Coal Mining, Health, and Morbidity: A Brief Overview of the Empirical Scholarly Literature from a Regional Science Perspective

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Abstract

Numerous peer-reviewed studies have documented significantly poorer health conditions across multiple health indicators among people residing in coal-mining areas versus those living in non coal-mining areas. This brief literature review provides an overview and limited critique of this literature for those whose environmental concerns encompass the world of coal mining and offers recommendations for future research on human helath and negative coal mining externalities.

1 Introduction

The burning of coal leads to the emission of poisonous gases that generate negative health impacts and environmental problems; these negative externalities are found in the air breathed and the water consumed by humans and other animals (Munawer, 2018, p. 87). Not surprisingly, in recent years, numerous studies have empirically investigated the linkage of various measures of compromised health and coal mining activities. It is commonplace for such studies to find that coal mining activities and coal dust exposure have adversely impacted upon the physical *health and well-being* among the population (e.g., Attfield, 1985; Jacobsen, 1993; Marine et al., 1988; Oxman et al., 2012; Lapp et al., 1994; Carta et al., 1996; Coggon and Taylor, 1998; Hendryx and Zullig, 2009; Zullig and Hendryx, 2011; Munawer, 2018; Liu and Liu, 2020; Richmond-Bryant et al., 2020; Glencross et al., 2020; Gasparotto and Martinello, 2021). More specifically, numerous peer-reviewed studies have documented significantly poorer health conditions across multiple health indicators among people living in mining areas versus those living in non-mining areas. This brief literature review provides an overview and limited critique of this literature for those whose environmental concerns encompass the world of coal mining. Arguably this paper could be regarded as a methodological extension of the very useful review article by Liu and Liu (2020) in which there is a focus on the toxicity of nanoparticles [nano-sized coal mine dust] and its harmful impact on human health.

2 The Literature Overview

The literature directed at coal mining and its externalities has an extensive history. In the interest of focusing on more contemporary scholarship, the focus in this study covers largely the last quarter of a century. Accordingly, we begin with the study by Carta et al. (1996), which focuses upon the role of coal dust exposure on the incidence of both respiratory symptoms and the decline of lung function in young coal miners. Their results show that even a pattern of only moderate such exposure to coal dust significantly deleteriously affects the lung function and incidence of symptoms of underground miners. Moreover, using logistic models, they have determined that coal dust exposure was also found to be a significant predictor of the onset of respiratory symptoms, along with age and smoking.

Indeed, such effects have been shown to extend beyond the general population of currently active/employed miners and ex-miners who by definition have been *directly* exposed to coal dust and even extend to new-born infants. For example, in an empirical study undertaken by Ahern et al. (2011), *birth defects* are examined in mountaintop coal mining areas and compared to other coal mining areas and non-coal-mining areas at the county level for *four* states in Central Appalachia, namely, the states of Kentucky, Tennessee, Virginia, and West Virginia. The hypothesis tested in this study was that higher birth-defect rates are present in mountaintop mining areas. National Center for Health Statistics natality files were used to analyze 1996–2003 live births in these four Central Appalachian states (N=1,889,071). Poisson regression models that control for a number of covariates compare birth-defect prevalence rates associated with maternal residence in mountaintop mining areas, other mining areas, and non-mining areas. In a finding that was compatible in principle with a majority of previous related published research, Ahern et al. (2011) infer that the prevalence rate ratio for essentially any categorized birth defect was found to be significantly higher in mountaintop mining areas as compared to non-mining areas, even after controlling for a host of covariates. In greater detail, it was found that prevalence rate ratios were significantly higher in mountaintop mining areas for six out of seven types of birth defects, namely: circulatory/respiratory, central nervous system, musculoskeletal, gastrointestinal, urogenital, and "other." Moreover, there was also preliminary evidence suggesting that spatial correlation between mountaintop mining and birth defects was present, implying in turn that there can be impacts (spillovers) from mountaintop mining in a local county on the incidence of birth defects in neighboring counties.

Shifting gears from health issues such as those identified above to *mortality* rates/probabilities *per se*, there is a published literature linking higher morbidity rates to coal dust exposure, albeit a literature accompanied by at least some degree of controversy. To illustrate the latter phenomenon, consider, e.g., the study by Borak et al. (2012), which seeks to determine the predictive value of coal mining activities and other risk factors for explaining disproportionately high mortality rates within Appalachia. Mortality and covariate data were reported to have been obtained from publicly available databases for 2000 through 2004. The study undertook OLS (i.e., ordinary least squares) regression with age-adjusted mortality being the dependent variable. Among other things, this study found that age-adjusted all-cause mortality was positively related to the percentage poverty rate, negatively related to median household income, negatively related to the percentage of the population with a high school diploma, and positively related to the percent of the population depicted as obese, but not related to (impacted by) the unemployment rate, the percent of the population having health insurance, the percent of the population with a four-year degree, the availability of physicians (per capita), smoking behavior, diabetes, or *coal mining*. The lattermost finding runs against the findings in effectively all of the related literature, whereas the Borak et al. (2012) study essentially stands alone and emphasizes instead the ramifications of substantial economic and cultural disadvantages that adversely impact health in Appalachia, especially in the more coal-mining intensive areas of Central Appalachia.

More specifically, this paper by Borak et al. (2012) appears fundamentally at odds not only with previous studies but also with subsequent studies (e.g., Liddell, 1973; Rockette, 1977; Miller and Jacobsen, 1985; Landen et al., 2011; Reynolds et al., 2017; Liu and Liu, 2020; Ghosh and Cebula, 2021; Gasparotto and Martinello, 2021). Not surprisingly, the validity of this study was seriously questioned in a 'Reply' crafted by Hendryx and Ahern (2012). In particular, Hendryx and Ahern (2012) state that they find significant effects of coal mining on population mortality that are robust to multiple model specifications, including the specification adopted by and estimated by Borak et al. (2012). Indeed, this disparity prompted a challenge by Hendryx and Ahern (2012) to Borak et al. (2012) to openly demonstrate the validity of their (arguably 'atypical') findings in terms of coal mining activities *per se*.

To more fully appreciate the position/perspective expressed by Hendryx and Ahern (2012), one could consider the study by Landen et al. (2011), which begins with the premise that background particulate exposure from air pollution has been found to elevate the risk of ischemic heart disease (IHD) mortality. Landen et al. (2011, p. 727) find that, after having adjusted for age, smoking, and body mass index, the risk of IHD mortality increased with greater levels of coal dust exposure. Other research yields very similar, i.e., parallel results to those in Ahern et al. (2011) and Landen et al. (2011), as evidenced by, e.g., by the Brabin et al. (1994) study of schoolchildren who have been exposed to coal dust and Reynolds et al. (2017), which looks at Coal Workers' Pneumoconiosis (CWP) across the nation. The study by Reynolds et al. (2017, p. 513) is pertinent if not compelling because it observes that "Coal is mined in approximately half of all U.S. states... ." Reynolds et al. (2017, p. 513) emphasizes the magnitude of the miner population, and hence of the population at risk in the coal-mining industry when observing that "...miners working outside central Appalachia account for 57.1% of the country's 65 000 coal miners."

Moreover, the concern over the health effects and ultimately, the morbidity effects (end-stage disease effects), of coal dust exposure continues on many fronts. As observed by Laney and Weissman (2014, p. S18),

> Coal mine dust causes a spectrum of lung diseases collectively termed coal mine dust lung disease (CMDLD). These include Coal Workers' Pneumoconiosis [CWP], silicosis, mixed dust pneumoconiosis, dust-related diffuse fibrosis. . . and chronic obstructive pulmonary disease. CMDLD continues to be a problem in the United States, particularly in the central Appalachian region. Treatment of CMDLD is symptomatic. Those with end-stage disease are candidates for lung transplantation. Because CMDLD cannot be cured, prevention is critical.

Another (and yet more recent) study of the health hazards attributable to or associated with coal mining is that by Shi et al. (2019). The authors of this empirical study endeavor to elevate our understanding of underlying factors that may be associated with the so-called "coal-county effect." Furthermore, Shi et al. (2019) aim to identify factors that can be targeted by policymakers to improve health in coal-mining counties. Among other things, this study is found to imply that the incidence of non-malignant respiratory diseases (NMRD) is a decreasing function of health insurance coverage and an increasing function of higher smoking rates as well as a shortage of physicians. Not surprisingly, analyzing individual-level mortality data, the study also finds that there is a higher risk of dying from NMRD associated with residence in a coal-mining county. Interestingly, however, this deduction is *not* found to apply to living in an adjacent county. Thus, wind, rain, flooding, and other means of geographic movement of coal dust and other pollutants associated with coal mining activities are not identified as culprits in the dismal relationship between increased mortality.

The very recent study by Gasparotto and Martinello (2021, p. 113) makes an observation that is compatible with most of the existing related literature, namely:

> The inhalation of hazardous substances such as coal micro-particles, nanoparticles, and its by-products constitutes. . . risk to human health. Although coal is predominantly composed of carbon, there are many other constituents including sulfur, nitrogen, organometallic compounds, and minerals, that contribute to the formation of extremely toxic secondary compounds that come in contact with the atmosphere.

Gasparotto and Martinello (2021, p. 113) proceed to observe what nearly all researchers on coal and human health have: inhaling of these substances as a trigger "to many diseases such as respiratory and cardiovascular disease, systemic inflammation, and euro degeneration."

However, they proceed to emphasize that due to extreme coal *heterogeneity* from one location to another, it is a very complex process to establish all the effects of the coal dust molecules on humans. Stated somewhat differently, each human cell can undergo different modifications depending on the stressing molecule. On that account, inhaling air contaminated with these particles can be highly dangerous but yield highly *unpredictable* health outcomes. Thus, the heterogeneity of the coal being mined, in and of itself, can greatly complicate the human health outcome prediction process and, by extension, the formulation of optimal medical treatment plans. The authors proceed to describe the impacts of inhaling coal dust and other related pollutants in terms of the lungs,[1] immune system (see also Glencross et al., 2020), heart, brain, reproductive system, and DNA, while acknowledging the significance of comorbidity factors such as smoking, lack of exercise, and poor diet. Ultimately, Gasparotto and Martinello (2021) take the position that the continued utilization of coal as an energy source requires that adequate measures are in place for environmental protection and to safeguard human health. Nevertheless, they emphasize that coal heterogeneity across geographical space complicates the formulation of practical, efficient, and sound public policies, a perspective that many previous researchers did not directly acknowledge.

[1] It is noteworthy that the inhalation of polluted air is ranked as the ninth leading risk factor for cardiopulmonary mortality (Kurt et al., 2016; Munawer, 2018).

3 A Critical Missing Consideration: Geospatial Estimation

This body of research, which extends significantly beyond the functionally representative list of studies alluded to and described here, and especially the evidence of the possible presence of spatial correlation between coal mining and human health as suggested in the early study by Ahern et al. (2011) along with the continued serious concern regarding coal dust effects in terms not only of a number of health markers but also in terms of morbidity *per se*, is troublesome. Moreover, it is argued here that further insights into the coal dust/health/morbidity issue are needed that formally address spatial correlation considerations (Elhorst, 2010, 2014; LeSage and Pace, 2009). Doing so would very likely help establish a stronger foundation for both a proper/efficient allocation of resources to address the consequences of both past and currently active coal mining activities as well as to establish appropriate forms and degrees of environmental regulation and control in order to more efficiently protect public health.

Relevant to this discussion is a recent study by Ghosh and Cebula (2021), which endeavors to take spatial correlation seriously into account. The existing body of scholarly studies regarding the impact of coal production on deaths are very useful insofar as they funnel attention to the critical public health/coal dust issue. Aside from Ahern et al. (2011), however, such studies for the U.S. take into consideration only the simple correlation between coal production and death rates. Indeed, Ahern et al. (2011) is one of the very few studies which considers the spatial correlation between coal production and the human health effects thereof, albeit for solely the case of birth defects in a limited number of counties across four states of the Appalachian Region.

The Ghosh and Cebula (2021) study contributes to the literature in terms of analyzing the spatial effects of coal production on deaths due to respiratory diseases throughout all of the counties of the *entire* Appalachian Region. In addition, the main findings of the Ghosh and Cebula (2021) article address the fact that the full impact in any given county of coal production on mortality rates is not strictly limited to or attributable simply to coal production in that particular county but rather reflects the fact that the amount of coal produced also has measurable spillover effects on the mortality rates of the neighboring counties (and vice versa). Thus, among other things, their findings imply that the hazardous health effects of greater coal production in fact lead to an increased death rate among the residents of neighboring counties as well. Furthermore, for reasons provided above, it may also very well be that the residents of the counties producing coal in the Appalachian Region also exhibit poor lifestyle choices, leading to even higher death rates.

One of the principal concerns addressed in the Ghosh and Cebula (2021) study is the set of endogenous regressors. Future research should focus on identifying possible endogeneity and, accordingly, should also focus on including appropriate instruments to address that endogeneity should it be necessary to do. Moreover, future research on the topic of this study might focus upon expanding the model to include additional explanatory variables as well as addressing the issue of coal heterogeneity (Gasparotto and Martinello, 2021). Finally, the findings in Ghosh and Cebula (2021) arguably may prove useful to the formulation of public policies towards coal mining by adding depth to the cost-benefit tools of policymakers dealing with the environment, public health, and regulatory efficiency.

In any case, this brief literature overview is in principle in agreement with the conclusions in Liu and Liu (2020) as well as Gasparotto and Martinello (2021), although the focus of the latter studies is different. In particular, we agree that much more research into the complexities of the coal/human health nexus is needed, including research that addresses the coal heterogeneity issue. Furthermore, we support the idea of applying much more sophisticated research techniques to the human health impacts of coal dust and correlated pollutants as in Elhorst (2010), Ahern et al. (2011), and Ghosh and Cebula (2021). A better and more accurate understanding of the human health as well as the economic costs of coal dust is needed in order to formulate efficient and effective public policies regarding this serious social/economic/human health problem.

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