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Unintended consequences of the Clean Air Act: Mortality rates in Appalachian coal mining communities

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ABSTRACT

The 1990 amendments to the US Clean Air Act (CAA) encouraged the growth of mountaintop removal (MTR) coal mining in Central Appalachia. This study tests the hypothesis that the amendments had unintended impacts on increasing mortality rates for populations living in these mining areas. We used a panel design to examine adjusted mortality rates for three groups (all-cause, respiratory cancer, and non-cancer respiratory disease) between 1968 and 2014 in 404 counties stratified by MTR and Appalachian/non-Appalachian status. The results showed significant interactions between MTR status and post-CAA period for all three mortality groups. These differences persisted after control for time, age, smoking rates, poverty, obesity, and physician supply. The MTR region in the post-CAA years experienced an excess of approximately 1200 adjusted deaths per year. Although the CAA has benefits, energy policies have in general focused on the combustion portion of the fossil fuel cycle. Other components of fossil fuel production (e.g. extraction, transport, and processing) should be considered in the comprehensive development of sustainable energy policy.

1. Introduction

Amendments to the Clean Air Act (CAA) were implemented in 1990 in the United States with the intent to reduce acid rain and other pollution consequences of burning coal in power plants. Coal reserves in the Central Appalachian region of the United States are relatively low in sulfur content and became more financially attractive after these amendments took effect (Copeland, 2015; Milici, 2000). The motivation to use low sulfur coal consequently increased mining in Central Appalachian areas that were not suitable to conventional techniques – places where coal reserves are located within steep mountaintops or ridges, often at depths of hundreds of feet or in multiple thin beds. The approach developed to reach these coals is a form of surface mining called mountaintop mining or mountaintop removal mining.

Mountaintop removal (MTR) occurred on small scales in Appalachia as early as the 1960s, but it became much more prevalent in the 1990s (Copeland, 2015; Szwilski et al., 2000), and by the current century it had become the largest driver of land-cover alterations in the Central Appalachians (Lindberg et al., 2011). In part, the increase in MTR beginning in the 1990s was because the CAA amendments encouraged the use of low sulfur coal predominant in Central Appalachia (Copeland, 2015; Milici, 2000). Speaking with respect to the 1990CAA amendments, the Vice-President of the West Virginia Coal Association stated, “It is because of the (Environmental Protection Agency's) action with respect to the acid rain provisions of the act that allowed for these large mountaintop mines to develop and flourish.” (State Journal, 2013)

Mountaintop removal mining involves clearcutting forests and using explosives and heavy machinery to remove up to hundreds of feet of rock and soil above and between coal layers. The excavated material creates an “immense quantity of excess spoil” (Copeland, 2015) that is dumped into adjacent valleys, burying headwater streams. A single valley fill may be over a 1000 feet wide and a mile long. As early as 1992 the Environmental Protection Agency (EPA) had estimated that 1200 miles of Appalachian streams had been buried by surface mining. MTR occurs in close proximity to human settlements and takes place in hundreds of sites over a land area in Central Appalachia roughly equal in size to the states of New Hampshire and Vermont combined. The negative impacts of MTR are both socioeconomic (Bell and York, 2010; Hendryx, 2011) and environmental (Bernhardt et al., 2012; Bernhardt and Palmer, 2011; Lindberg et al., 2011; Palmer et al., 2010), both of which may contribute to

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poor public health outcomes for nearby populations. Environmental impacts of MTR include impaired air and water quality in communities proximate to the mine sites (Kurth et al., 2014; Kurth et al., 2015; Orem et al., 2012). MTR sites can be mined with fewer employees per ton of coal extracted relative to other mining forms, and the resulting environmental destruction makes the land unattractive for alternative economic development. In consequence, counties where MTR is practiced have lower income levels, higher poverty rates, and higher unemployment rates compared to other parts of the region (Hendryx, 2011; Hendryx and Ahern, 2009).

The 1990 amendments to the CAA have resulted in a number of benefits. Since its enactment, reductions in the US have been observed for all six of the criteria air pollutants: particulate matter, ozone, lead, carbon monoxide, nitrous oxides and sulfur dioxide. According to the EPA, acid rain decreased 55% between 1990 and 2010 (EPA, 2015). These improvements in air quality translate to improvements in public health, as pollutants from coal combustion contribute to morbidity and premature mortality (Gohlke et al., 2011; Laden et al., 2000; Lewtas, 2007).

However, well intended public policies sometimes have unintended and unanticipated negative consequences (IOM, 2001; Peters et al., 2013). The CAA itself may have provided unintended disincentives to promote development of cleaner power plants (List et al., 2004). Other instances exist in areas of agriculture (Karp et al., 2015), health care (Naylor et al., 2012; Song et al., 2013) and education policy (Metos et al., 2015) where unintended negative consequences resulted from well-meaning policy interventions.

Previous research on the public health impacts of mountaintop removal mining has demonstrated that mortality rates are higher in MTR communities compared to control communities in ways not explained by age, smoking, obesity, socioeconomic status or other risks. Elevated rates have been observed for all-cause mortality (Hendryx, 2011; Hendryx and Ahern, 2009), heart, lung and kidney disease (Hendryx, 2009), and some types of cancer (Ahern and Hendryx, 2012). However, the previous mortality studies were limited to a narrow range of years and did not examine possible CAA effects. The current study extends prior research by testing a specific hypothesis regarding possible unintended consequences of the CAA. We employ a panel analysis design to use counties as their own controls to examine mortality rates pre- and post-CAA in MTR and control areas. If CAA-dependent mortality differences are detected, then they are not due to sociodemographic differences in MTR versus other areas to the extent that the pre-CAA observations in the MTR area serve as an internal control. We also have group comparisons to examine CAA effects in the MTR region compared to other regions. We examine mortality rates for a 47 year period from 1968 through 2014 to test whether all-cause mortality in MTR areas of Central Appalachia increased in the post-CAA years as this method of mining became predominant.

2. Methods

2.1. Design

The study is a secondary analysis of publicly available county-level data. Annual age-adjusted mortality rates for 1968–2014 are investigated in relationship to mountaintop removal mining in Central Appalachia and the implementation of the 1990 amendments to the Clean Air Act (CAA).

The study area consists of the four states where mountaintop removal mining has been practiced, including Kentucky, Tennessee, Virginia and West Virginia. Counties within these states were classified into three groups: those where any amount of mountaintop removal coal mining had been practiced, other counties in Appalachia without mountaintop removal, and the remaining non-Appalachian counties in those states (the latter used as the referent in statistical models). The Appalachian non-MTR group provides a control for general Appalachian effects. Mountaintop removal counties were identified using satellite imagery as reported in earlier papers (Esch and Hendryx, 2011) and confirmed using Energy Information Administration data on tons of coal mined from surface mines (EIA, 2016). Appalachian counties were identified based on Appalachian Regional Commission designations in place in 2010.

2.2. Measures

Age-adjusted all-cause mortality rates for the four states were obtained from the Centers for Disease Control and Prevention (CDC, 2016). Mortality rates are per 100,000 persons and are age-adjusted to the 2000 US population. Mortality rates were reported for each county on an annual basis for the years 1968–2014.

In addition to total mortality, we also examined age-adjusted mortality rates for two diagnostic classes, including respiratory cancer, and all other non-cancer respiratory disease. These classes were selected because of prior evidence that MTR activities generate local air pollution (Kurth et al., 2014; Kurth et al., 2015) and may promote poor health outcomes for these conditions (Christian et al. 2011; Hendryx et al., 2008; Hendryx, 2009; Hendryx and Luo, 2015). Toxicological data suggest ultrafine particulate matter, a chief air pollutant from MTR mining, may promote pulmonary inflammation, oxidative stress, and Ca^{++} influx within lung cells (Donaldson et al., 2004). These may act as a mechanism for long-term, delayed, neoplastic promotion. In instances of small numbers of cases in counties within single years, the CDC suppresses the data values to protect patient confidentiality. For this reason, we aggregated mortality rates for these diagnostic groups into five-year blocks to increase case numbers and eliminate suppressed values.

Data on covariates were obtained from the County Health Rankings data for 2015 (County Health Rankings, 2016). Each county had single cross-sectional measures for the adult smoking rate, obesity rate, child poverty rate, and per capita supply of primary care physicians. In a few instances where covariate data were missing for the county, the missing observations were replaced with state averages.

Descriptive summaries of annual age-adjusted mortality rates were found for the three county groups (MTR, other Appalachian, and other). Then, a panel design analysis was conducted to investigate age-adjusted mortality rates in relationship to time, county group, covariates, and implementation of the CAA amendments of 1990. The years 1968–1989 were designated as pre-CAA and the years 1990–2014 were designated as post-CAA. The analyses were conducted using SAS version 9.4 Proc Mixed, specifying the year as a repeated measure, and the county, county group, and CAA dummy variable as class variables. An autoregressive value of 1 was specified to account for correlated mortality rates from one year to the next. We first tested a model with main effects for year, the CAA dummy variable, and county group. A second model added covariates. A final model was estimated after adding an interaction term between county group and the CAA indicator. The final interaction term tests whether age-adjusted mortality rates were significantly higher in the MTR areas in the post-CAA period while controlling for covariates and year-to-year trends.

3. Results

Data for a total of 404 counties were available for the analysis, including 37 MTR counties, 149 other Appalachian counties, and