidth parameter, T is the sample size, and k is the number of degrees of freedom used in model fitting.

Table 4: FMOLS Results

Individual Coefficient		
State	Coefficient	*t*-statistic
Alabama	-0.440	-2.880***
Alaska	0.290	3.910***
Arizona	-0.110	-1.830*
Arkansas	-0.490	-2.320**
California	-0.680	-5.940***
Colorado	-0.410	-2.880***
Connecticut	-0.560	-5.240***
Delaware	-0.060	-0.610
District of Columbia	-0.340	-4.690***
Florida	0.340	6.010***
Georgia	-0.040	-0.450
Hawaii	0.120	2.880***
Idaho	-0.230	-2.610**
Illinois	-0.490	-4.570***
Indiana	-0.050	-0.720
Iowa	0.020	0.310
Kansas	-0.050	-0.480
Kentucky	-0.740	-17.390***
Louisiana	0.010	0.300
Maine	0.080	1.360

Maryland	-0.290	-4.850***
Massachusetts	-0.290	-2.260**
Michigan	-0.010	-0.420
Minnesota	-0.080	-2.800***
Mississippi	-0.600	-4.370***
Missouri	0.040	0.990
Montana	-0.180	-1.920*
Nebraska	0.010	0.130
Nevada	-0.020	-0.140
New Hampshire	-1.190	-3.820***
New Jersey	-0.520	-4.870***
New Mexico	-0.340	-3.360***
New York	-0.730	-6.570***
North Carolina	-1.500	-5.440***
North Dakota	0.040	0.170
Ohio	-0.050	-1.290
Oklahoma	-0.090	-2.210**
Oregon	-0.040	-1.110
Pennsylvania	-0.010	-0.240
Rhode Island	-0.230	-1.080
South Carolina	-0.740	-10.980***
South Dakota	-0.760	-3.320***
Tennessee	-0.380	-4.590***

Texas	0.430	4.160***
Utah	-0.270	-0.910
Vermont	0.250	1.260
Virginia	-0.170	-2.150**
Washington	-0.340	-7.680***
West Virginia	-0.600	-5.190***
Wisconsin	0.000	0.000
Wyoming	-0.010	-0.070
Panel Coefficient		
	-0.250	-15.790***

Notes: 1. * indicates significance at 10% level. 2. ** indicates significance at 5% level. 3. *** indicates significance at 1% level.