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Down comes the mountain : coal mining and health in central Appalachia from 2000 to 2010.

James Kent Pugh
University of Louisville

DOWN COMES THE MOUNTAIN: COAL MINING AND HEALTH IN CENTRAL
APPALACHIA FROM 2000 TO 2010

By

James Kent Pugh
B.A., Berea College, 2012

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April 7, 2014

by the following Thesis Committee:

_____

Robin S. Högnäs, Chair
Assistant Professor of Sociology

_____

Cynthia Negrey, Member
Professor of Sociology

_____

Kristina M. Zierold, Member
Associate Professor of Epidemiology & Population Health

DEDICATION

This thesis is dedicated to my parents,

Mrs. Jeanie Denise Pugh

and

Mr. James Scott Pugh (R.I.P.).

Thorough their hard work and dedication I am here today.

ABSTRACT

DOWN COMES THE MOUNTAIN: COAL MINING AND HEALTH IN CENTRAL

APPALACHIA FROM 2000 TO 2010

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Appalachia is one of the unhealthiest and most economically disadvantaged regions in

America. It has higher rates of diseases (including heart disease and cancer) than the rest

of the United States. Past research posits that low socioeconomic conditions in

Appalachia are the main determinants of health disparities, and a burgeoning body of

literature is examines the relationship between coal mining and health. The latter shows

that, when controlling for socioeconomic status, health status remains significantly lower

in coal-producing, Appalachian counties compared to non-coal producing Appalachian

counties. While previous studies examine coal production over one or two years, they do

not consider change in coal production and health over a longer period of time. This work

focuses on the relationship between coal production and health over an 11 year period in

counties in Eastern Kentucky and West Virginia. The results suggest that regional

changes in coal production are associated with changes in average county-level health.

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INTRODUCTION

Appalachia has long been an unhealthy and poor region in the United States. Central Appalachia, i.e., Eastern Kentucky and West Virginia, has higher rates of heart disease, cancer, particularly breast cancer, stroke, and chronic obstructive pulmonary disease (COPD) compared to the United States as a whole (Halverson, Ma , and Harner 2004). In 2009, approximately 6.5% of the adult population in West Virginia had experienced a heart attack (Shanholtzer 2012). In 2011, 6.6% of adults in Kentucky had experienced a heart attack compared to the overall national average, which was 4.4% of adults (Kentucky BRFSS Data 2011).

While the overall rates of disease in Kentucky are concerning, these rates increase dramatically across communities in Eastern Kentucky, where between 8-10% of the population has experienced a heart attack, which is nearly double the national rates (Kentucky BRFSS Data 2011). One characteristic associated with differences in chronic illness both within Appalachia and between the region and other parts of the United States is coal mining. The extent to which coal mining influences health adversely in Appalachia is of increasing interest in the extant literature (and beyond) and is the primary focus of this study.

History of Coal in Appalachia

Since the mid-19th century, coal mining and production in Central Appalachia has been a primary energy source for many Americans. Coal mining started in earnest in the

1870s and 1880s following the Civil War. Young men from the North, who visited Appalachia during wartime, discovered the unexploited abundance of coal and timber in the region and returned to invest in the extraction of these natural resources after the war (Williams 2002). What followed was the opening and operation of coal mines by some of America's largest corporations such as US Steel and International Harvester (Williams 2002; Burns 2007). Coal is a big commodity and has arguably shaped Appalachia's political, economic, and social history.

As a commodity, coal is prone to "boom and bust" cycles (Williams 2002; Burns 2007; Goodell 2007; Eller 2008). Boom and bust cycles involve periods of high demand and low supply and are usually followed by a glut, i.e., excess production with decreases in price and demand (Williams 2002; Burns 2007; Goodell 2007; Eller 2008). During the two World Wars of the first part of the 20th century, coal production in Appalachia boomed but was followed shortly by a bust (i.e., mass layoffs and mine closings) once the wars ended (Burns 2007; Eller 2008). The bust following World War II, however, stretched well into the 1950's and 1960's, and had a far sharper increase in unemployment due to changes in the energy market and the production of coal (Burns 2007; Eller 2008).

Changes in Coal Mining Technology

Technological improvements and energy-use shifts from coal to oil meant dramatic declines in coal mining employment in Appalachia (Burns 2007; Eller 2008). For example, in West Virginia, approximately 100,000 miners where employed during the 1950s, but fewer than 10,000 miners were employed in the year 2000, just 50 years later (Burns 2007). New technology, including a machine called a "Continuous Miner,"

which has a large drill bit and a conveyer belt, replaced workers and would dig and transport coal to the surface. These shifts in production created a new form of mining in Central Appalachia, Mountaintop Coal Removal (Eller 2008). Mountaintop Coal Removal (MTR), or surface mining, began in the late 1960's and 1970's as a cheaper way to mine for coal (Goodell 2007; Eller 2008). This mining process allows for the tops of mountains to be removed and shoveled into lower valleys (Burns 2007). Outrage from this mining process by many citizens from Central Appalachia brought about the passage of the Surface Mining Control and Reclamation Act of 1977 in the U.S. Congress (Eller 2008). This law required that coal companies reclaim the land to the original contour of the mountain (Burns 2007; Eller 2008). However, a loophole in the law means that reclamation is not required if the newly flattened land is used for "economic development" (Eller 2008). While land reclamation is averted because of this loophole, companies do not necessarily use the land for economic development and most of the former MTR sites, which are largely geographically isolated, sit vacant (Burns 2007; Eller 2008). As MTR coal mining increased between the 1970's and 1990's, the number and extent of abandoned mine sites increased.

Following the Oil Crisis in the 1970's and continuing through the 1990s, coal production in Appalachia rebounded (Goodell 2007). The Clean Air Act provided an opportunity for Appalachian coal producers. That is, coal mined in Central Appalachia burned cleaner than coal produced elsewhere; so many power plants began to switch from coal mined in Wyoming, for example, to coal mined in West Virginia and Kentucky (Goodell 2007). Reliance on Appalachian coal was accompanied

by an increase in MTR coal mining. By the year 2000, MTR made up nearly half of all of the coal mined in the Appalachian region (Eller 2008).

Coal production in Appalachia, overall, has steadily decreased in the years following a boom in the late 1990's and early 2000's (Bruggers 2013). In 2001, coal production in Eastern Kentucky was 109,098,000 tons of coal, but by 2010, coal production had fallen to 68,000,000 tons of coal produced (Annual Coal Report 2000-2010). In West Virginia, coal production was 158,257,000 tons of coal in 2000, but had decreased to 135,220,000 tons of coal by 2010 (Annual Coal Report 2000-2010). While coal mining in Appalachia increased during the 1990's, health trends were heading in the opposite direction.

Appalachian Health Trends

Appalachia is and has been an unhealthy region for an extended period of time. Halverson (2004) found that, between 1990 and 1997, Appalachian counties had a higher median mortality from all cancer types and heart disease than the U.S. national median. During the same period, white men in Appalachia ages 35 to 64, had a median heart disease mortality rate of approximately 230 deaths per 100,000 people compared to white men in all of the U.S., at approximately 188 deaths per 100,000 (Halverson 2004). White men ages 35 to 64 in Appalachia had a cancer (all types) mortality rate of approximately 198 deaths per 100,000 people compared to approximately 174 in all of the U.S. (Halverson 2004). The highest rates of mortality for heart disease and cancer for white men and women are found in counties in Eastern Kentucky and West Virginia (Halverson 2004). Halverson also found that these rates have continued to increase into the 2000's.

Mortality rates suggest cause for concern about larger health problems in the Appalachian region.

Coal Mining and Health in Appalachia

A growing body of literature shows a significant association between MTR coal mining and health and well-being for the people who live in the coalfields of Central Appalachia. Recent studies, of coal mining in Central Appalachia, show higher rates of cancer (Hendryx, O'Donnell, and Horn 2009), cardiovascular disease (Hednryx and Zullig 2009), kidney and respiratory diseases (Hendryx 2009) and associated risks for people living in coal producing versus non-coal producing communities in the Central Appalachian region. A 2013 comparative study of three counties in Eastern Kentucky, one that produced MTR coal and two that did not, found significant differences in health outcomes (Hendryx 2013). Respondents in MTR coal mining counties reported two times as many heart attacks, two times the number of cases of hypertension and asthma, and more than three times as many cases of chronic obstructive pulmonary disease (COPD) compared to non-MTR coal mining counties in Eastern Kentucky (Hendryx 2013). Hendryx compared counties with similar demographics (e.g., SES, age, race) and found that living in counties with MTR coal mining exacerbated existing health inequalities (2013).

While research has found significant links between coal mining and health, there has been little research examining changes in the association between Appalachian coal mining and health over time. A total of 20 to 30 peer-reviewed journal articles have been written about the impacts of coal mining on the environment in the Appalachian region. Less than half of these articles have examined the relationship between coal mining and

population health. Many previous studies have examined mortality, morbidity, and disease prevalence over a one to two year period of time (Hendryx, O'Donnell, and Horn 2009; Hednryx and Zullig 2009; Hendryx 2009). Hendryx and Ahern (2009), on the other hand, examined coal mining and health over more than two years, but they emphasized mortality rates and the "Value of Statistical Life Lost" between 1979 and 2005. Their study does not focus explicitly on how changes in the production of coal influences changes in health among those who live in coal and non-coal producing counties.

This work seeks to fill the gap in the extant literature by posing the following research question: Do changes in coal production in counties within Eastern Kentucky and West Virginia between the years of 2000 and 2010 influence changes in self-reported health during this same period? To examine this question, I use county-level data from the Behavioral Risk Factor Surveillance System (N=83) with a focus on the 11-year period between 2000 and 2010. The primary goal of this research is to contribute to the existing body of literature a better understanding of how the dynamic process of coal production, particularly MTR coal production, influences health among populations where health is already compromised by poverty and inequality.

LITERATURE REVIEW

Conceptual Model of SES, Environmental Exposure, and Health

I begin the literature review with a conceptual model which describes the factors associated with social and physical environment and health. The link between socioeconomic status and health is well established (Taylor 2000; Brown 1995; Krleger 2001; Bruelle and Pillow 2006; Hendryx 2011). In addition, research shows that the physical environment to which a person is exposed has an impact on their health (Northridge et. al. 2003; Bruelle and Pillow 2006). Subsequently, socioeconomic status (SES) and exposure to environmental hazards may negatively impact health either independently or conjointly (Northridge et. al. 2003). Environmental factors may compound the negative impact of poverty on health. For example, the poor who live near toxic waste facilities may live there because they are poor, the rent is cheaper than elsewhere, and they lack the resources to move or protect themselves from environmental toxins. Environmental exposure to toxins, in this example, compounds existing risks to health associated with being poor. For instance, a family may have few financial resources to purchase healthy food or to purchase medical care, and thus lack the economic and social resources to protect their health. A lack of resources makes families susceptible to disease and health problems, and thus living in an environmentally hazardous community increases and compounds existing risks.

Drawing from Adler and Ostrove (1999), Figure 1 shows a conceptual model[1] for understanding the relationship between physical environment, social environment (e.g., SES, income, occupation) and population health and illness. Physical[(1)] and social environment[(2)] likely interact with each other to impact a population's exposure to environmental risk[(3)] and subsequently the overall health and wellbeing of a community[(4)]. While the interaction between physical and social environment is not the primary focus of this study, I discuss it as it relates to population health and view it as an important direction for future research.

Physical environmental[(1)] risks include residence near toxic waste landfills, impacts of pollution on water or air quality, and flooding or damage done because of mining or construction among others. Environmental Hazards[(3)] expose individuals to health risks from contact, consumption, or exposure to substances that are harmful to health and well-being. Environmental hazards can be chemical agents such as pesticides or air pollutants, physical agents such as noise or heat, or biological agents such as micro-organisms and their toxins. Individuals living in physical environments where environmental hazards exist can do little to control their exposure (Northridge et al 2003; Bruelle and Pillow 2006). Many of the factors that limit the ability for people to control their exposure to environmental hazards are related to their social environment[(2)].

Socioeconomic Status and Health

In the conceptual model in Figure 1, social environment[(2)] has to do with whether or not people live in a high poverty area (e.g, Appalachia), the educational attainment in a community, unemployment rates, among others (Northridge, et al 2003; Bruelle and

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[1] Concepts identified by superscripts 1-4 (which appear in parentheses in this section) correspond to concepts presented in Figure 1.

Pillow 2006). Research consistently shows that socioeconomic status influences individual and population health (Ross and Wu 1995; Adler and Ostrove 1999; Currie and Hermann 2012). The famous Whitehall Study, dating back to 1967, examined the association between socioeconomic status and health (Marmot, et al. 1978; Marmot and Smith 1991; Adler and Ostrove 1999). The original Whitehall study examined the health of male British Civil Servants and found that occupational hierarchy was associated with differences in all-cause and cause-specific mortality (Marmot, et al. 1978; Marmot and Smith 1991). However, the key finding of the Whitehall study was a socioeconomic health gradient, as socioeconomic status (e.g., education levels, income) increases, health outcomes improve.

Since the Whitehall study, researchers have extended knowledge with respect to the socioeconomic gradient in health. Many researchers now point to education as the key component of understanding health outcomes (Palloni, Milesi, White, and Turner 2009). Palloni, Milesi, White, and Turner (2009), for example, used data from a 1958 British cohort to examine the influence of early health conditions on the educational attainment and consequently the SES gradient in health. Findings suggest a small, but important influence of early health conditions on educational attainment and SES mobility. Palloni et al. (2009) further found that increased education is associated with fewer negative health behaviors such as smoking.

In addition to the direct effects of educational attainment and SES on health, researchers have identified stress as a possible mediator between SES and health outcomes. Scholars have consistently found that stress levels, in particular chronic stress, are higher among lower SES groups, African Americans, and other racial and ethnic

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minorities (Adler and Ostrove 1999; Turner and Avison 2003; Grzywacz et al. 2004). Increased stress and chronic stress in particular, and which many lower SES groups experience, has been linked to an increased susceptibility to disease and infection (McEwen and Stellar 1992; Grzywacz et al. 2004; Turner and Avison 2003).

Appalachia is an economically poor region and many researchers point to this as a major factor associated with widespread poor health within the region (Halverson 2004). In a review of the literature, Adler and Ostrove (1999) revealed a consistent SES gradient in morbidity and mortality for cardiovascular disease, diabetes, metabolic syndrome, arthritis, tuberculosis chronic respiratory disease, gastrointestinal disease, and adverse birth outcomes among others. In the case of Appalachia, even when SES is controlled, health status remains significantly poorer in coal-producing Appalachian counties compared to non-coal producing Appalachian counties (Hendryx and Ahern 2009; Hendryx 2013). This research suggests that the production of coal exacerbates existing health problems within these counties.

Health-wise Appalachia has higher than national rates of mortality from all cancers, heart disease, and respiratory diseases (Halverson, et al. 2004; Krause et al. 2011). The mortality rate from heart disease is exceptionally high for the Appalachian region. From 1990 to1997, the mortality rate among Appalachian adults age 35 or older remained above 600 deaths per 100,000 (and 800 to 700 per 100,000 in some counties) while nationally the corresponding mortality remained below 600 deaths per 100,000 (Halverson et al. 2008). Despite Appalachia's disadvantaged SES and health well-being, the region produces 335,248,000 tons of coal, 31% of the U.S. Appalachia produced a total of 1.08 billion tons of coal in 2010. Paradoxically, coal production makes

Appalachia a wealthy region in terms of its natural resources (Young 2010), yet the production of coal itself is argued to negatively influence the health of the Appalachian population.

In addition to poorer health in coal mining counties, these counties tend to have higher rates of mortality compared to the non-coal producing counties in Appalachia and in the U.S. overall (Hendryx and Ahern 2009). This is not surprising given that income levels are also lower, poverty rates are higher, and the population is less educated and more likely to be unemployed—each of which is associated with poor health and mortality. Hendryx and Ahern (2009) found that mining counties in Appalachia had a significantly higher average poverty rate (18%) than the United States (13.3%) and non-mining communities in Appalachia (14.5%) between 1979 and 2005. Coal mining Appalachian counties compared to the overall U.S. had significantly lower average median household incomes ($28,287 versus $36,622 in rest of the U.S.) and a significantly higher average mortality rate (1,049 per 100,000) compared to both the U.S. overall (923.7 per 100,000) and to non-mining regions of Appalachia (985.6 per 100,000) between 1979 and 2005 (Hendryx and Ahern 2009). Appalachia continues to be a region with a fragile socioeconomic environment.

Appalachia lags behind the rest of the country in educational attainment (Pollard and Jacobsen 2012). Moreover, between 2007 and 2011, the average poverty rate in Appalachia was 16.1% compared to an average national rate of 14.3% (Appalachian Regional Commission). However, the poverty rates in Central Appalachian regions of Eastern Kentucky and West Virginia were considerably higher than Appalachia overall and the country as a whole, 24.8% and 17.5% respectively (Appalachian Regional

Commission). Between 2007 and 2011, Appalachia had fewer adults who had completed high school than the country as a whole. Approximately 83.5% of adults had completed high school in Appalachia compared to 85.4% in the United States; even fewer adults had a high school degree in Eastern Kentucky (72.6%) and West Virginia (82.6%) (Appalachian Regional Commission 2007-2011). Appalachia's fragile social environment makes it more susceptible to the environmental and health impacts of coal mining.

Coal mining's impact upon health exacerbates the already distressing social and economic problems in Appalachia. Hendryx and Ahern (2009) estimated the Value of Statistical Life (VSL) lost in Appalachian coal mining communities. VSL is a measure used by environmental regulatory agencies within the government to determine the value of economic output lost because of higher excess mortality as a result of pollution (Hendryx and Ahern 2009). Hendryx and Ahern (2009) found that between 1979 and 2005, an average of 2,889 excess deaths related to coal mining occurred annually in Appalachia. In addition, the VSL for each of those lives in the same time period was valued at a cost between $4.67 million to $7.74 million per person, placing the total health impact of coal mining in Appalachia at a value of $18,166 billion annually (Hendryx and Ahern 2009). These findings suggest that the physical environment surrounding a population has an important and costly impact on mortality.

Physical Environment and Health

The most impoverished and heavily mined areas of Appalachia are concentrated in West Virginia, southwest Virginia, and Eastern Kentucky. These Appalachian counties with Mountaintop Coal Removal have the highest rates of poverty and significantly higher mortality rates compared to non-mining and underground mining counties

(Hendryx 2011; Hendryx 2013). However, research in this area relies on data which do not allow for the identification of mining sites, rather scholars in this field tend to rely on estimates at the county-level. County-level data are useful and informative, however they do not allow for a more micro-level examination of environmental exposure (Hendryx 2011). Thus, to get at understanding the link between coal mining and health, scholars rely on understanding community-level environmental risks.

Understanding the links between the physical environment and health, in part, has to do with individual- and community-level exposure to risk. In this study, the county-level will serve as proxy for community-level exposure. The proximity of chemical plants, waste dumps, and other human health hazards to communities may put nearby people at a higher risk of contracting disease and developing health problems (Northridge, et. al 2003; Bruelle and Pillow 2006). The location, size, regulations, provisions, and operating procedures are decided largely by the policies of large corporations and local, national, and state governments. Local communities may have a voice, but in many instances it is not until decisions regarding environmental risks and hazards have been made (Bruelle and Pillow 2006). It is from decisions by governments, corporations, and other change agents that environmental inequality along race and class lines develops in addition to other forms of "environmental inequality" (Bruelle and Pillow 2006). Low-income communities and minority communities disproportionately bear the brunt of environmental injustice (Taylor 2000; Brown 1995; Krleger 2001; Bruelle and Pillow 2006) which puts low-income and minority communities at a higher risk for poorer health outcomes (Northridge, et al. 2003; Krleger 2001). Thus, the the overall SES of a community and lack of ability to influence the regulatory process within

a community, potentially impacts the community's risk of exposure to environmental toxins.

In the context of Appalachia, there is a long and documented history of little community involvement in approving and regulating coal mines, including Mountaintop Coal removal (Burns 2007). Large coal companies have long had an outsized impact on regulation and government policy in Appalachia through political intimidation, campaign contributions, and corruption of elected officials (Burns 2007). The outcome of this control is lax mining and lax environmental regulations in Kentucky and West Virginia, despite the protest and ire of many citizens and community groups (Burns 2007). Thus, the power of large coal interests to dominate politically and to influence the regulation of mines and the environment has increased the risk of exposure to toxins for residents of coal mining communities, many of whom are poor (Burns 2007). Large coal interests (i.e., physical environment [1] in Figure 1) thus impact the social and economic consequences (i.e., social environment [2] in Figure 1) of communities and their exposure to environmental toxins. Overall, the process through coal mining decisions are made, along with all that follows, leads to environmental inequality.

Intuitively, environmental inequality is closely linked to—if not synonymous with—social inequality and while I am not proposing to examine the process through which environmental inequality emerges, a brief discussion is warranted. Gould Schnaiberg argues that environmental inequality is the product of what he refers to as the "treadmill of production" (Schnaiberg 1994; Bruelle and Pillow 2006). His argument suggests that ecological problems are created and reinforced by economic production and consumption. Market economies require a continual production of commodities, which

subsequently relies on continuous consumption of materials and energy (Schnaiberg 1994; Bruelle and Pillow 2006). The result of ongoing production and consumption is wealth and negative byproducts. This creates an alliance between governments, labor, and businesses to keep the treadmill of production going at all costs (Schnaiberg 1994; Bruelle and Pillow 2006). Governments benefit through higher taxes, labor through higher wages, and business through larger profit margins. Thus the ecological negative byproducts, such as coal dust from mines, pollution from factories, impact those who have the least power to resist such forces (e.g., the poor, the working class, racial and ethnic minorities) and are therefore increasingly likely to be exposed to environmental hazards (Bruelle and Pillow 2006).

Physical Environment Health Risks in Appalachia

The Appalachian region provides an interesting location to see the influence of the social production of environmental inequalities on health status. New research has begun examining the impact that coal mining has on health in Appalachia. Mountaintop Coal Removal (MTR) in particular is associated with health hazards and the risk of disease (Hendryx 2013).

Mountaintop Coal Removal is a process of extracting coal that requires removing mountain tops to extract coal. The remaining rock and soil is then pushed into valleys and hollows where it overlays streams (i.e., valley fills) (Palmer, et al 2010; Hendryx 2011; Hendryx 2013). Nearly 4,000 kilometers of streams in Central Appalachia have been covered with valley fills (Hendryx 2013). These sites are prone to flooding and have caused increased flooding in the region (Epstein, et al. 2011; Hendryx 2013). Rain pushes

heavy metals that are located in the valley fills to leak into streams and local water sources (Epstein, et al. 2011; Palmer, et al 2010).

Understanding the health risks associated with coal production and mining in Appalachia has much to do with the role of water in the mining process. Mining includes washing and processing coal, which produces water waste or slurry (Epstein et al. 2011). Slurry is stored in ponds located near mining sites and often leaks and additionally impoundments which contain slurry occasionally fail. In 2000, nearly 309 million gallons of coal slurry spilled out of an impoundment in Martin County, Kentucky, the single largest environmental disaster in United States history until the Deepwater Horizon spill in 2010 (Epstein et al. 2011). The heavy metals and toxic chemicals in slurry are hazardous to human health and have been associated with cancer, reproductive disorders, kidney disease, diabetes and birth defects (Epstein et al. 2011). It is estimated that 19 different chemicals used to process coal may be cancer causing agents, and some of these chemicals have been linked to lung damage and heart problems (Epstein et al. 2011). Many of these chemicals have been associated with emotional and behavioral disorders in children, delinquency, sleep problems, low IQ, ADHD, anxiety, social disorders, and learning disabilities (Epstein et al. 2011). Currently an estimated 110 billion gallons of coal slurry is impounded in the state of West Virginia alone (Epstein et al. 2011). However, water is not the only mechanism by which coal mining pollution affects the health of people.

Another mechanism through which health is adversely affected is through the release of pollution into the air, reducing air quality, and negatively altering respiratory functions (Northridge et Al. 2003). Metals can be released as pollutants or released into

ground water. Exposure to toxic chemicals such as lead, mercury, and selenium are also significantly hazardous when released into the air. These chemicals have the potential to be transported into ground water from air emissions, landfills, or water emissions. In communities that have no running water and use uninspected wells, exposure could be great (Northridge et al. 2003; Palmer et al. 2010).

Growing research suggests a strong association between coal mining in communities and an array of negative health outcomes. Hendryx (2008), for example, found that mortality rates are higher for chronic heart, respiratory, and kidney diseases in counties with coal mining compared to non-mining counties. Exposure to contaminated water and air with high levels of zinc, cadmium, lead, mercury and arsenic, which are by-products of the mining process, also have been associated with adverse health outcomes (Hendryx 2008). Mining is a localized activity and a given county may have few mining sites that are located in sparsely or densely populated areas. Depending upon population density and other risks of exposure (e.g., runoff from a stream into a river within a county, geography, temperature), researchers may not find similar concentration levels across one county (Palmer, et al. 2010; Hendryx 2011). Exposure related to underground mining sites comes largely from particulate matter (Hendryx 2007). Particulate matter is released from mining sites through the processing and transportation of the coal, which may increase the risk of cardiovascular disease and respiratory problems (Epstein et al. 2011). Particulate matter is composed of heavy metals such as lead, mercury, and arsenic (Epstein et al. 2011; Pope et al. 2002) which are hazardous and high levels of exposure may increase the risk of disease and other negative health outcomes (Pope et al. 2002).

Again, the use of mountaintop coal removal and associated health consequences is of particular concern in Appalachia. Zulig and Hendryx (2011) examined the links between mountaintop coal removal and health-related quality of life (e.g., mental and physical indicators). Controlling for smoking, BMI, alcohol consumption, metropolitan residence status, and demographic characteristics, data from the 2006 round of the Behavioral Risk Factor Surveillance Survey showed significant health disparities in health-related quality of life between mountaintop coal removal counties and those with underground coal mining and no coal mining (Zulig and Hendryx 2011).Their findings suggest that an area's socioeconomic disadvantages increase the risk of adverse health in these regions, but net of SES, Zulig and Hendryx (2011) found significant health differences between those who do and do not live in coal mining counties.

The literature strongly suggests an association between coal mining and negative health outcomes for residents of coal mining communities in Appalachia. Research in this area is growing; however, gaps in knowledge about coal mining and health remain. For example, it is not clear how the effects of Appalachian coal mining affects health in the region over time. Coal production is not static—it increases and decreases often in concert with fluctuating economic markets and governmental influences. Currently U.S. coal production and consumption is decreasing in large part to the impacts of cheaper, more plentiful domestic natural gas reserves and decreased energy consumption following the recession in 2008 (Pulmer 2012). This could mean positive things for overall health in Appalachia; however, the environmental degradation (e.g., polluted streams, filled in hollows) will remain despite the reduction in the production of coal. The decrease in coal mining jobs could also increase poverty and unemployment, which

would have a negative impact upon health. Changes in coal mining, and the subsequent production of coal, warrants an investigation of the relationship between coal production and health over time.

This research seeks to extend the literature by examining the extent to which changes in coal mining in Appalachian counties impacts the population health within those counties. Specifically, I used data from the Behavioral Risk Factor Surveillance System to examine changes in the relationship between coal mining and health within counties specifically in Eastern Kentucky and West Virginia during the period of 2000 to 2010. Kentucky and West Virginia combined account for nearly two-thirds of the coal produced in Appalachia in 2010 (Young 2011). These two areas are also characterized by a high level of importance of the coal industry on economic and social life and well-being (Eller 2008; Goodell 2007; Burns 2007). Figure 2 shows a map of the Appalachian regions that will be included in the study. All of the 55 counties of West Virginia are classified as part of the Appalachian region; however, only 54 of Kentucky's 120 counties are classified as part of Appalachia by the Appalachian Regional Commission. Eastern Kentucky and West Virginia are characterized by high rates of poverty and the highest coal production in the Appalachian region, and are therefore the focal regions in this study (Goodell 2007; Young 2010; Hendryx 2013).

Prior research has found that coal mining is negatively associated with health; however, previous studies focusing specifically on the production of coal and health in Appalachian regions are limited to cross-sectional designs which do not account for how changes in coal mining affect changes in health (Hendryx, O'Donnell and Horn 2008; Hendryx and Zullig 2011; Hendryx and Zullig 2010; Hendryx and Zullig 2009; Michael

Hendryx 2009). My study extends prior research by examining change over time as an important factor in understanding the impact of coal production on health in the Appalachian region. Moreover, given that MTR coal mining has been a primary source of extracting and producing coal in Appalachia, I hypothesize that an increase in MTR coal production between 2000 and 2010 is associated with lower county-level self-reported health.

It is important to note early on that this study uses self-reported health at the county-level as the outcome measure (i.e., individual-level reports are aggregated to the county level). Previous research has used self-reported health (Hendryx and Zullig 2011; Hendryx and Zullig 2010), but only as part of a large index of "Health-related Quality of Life" which was not used for this project because a section of questions used to create the index was not asked for a number of study years. While admittedly, county-level self-reported health has drawbacks (i.e., it is not a direct measure of population health as are indicators of specific conditions or diseases), previous research suggests that self-reported health tends to be consistent with other direct health indicators and tends to accurately capture   general health and wellbeing (e.g., see Miilunpalo et. al. 1997).

METHODS

Data

To analyze the relationship between coal mining in Appalachia and health, data from the Behavioral Risk Factor Surveillance Survey (BRFSS) from years 2000 to 2010 are used. The BRFSS is an annual survey of more than 350,000-500,000 adults aged 18 and older who are randomly selected in 50 (U.S.) states and Puerto Rico. Many states oversampled underrepresented populations, such as African Americans, poor people, and those who live in rural communities (Hacker 2009). Beginning in 1984, the BRFSS included ongoing telephone (i.e., landline and cellular phones after 2009) interviews with one adult per household and have been conducted by the Center for Disease Control and Prevention in partnership with state health departments (Office of Surveillance, Epidemiology, and Laboratory Services 2008). Each state health department is responsible for administering the survey in their respective state (Hacker 2009; Office of Surveillance, Epidemiology, and Laboratory Services 2008).

The BRFSS includes core of questions about individual health problems along with basic demographic questions about race, sex, and income among others. The BRFSS survey also includes modular questions about health-related issues such as diabetes and cancer (among others) that are asked in a three year rotating cycle (Office of Surveillance 2008). States can opt to add additional questions regarding specific health conditions as they relate to the specific state's population and health concerns (Office of Surveillance 2008).

The BRFSS is a repeated cross-section survey of current health problems that is a nationally representative sample with random samples selected within each state (Office of Surveillance 2008). The target sample size is *N*=4,000 per state, and when combined with other states may be weighted to adjust for differences in state sizes (Office of Surveillance 2008). Some states, however, oversample certain geographic regions, such as rural communities, that have smaller populations and underrepresented populations to oversample subgroups whose regional representation does not match their national representation (Office of Surveillance 2008; Overview BRFSS 2010). Weights are not applied in the current study because samples are representative at the state level, although not at the county level (Hacker 2009; Kentucky Behavioral Risk Factor Surveillance System Survey Data 2011). The sample from Kentucky was randomly selected across the state, not specifically within Eastern Kentucky; therefore, the sample for Eastern Kentucky may not be representative of the region and should be interpreted with caution.

The BRFSS does not include smaller geographic identifiers than county level, which is problematic because it is not possible to identify individual proximity to coal mining and coal processing facilities. However, using county-level data will allow me to examine the community level impacts of coal production mining on overall county-level population health. While county level measures are not as precise as smaller geographic identifiers such as census tract or zip code, prior research (Hendrxy and Ahern 2009; Zullig and Hendrxy 2011) has used the approach employed in the current study and demonstrated that much is to be learned despite the limitations.

I do not, however, foresee the introduction of bias due to this limitation. While the highest and most extreme impacts happen within the geographical area closest to coal

mining and production, environmental impacts such as air and water pollution travel and

may transport and impact streams in areas within a counties that are not necessarily

proximally close to mining and production sites. Despite the limitations, this data is the

best available to conduct this research and has been used by pervious researchers to

examine similar research questions (Hendrxy and Ahern 2009; Zullig and Hendrxy

2011).

While the BRFSS includes additional years, the surveys administered between the

years of 2000 and 2010 will be used for the current analysis. Individual-level responses

are aggregated up to the county level and combined with county-level coal production

data available through the U.S. Department of Energy's Energy Information

Administration (for each of the focal years). The total number of individual-level

responses in Eastern Kentucky and West Virginia range from N=4,386 to N=7,982

between 2000 and 2010. After aggregating individual-level responses, the total number of

counties included in the current analysis is N=83.

Dependent Variable

The dependent variable is self-reported health, which for this study has been

reverse coded and averaged at the county level. Between 2000 and 2010, respondents

were asked: "Would you say that in general your health is: 1=*Poor*; 2=*Fair*; 3=*Good*,

4=*Very Good*; and 5 =*Excellent*." I reversed coded the variable so that self-reported

health ranged from bad health to good health, which is consistent with previous research.

Self-reported health will be treated as a continuous measure in the current study, again,

consistent with other research (Hendryx 2011; Hendryx and Zullig 2010; Hendryx and

Zullig 2011). Missing values for self-reported health were minimal with no more than

n=30 missing on the individual level in a given year. Missing values for item responses on the individual level were coded as missing prior to aggregating the data to the county level. Once individual responses were aggregated, there were no missing values for the analytic counties. That is, the aggregate values were the central tendencies (i.e., mean or median) of the non-missing individual responses for each county and year; therefore, all counties had a value for a given year.

Independent Variables

Coal production is determined by using the 2000-2010 Coal Reports provided by the U.S. Energy Information Administration. The continuous measure of coal production was recoded into dummy variables based on the level of coal produced (i.e., no or little production, low, medium, and high levels). The cut point for levels of coal production was based on what previous researchers have done (Hendryx, O'Donnell, and Horn 2008), yet levels were modified based on an examination of the distribution of coal production to provide a more diverse distinction in levels of coal production. The cut point levels of coal production were as follows: MTR coal production >100,000 tons classified as "No or Little MTR coal production," between 100,001 and 1 million tons classified as "Low MTR production," between 1,000,001 and 10 million tons classified as "Medium MTR production," and >10,000,001 tons classified as "High MTR production." The current study examined both the association between Mountaintop Coal removal and underground mining and average self-reported health; however, given that underground mining was not significantly associated with county-level health in any of the models examined, only the results for MTR and average self-reported health are reported.

Covariates

Covariates are measured as averages (at the county level) of all the individuals interviewed in a given county. Age and BMI will be continuous measures with age ranging from 18 to 99, and BMI ranging from 1 to 99. Education is measured by using the highest grade completed with the following categories: Less than High School=1, High school graduate=2, Attended College or Technical School=3 and Graduated from College or Technical school=4. Missing responses at the individual level ranged from .1% to 1.2%, which is not worrisome. Income is measured using the following categories: Less than $14,999=1, $15,000 to less than $24,999=2, $25,000 to less than $34,999 =3, $35,000 to less than $49,999=4, and $50,000 or more=5.

Smoking is measured by the percentage of smokers and percentage of non-smokers in a county (the percentage non-smokers in a county is the reference category). Gender is also a dummy measure, with the percentage of females in a county as the reference category. Race is measured as the percentage of whites and percentage of not-whites in each county, with the percentage non-whites as the reference category. Health insurance is measured as the percentage in each county that has health insurance and the percentage that does not have health insurance (reference category).

Analytic Strategy

I estimate Ordinary Least Squares regression models, random-effects, and fixed-effects models. Each model brings a different element to understanding the relationship between coal production and health in Appalachia. Each one also has its own limitations. The OLS models estimates the linear patterns and relationships between coal production and health which includes all 11 years of observations. This model provides a general

understanding of the pattern without accounting for the potential for unobserved differences within and between counties over time.

Random-effects models are able to capture both within and between county influences of coal production on average self-reported health. Random-effects models assume that the errors terms are not correlated with the independent variables. Many factors including personal, psychological, environmental, and social impact the health of individuals and whole communities that may not be observed in the available data. To address this potential unobserved heterogeneity, fixed-effects regression models are estimated. Fixed-effects regression estimates the extent to which changes in coal production within a given county impacts changes in average self-reported health within the same county. This regression technique is the most conservative compared to OLS and RE approaches and allows for counties to be compared against themselves over time. In this sense, counties control for themselves in terms of accounting for possible unobserved characteristics which do not change over time and may affect both the production of coal at the county level and average county-level self-reported health. Fixed-effects regression does not assume an independence of the errors in the model (which is what allows for unobserved variables that do not change overtime to be controlled). Fixed effects models, however, do not control for unobserved factors that change over time such as individual health-related behaviors. However, many of the factors of primary concern, which change over time, are included as covariates in the models.

RESULTS

Descriptive Statistics

Table 1 includes the descriptive statistics for the dependent variable average county-level self-reported health, the primary independent variable Mountaintop Coal removal production, and covariates for health indicators, demographic characteristics, and SES characteristics for both Eastern Kentucky and West Virginia. Descriptive statistics are reported separately for each of the areas and for Eastern Kentucky and West Virginia combined. These figures are for the total sample of 11 years (2000-2010) across the counties and years included in the study. These figures are aggregated to the county level and are the average of the percentages (or medians) of the counties in the surveys for each year.

Table 1 shows the combined areas, or Central Appalachia, with nearly 60% of the counties produced very little or no coal at all (<100,000 tons). Fourteen percent of counties produced on average between 100,001-1 million tons while 23% produced between 1,000,001-10,000,000 tons of MTR coal across both states. Less than 4% produced on average 10 million tons or more of MTR coal. Table 1 shows 59% of counties in West Virginia produced very little or no MTR coal at all. Table 1 shows 14% in West Virginia produced between 101,000 – 1 million tons of mountaintop removal (MTR) coal. Table 1 shows 23% of counties in West Virginia produced between

1,000,001-10,000,000 tons of MTR coal and 3% produced more than 10,000,001 tons of

MTR coal. In Eastern Kentucky 60% of the counties produced no or very little MTR

coal. Fourteen percent of counties in Eastern Kentucky produced between 101,000 – 1

million tons of MTR coal and 22% produced 1,000,001-10,000,000 tons of MTR coaland

4% produced more than 10,000,001 tons of MTR coal. The majority of counties in

Central Appalachia produce very little or no MTR coal (<100,000 tons).

The combined sample, or Central Appalachia, has a mean county-level self-

reported health of 3.05 (again the range being 1=Poor to 5=Excellent health). The

minimum mean for a county was 2.42 and the maximum was 3.74. West Virginia has an

average county-level self-reported health of 3.16. West Virginia counties scores ranged

from 2.50 to 3.74. West Virginia had slightly higher health than Eastern Kentucky.

Average county-level self-reported health in Eastern Kentucky was 2.92 with a range

between 2.42 and 3.59. The median Body Mass Index (BMI) for counties in Central

Appalachia was 27 with a minimum of 24 and a high of 32. This puts half of Central

Appalachian counties with a median BMI status of overweight or above (obese). In West

Virginia the median BMI is 27, within a range between 24 and 30. Half of West

Virginian counties have a BMI status of overweight or obese. In Eastern Kentucky the

median BMI is 27 within a range of 25 and 32. Half of the Eastern Kentuckians in the

sample counties have a BMI status of overweight or obese. These data from the BRFSS

suggest that, over the years of 2000 and 2010, on average individuals within Central

Appalachia were overweight or obese.

The average percentage of uninsured in counties in Central Appalachia was 16%,

with a range between 0-99% uninsured. West Virginia has an average percentage of 14%

uninsured, with a range between 2-31%. Eastern Kentucky had an average percentage of 18% uninsured, with a range between 0-99%. Central Appalachia has less than a fifth of the population without health insurance, despite a lot of variation among the counties.

The average percentage of smokers in Central Appalachian counties is 27%, with a range between 7-50%. In West Virginia the average percentage of smokers is 25%, with a range between 7-42%. In Eastern Kentucky, the average percentage of smokers is 29%, with a range between 11-50%. Central Appalachia has an average of 27% of the population reporting that they are smokers.

The average percentage of males surveyed in the county samples from Central Appalachia is 36% with a range from 0-58%. West Virginia had an average percentage male of 39%, with a range of 24-58%. Eastern Kentucky had an average percentage male of 33%, with a range between 0-52%. The 0% of males in Eastern Kentucky is drawn from one county for one year, where respondents happened to be all female. This small, rural county was Powell County, KY, with a total of 12 respondents. Powell County remained in the study because for all other observed years the sample was more heterogeneous in terms of gender composition. Overall, the sample counties appear to over represent female respondents. Therefore, the association between coal production and average self-reported health could be upwardly biased along gender lines given the representation in the sample and because women tend to report better health, on average, than men (Turner and Avison 2003).

The average percentage of whites in Central Appalachian counties is 97%, with a range between 78-100% white. In West Virginia and Eastern Kentucky the average percentage of whites is 97%, both with a range between 78-100% white. Appalachian

counties in both states are between 70-100% white. This is consistent with what other researchers have found in regards to racial demographics of Appalachia, with very low non-white populations (Blackley, Behringer and Zheng 2012).

The average median age for counties in Appalachia is 53, with a range between 39 and 65. In West Virginia the average county median age was 53, with a range between 39 and 63. Eastern Kentucky had an average median age of 52, with a range between 43 and 65. Eastern Kentucky has a lower median age than West Virginia; however, West Virginia has counties with much lower minimum median age range. This is consistent with what other researchers have found in terms of age demographics in Appalachia (Blackley, Behringer and Zheng 2012).

Central Appalachia is a region that has low levels of income and educational achievement. The average county level median income category for Central Appalachia was 4.86 (corresponding to $25,000 to $35,000), with a range between 2 (Less than $15,000) and 7 ($50,000-$75,000). In West Virginia average median income category was 5.18 ($35,000 to $50,000), with a range between 3 ($15,000-$20,000) and 7 ($50,000-$75,000). West Virginia was slightly higher than Kentucky's average median income range of 4.51 ($25,000-$35,000) with a range between 2 (Less than $15,000) and 7 ($50,000-$75,000). While there is a difference between Eastern Kentucky and West Virginia, it did not impact the results when estimated separately.

Eastern Kentucky and West Virginia have similar educational levels. The average median highest grade completed for the combined Central Appalachian region was 4.28 (corresponding to High School graduate/Grade 12), with a range between 3(Grades 9-11) and 5 (1-3 years of college). West Virginia has an average of 4.38 (High School

graduate/Grade 12), with a range between 3 (Grades 9-11) and 5 (1-3 years of college).

Eastern Kentucky had an average median county-level highest grade completed of 4.16,

with a range between 4 (High School graduate (Grade 12)) and 5 (1-3 years of college).

Appalachian counties generally have a lower educated population, with over half of the

population having at or below a high school diploma. This is consistent with what other

researchers have found when they have examined educational attainment in the

Appalachian region (Shaw, DeYoung, and Rademacher 2005).

Figures

Mountaintop Coal removal production has decreased over the eleven year study

period. Figure 3 shows the average county-level Mountaintop Coal removal production in

Central Appalachia between 2000 and 2010. West Virginia reached a peak coal

production in 2006, with an average of MTR coal production of 2.1 million tons. West

Virginia decreased to its lowest production by the year 2010 with its lowest average MTR

coal production of 1.1 million tons of coal. Eastern Kentucky reached its peak MTR coal

production in 2006, with an average county-level MTR coal production of 1.7 million

tons. MTR production decreased in 2010, reaching its lowest production during the study

period with an average of 864,000 tons. During the study period, MTR coal production

also decreased in both Eastern Kentucky and West Virginia. Despite an increase in MTR

coal production between 2005 and 2006, the overall trend is a decline in production.

Total coal production (i.e., underground and MTR combined) has also decreased

over the eleven year study period. Figure 4 shows the average total level of coal

production between 2000 and 2010. West Virginia's average county-level total coal

production peaks in 2001 with an average 5 million tons of coal produced. However, the

trend for West Virginia is a gradual decrease to an average total coal production of 3 million tons in 2010. In Eastern Kentucky, the downward trend is similar to West Virginia; however, Eastern Kentucky's average coal production peaks in 2006 with 3.6 million tons. Eastern Kentucky's lowest production is in 2010 with a decrease to 1.5 million tons of coal produced, a reduction of over 50% in a period of 5 years. Overall, Central Appalachia is experiencing a decline in coal production, with peaks in the early and midpoint of the study time period, substantially decreasing by the end of the period in 2010.

Average county-level self-reported health in Appalachia decreased over the eleven year study period. Figure 5 shows the average county-level self-reported health (1=poor to 5=excellent health) in Central Appalachia between 2000 and 2010. County-level self-reported health in Eastern Kentucky and West Virginia decreased during the 2000-2010 period. In West Virginia, average health is at its highest in 2000, with a score of 3.27. It decreased in 2008 to 3.08, the lowest in the study period. In Eastern Kentucky average health reaches its peak in 2001 at 3.02 and decreases to its lowest level in the study period in 2007 with 2.84. Overall Eastern Kentucky has a lower average county-level self-reported health than West Virginia. This is partially because the dataset includes the entire state of West Virginia, which includes metropolitan areas such as Charleston and Morgantown, WV, while Eastern Kentucky is a largely rural region of the state. The trends for both states show a decrease for average county-level self-reported health.

To examine the relationship between coal production and average county-level self-reported health in Appalachia, OLS, random-effects, and fixed-effects models were estimated. Baseline models included county-level MTR coal production and county-level self-reported health. Full models added covariates for health, demographic characteristics, and socioeconomic characteristics. The overall results suggest a similar impact of county-level self-reported health by MTR coal production across four of the six models. Additional models were estimated for underground and total coal production; however, the results were not significant and are therefore not reported.

Table 2 reports the results from the OLS, random-effects and fixed effects models predicting average county-level self-reported health by MTR coal production. The OLS baseline model (M 1.1) shows a negative association between medium (-.25) and high (-.30) levels of MTR coal production versus no coal production and average self-reported health. The R^2 estimated for model 1.1 is .19, suggesting that MTR coal production can explain nearly one-fifth of the total variance in county-level self-reported health. The addition of covariates in the second, full OLS model (M 1.2), decreases the magnitude of the estimates for medium (-.11) and high (-.12) MTR coal production versus no coal production. So, the results suggest that as the level of MTR coal production increases, average county-level self-reported health decreases, which is consistent with my expectation. Net of the covariates, the association between MTR coal production and county-level self-reported health remains significant across the baseline and full models. Health characteristics were significant and negatively associated with self-reported health, with a -.05 coefficient for BMI and a -.38 coefficient for smokers. Additionally

county-level socioeconomic predictors for income (.06) and education (.38) showed statistically significant and positive relationships with self-reported health. Higher percentages of females is significant and positively associated with county-level self-reported health (.44) while increasing age had a significantly negative relationship (-.01). The OLS models show a statistically significant association between medium and high levels of MTR coal production and average self-reported health, and this association holds once covariates are included. The R^2 estimated for model 1.2 is .68, suggesting that over two-thirds of the variance in county-level self-reported health can be accounted for using this model. Also of note, tests for violations of OLS assumptions of normality, multicollinearity, linearity, and heteroskedasticity were performed for the baseline and full models and were met.

The random-effects models estimates both change over time within counties and between counties in Central Appalachia between 2000 and 2010. In the random-effects models, I find a similar pattern to what was found in the OLS models. Model 2.1 estimates county-level self-reported health by medium (-.14) and high (-.21) MTR coal production versus no MTR coal production, which is a statistically significant negative association. The R^2 estimated for model 2.1 is .19, which is the same as the R^2 for model 1.1, again suggesting that nearly one-fifth of the variance in county-level self-reported health is associated with MTR coal production. In the second model (M 2.2) once additional covariates are added, medium (-.11) and high (-.13) MTR coal production versus no MTR coal production is negatively associated with average self-reported health. Overall, RE suggest that both medium and high MTR coal production versus no MTR coal production is associated with a decrease in average self-reported health.

However, the magnitude of the association decreases in size with the addition of covariates. Health-related covariates were significantly and negatively associated with self-reported health, smokers (-.34) and BMI (-.04). Socioeconomic indicators of income (.05) and education (.33) were positively associated with health. Demographic characteristics for percentage of females (.27) had a positive relationship, while age (-.01) had a significant negative association. The R^2 for model 2.2 is .67, which is similar to the R^2 estimate in model 1.2. The R^2 estimate suggests that over two-thirds of the explained variance in self-reported health can be accounted for in the model. For the random-effects model, as MTR coal production increases, the average county-level self-reported health decreases (i.e., decreases in both change between and within counties). The fixed-effects models, however, showed different results compared to the random-effects models.

Next, unobserved heterogeneity is taken into account by looking at only within-county change in MTR coal production and self-reported county-level health in the fixed-effects models. These models reduce the chance that unobserved factors could be influencing results by allowing counties to control for themselves, i.e., factors that do not change (e.g., geography, natural environment) are accounted. A Hausman test was estimated and suggested that fixed-effects regression is an appropriate approach for the baseline and full models. Beginning with the baseline model, M 3.1, neither medium MTR coal production nor high MTR coal production versus no or little MTR production was significantly associated county-level self-reported health. This pattern holds with the addition of additional covariates in the full model (M 3.2). However, in the fixed effects model health characteristics of BMI (-.03) and smokers (-.29) remained significantly associated with average self-reported health. As well, socioeconomic characteristics,

income (.04) and education (.23) remained significant. Age (-.02) and percentage white

(.65) were also significantly associated with average self-reported health.

Despite the lack of significance of the baseline models (3.1), the R^2 for the model

is .69, and the full model (3.2) R^2 is .77. This suggests that for the baseline model (3.1)

more than three fourths of the within-county variation in self-reported health is explained

by MTR coal production. Eighty percent of the within-county variation of self-reported

health is explained by MTR production in the full model (3.2).

DISCUSSION

My findings are consistent with what other researchers have found regarding a negative association between coal mining, in particular MTR coal production and health in Appalachia. However, my project differs in two main respects. Previous research has focused on mortality or morbidity (Hendryx 2011; Hendryx and Ahern 2009; Hendryx, O'Donnell and Horn 2008; Hendryx and Zullig 2009; Hendryx 2009), while this study focuses specifically on self-reported health. This is similar to what others have done, yet this work has included self-reported health within a composite variable to measure "Health-Related Quality of Life" (Hendryx and Zullig 2011; Hendryx and Zullig 2010).

My study is different from prior research in two other important ways. First, I examine the impact of change over time of coal production on change in self-reported health and have done this on the county level. The OLS and the random-effects models found that medium and high levels of MTR coal production are associated with decreased county-level self-reported health. However, in the fixed-effects models, medium and high MTR coal production versus no or little MTR production was not significantly associated with county-level self-reported health.

The OLS models show that there is a statistically significant negative association between the medium and high versus no or little MTR coal production and county-level self-reported health. This relationship holds once the additional covariates are added in the full model. These models support what pervious research has shown in regards to

higher MTR coal production's impact upon health in Appalachia (Hendryx and Zullig 2011; Hendryx and Zullig 2010).

In the random-effects models, there is a statistically significant association between the medium and high versus no or little levels of MTR coal production and average self-reported health. The random-effects models account for both between-county and within-county impact of change in MTR coal production on change in county-level self-reported health. It is reasonable that the impacts of MTR coal production would not be limited to within-county differences, but have implications across socio-political borders. Based on prior research, there are impacts of coal mining on the physical environment, and we know that watersheds and streams are impacted the most (Epstein et al. 2011). Thus, the mining waste and pollution can impair communities along streams and in watersheds (Epstein et al. 2011). Of particular concern is the fact that many people in rural areas of Appalachia still rely upon groundwater for their basic needs, lacking critical water infrastructure (Epstein et al. 2011; Hendryx and Zullig 2011; Hendryx and Zullig 2010; Eller 2008; Burns 2007). Thus, the between-county findings in the random-effects models are intuitive given the likelihood that coal mining and production is likely to impair communities and by extension community health across county lines. Moreover, given this reality, it is not surprising that the findings for the fixed-effects models, accounting for change within-counties, were not statistically significant.

In both the baseline fixed-effect models and the full fixed-effects models, all levels of MTR coal production were found to not be statistically significantly associated with average county-level self-reported health. However, the lack of statistically

significant association may be the result of less within-county change overall than between-county change. In addition, fixed-effects models only include counties that had both change in MTR coal production and change in county-level self-reported health over the observation period, and thus those counties where health or coal production (or both) did not change, they were not included. Additionally, the R^2 for both the baseline and full models suggests that within-county change in MTR coal production may explain a sizeable proportion of the variation in average self-reported health, but due to the limitations of the data, is not significantly doing so. Also important to note, nearly half of the counties (*N*=83) included in the model were not surveyed in the 2000-2006 period, which may have also influenced the change observed within counties.

Despite data limitations, and non-significant results in the fixed-effects models, the results from the OLS and random-effects suggest a region-wide impact of MTR coal production on average county-level self-reported health over time. These findings are not surprising considering prior research showing impacts of MTR coal mining on the physical environment. "Over-burden" or mine waste that pollutes the streams and watershed and air pollution from trucks and mining facilities that spread over large distances all impact areas immediately surrounding MTR coal mines (Epstein, et al 2011), but also spread beyond the political boundaries of counties. Despite findings in the current study, however, it is important to acknowledge that coal production, overall, is not an optimal proxy for environmental degradation.

One of the key overall limitations of the current study is lack of data available to measure the extent to which residents in a given county may be exposed to pollution from mines. Federal, state and local government agencies do not collect air quality or water

quality data outside of large metropolitan areas, which the study area for this project includes few such areas. Thus, coal production has had to serve as a proxy for environmental degradation identified in the conceptual model for understanding how physical and social environment impact health (Figure 1, superscript number 3).

Another limitation is that the BRFSS does not include information about individual occupations, specifically occupations related to coal mining. One who lives in a county with a high level of coal mining and production, but does not work in the mines or is not associated with mining businesses, may have significantly different health outcomes compared to someone who works in the mines. Occupations are important because of the links between employment in underground coal mining and black lung disease (Halverson, et al. 2004; Krause et al. 2011). Black lung disease is common to miners who work in underground mines, it is caused when coal dust from the mines builds up in the lungs and the body becomes unable to expel it (Lapp and Parker 1992). However, coal mining is a traditionally male dominated occupation (Eller 2008) and the sample counties have higher percentages of females versus males, thus limiting the impact of such health concerns.

A larger percentage of females than males live in the analytic counties. This may bias the results given that previous research shows that women tend to report better health than men (Grzywacz 2004; Krleger 2001). Thus, despite a large percentage of women in the analytic counties, the results from the random-effects and OLS models suggest that medium and high MTR coal production is negatively associated with self-reported health. Even so, the oversampling of females in the BRFSS may downwardly bias the results given that women tend to be healthier than men. I suspect that the strong association

between MTR coal production and health found in this study may be stronger if the sample included a more equal distribution of men and women.

One of the key findings of the current study is that county-level MTR coal production is significantly associated with average self-reported health net of SES and other health-related covariates. In the conceptual model in Figure 1, SES impacts health alone and jointly through exposure to environmental exposure and while the results from the OLS and random-effects models show that SES and MTR coal production are significantly associated with average self-reported health, the interaction between MTR production and SES was not tested, but is an important avenue for future research.

CONCLUSION

Appalachian coal has fueled American industry for over a hundred years (Eller 2008; Goodell 2007). During the past 30 years, newer mining techniques, and in particular Mountaintop Coal Removal, have begun to change how mining is done (Eller 2008). These new mining techniques have greater environmental impact and potential for serious human health impacts compared to previous mining techniques (Epstein et al. 2011; Palmer et al. 2010). Researchers have consistently found that the Appalachian region, and in particular coal producing areas of the Appalachian region, have worse health outcomes than non-coal producing areas of Appalachia and the United States as a whole (Hendryx 2013; Hendryx and Zullig 2010). Moreover, it is documented that coal production in the Appalachian region influences health status (Hendryx 2008; Hendryx 2013; Hendryx and Zullig 2010). My research builds upon this literature, showing a cross-county, regional impact for MTR coal production on average self-reported health in Appalachian counties within Eastern Kentucky and West Virginia. However, I argue below that the current study has far broader implications for the changing nature of coal production in the Appalachian region.

Coal mining in Appalachia is declining. In 2012 coal production in Appalachia was at the lowest levels since 1965 (Estep and Cheves 2013). A combination of factors including depleted stocks of coal in the region, cheaper natural gas that competes with coal in power plant use, lower demands for coal both domestically and internationally,

and higher costs of mining have all lead to significant reductions in coal production

(Estep and Cheves 2013; Fowlkes 2013). This significant decline in coal production in

Appalachia has a number of implications. These implications include higher

unemployment and underemployment in the region, a rise in poverty rates, a rise in

uninsured populations, and increased instability and insecurity in the economy more

generally. Even so, the greatest impacts on Appalachian communities may be associated

with the environment and environmental degradation.

The decline in coal production, in particular that of MTR coal production, may

have long term implications. Sludge ponds, MTR mine sites and other waste material

may last far beyond the years of coal production and operation. A study conducted by the

National Resources Defense Council in 2009 found that of the 500 mountains that have

been mined using MTR, 410 have been "reclaimed" or reconstituted to their pervious

contour, albeit without the previous vegetation or topsoil, while the rest have not

(Geredien 2009). Nearly 1 in 5 MTR sites have not been reclaimed and this leaves many

open to erosion, rock slides, and continued pollution of local streams and watersheds.

This is not counting the nearly 110 billion gallons of coal slurry impounded in the state of

West Virginia alone (Epstein et al. 2011). As was the case of Martin County, KY, where

an abandoned slurry pond broke and released 309 million gallons of coal slurry

containing selenium, lead, and zinc among others, polluting miles of streams and

watersheds (Epstein et al. 2010). These sludge ponds do not legally have to be remediated

or removed once the coal production has ended, which leaves billions of gallons of toxic

sludge in many communities in Appalachia (Epstein et al. 2010; Burns 2006). In the long

term, these facts showcase the stark reality that environmental health concerns in the Appalachian region from MTR coal production may outlast the initial coal mining.

Given the potential that the environmental degradation associated with coal production is likely to remain even when coal is no longer produced, my future research will consider the potential lagged impact of coal mining on health in Appalachia over an extended time period. Environmental processes take time, and as such the impacts of coal mining on health may not move at the same pace as changes in coal production. Thus, an analysis which allows for a lagged effect would contribute an understanding how coal impacts the environment and population health long-term or over a period of time that extends far beyond the production of coal.

Understanding the long term impacts of coal is important. It is also important to understand the interaction between coal mining and socioeconomic status. The model in Figure 1 shows how physical environment [1] and social environment [2] interact with each other to impact environment exposure risk and then impact health. Coal mining then would serve as a compounding factor on the disadvantages of lower SES on health. I plan to run additional analyses including interaction terms to examine the compounding impacts of SES and coal mining on health in Appalachia. In addition to understanding the links between SES and coal mining, more research is needed looking at the extent of environmental exposure and health outcomes.

In the current study, coal production served as a proxy measure for environmental degradation. Future research will use newer geographic techniques to get at the extent and acreage of environmental exposure. Perhaps biometric and cross-disciplinary techniques may be applied in communities with coal mining, including possible sampling

of water systems and streams near MTR coal production sites. All of these are additional approaches to better understand the environmental exposure element of Mountaintop Coal removal. Additionally, examining other types of health outcomes, those that can be more easily linked to the toxins and pollutions associated with coal mining may also be informative.

While self-reported health has been used by pervious researchers in this field, additional health outcomes are worth exploring (Hendryx and Zullig 2011; Hendryx and Zullig 2010). Specific disease prevalence and mortality and morbidity rates for illnesses related to MTR pollution may be important to examine over time. There is still a great deal to understand about MTR coal mining and its impact upon health in Appalachia.

Recently events in West Virginia and North Carolina are exemplary with respect to the importance of how coal mining and coal burning affect population health (Friend 2014). Nearly 300,000 people were impacted by a chemical spill in Kanawha County, West Virginia in January 2014. The chemical in question (4-methylcyclohexane methanol) is one of the many used to clean coal (Friend 2014).This chemical polluted the waterways of Charleston, WV and continues to cause problems, sending people to the emergency room with chemical burns and other illnesses. This is an example of how coal mining and its related industries negatively impact the health of people in Central Appalachia.

One of the most salient implications of the current study is over the significance of understand the influence of coal production on long term population health. Additional research is needed to examine the specific exposure risks and pathways through which the health of individuals is impaired by the mining of coal. Policymakers know how coal

mining is impacting the health of the Appalachian region, and growing research

documenting these harmful effects potentially increases the likelihood of more informed

legislation in coal-producing Appalachian regions.

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Table 1: Sample County Characteristics for Eastern Kentucky and West Virginia, 2000-2010 (N=83)

	Central Appalachia				West Virginia				Eastern Kentucky			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
***MTR* Coal Production**												
% No or Little MTR Production (<100,000, Ref)	59				59				60			
% Low MTR Production (101,000-1 million tons)	14				14				14			
% Medium MTR Production (1-10 million tons)	23				23				22			
% High MTR Production (>10 million tons)	3				3				4			
Health/Behavioral Characteristics												
County Level Self-Reported Health (Range=1-5)	3.05	.25	2.42	3.74	3.16	.24	2.50	3.74	2.92	.20	2.42	3.59
Median Body Mass Index	27	1	24	32	27	.95	24	30	27	1.03	25	32
Health Insurance												
% with Health Insurance	84	7	1	100	86	5	69	98	81	9	1	100
% Uninsured (Ref)	16	7	0	99	14	5	2	31	18	9	0	99
Smoking												
% Smokers	27	7	7	50	25	6	7	42	29	6	11	50
% Non-Smokers (Ref)	73	7	50	93	75	6	58	93	71	6	50	89
Demographics/County Characteristics												
Sex												
% Male	36	7	0[1]	58	39	6	24	58	33	6	0[1]	52
% Female (Ref)	64	7	42	100	61	6	42	76	67	6	48	100
Race												
% White	97	3	78	100	97	3	78	100	97	3	78	100
% Non-White (Ref)	3	3	0	22	3	3	0	22	3	3	0	22
Median Age	53	4.30	39	65	53	4.30	39	63	52	4.25	43	65
Socioeconomic Characteristics												
Median Income (Range=1-7)	4.86	.80	2	7	5.18	.71	3	7	4.51	.74	2	7
Median Highest Grade Completed (Range=1-6)	4.28	.28	3	5	4.38	.27	3	5	4.16	.24	4	5

*MTR = Mountaintop Removal; [1]0% male is for one county in one year of data; because of the small sample size from this low population county, all of the respondents were female.

Table 2: County-Level Health in Eastern Kentucky and West Virginia, 2000-2010: OLS, Random, and Fixed Effects Models

Coal Mining & Covariates	OLS (M 1.1)	OLS (M 1.2)	RE (M 2.1)	RE (M 2.2)	FE (M 3.1)	FE (M 3.2)
MTR Coal Production (>100,000=ref)						
Low MTR Production (100,001-1,000,000 tons)	-.05	-.02	-.03	-.02	.00	.02
Medium MTR Production (1,000,001-10,000,00 tons)	-.25 ***	-.11 ***	-.14 ***	-.11 ***	-.06	-.02
High MTR Production (>10,000,001 tons)	-.30 ***	-.12 ***	-.21 ***	-.13 **	-.12	-.03
Health/Behavioral Characteristics						
% Smokers		-.38 **		-.34 ***		-.29 **
% with Health Insurance		-.13		-.10		-.07
Median Body Mass Index (BMI)		-.05 ***		-.04 ***		-.03 ***
Demographics/County Characteristics						
% Male		.44 ***		.27 ***		.14
% White		.18		.41		.65 **
Median Age		-.01 ***		-.01 ***		-.02 ***
Socioeconomic Characteristics						
Median Income (Range=1-7)		.06 ***		.05 ***		.04 ***
Median Highest Grade Completed (Range=1-6)		.38 ***		.33 ***		.23 ***
R^2	.19	.68	.19	.67	.69	.77
N	83	83	83	83	83[1]	83[1]

*$p \leq .05$ **$p < .01$ ***$p \leq .001$

[1]Fixed Effects models only include counties that experience both change in MTR coal production and change in health status.
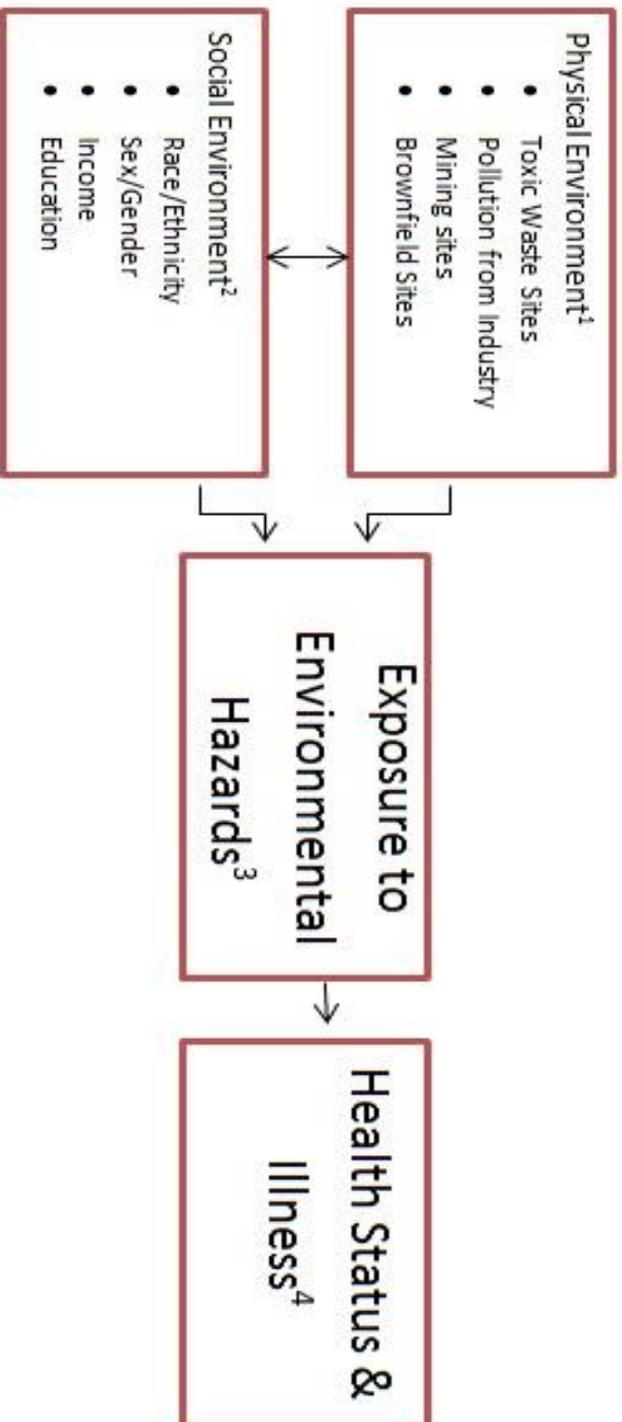
Figure 1: Environmental Health Pathway

Physical Environment[1]
- Toxic Waste Sites
- Pollution from Industry
- Mining sites
- Brownfield Sites

Social Environment[2]
- Race/Ethnicity
- Sex/Gender
- Income
- Education

Exposure to Environmental Hazards[3]

Health Status & Illness[4]

Figure 2: Proposed Study Area - Eastern Kentucky and West Virginia
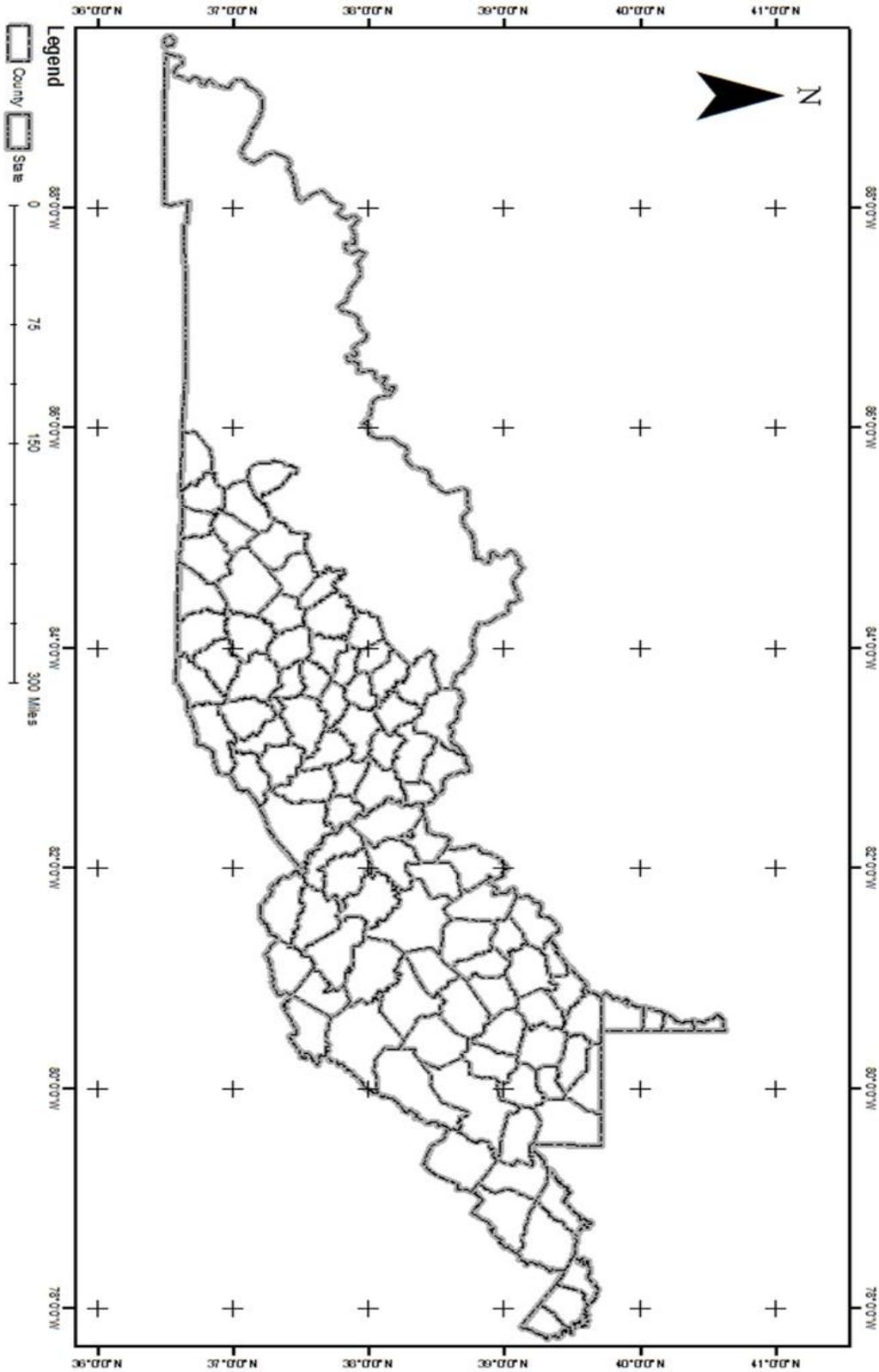
FIGURE 3: AVERAGE COUNTY-LEVEL MTR COAL PRODUCTION IN CENTRAL APPALACHIA, 2000-2010
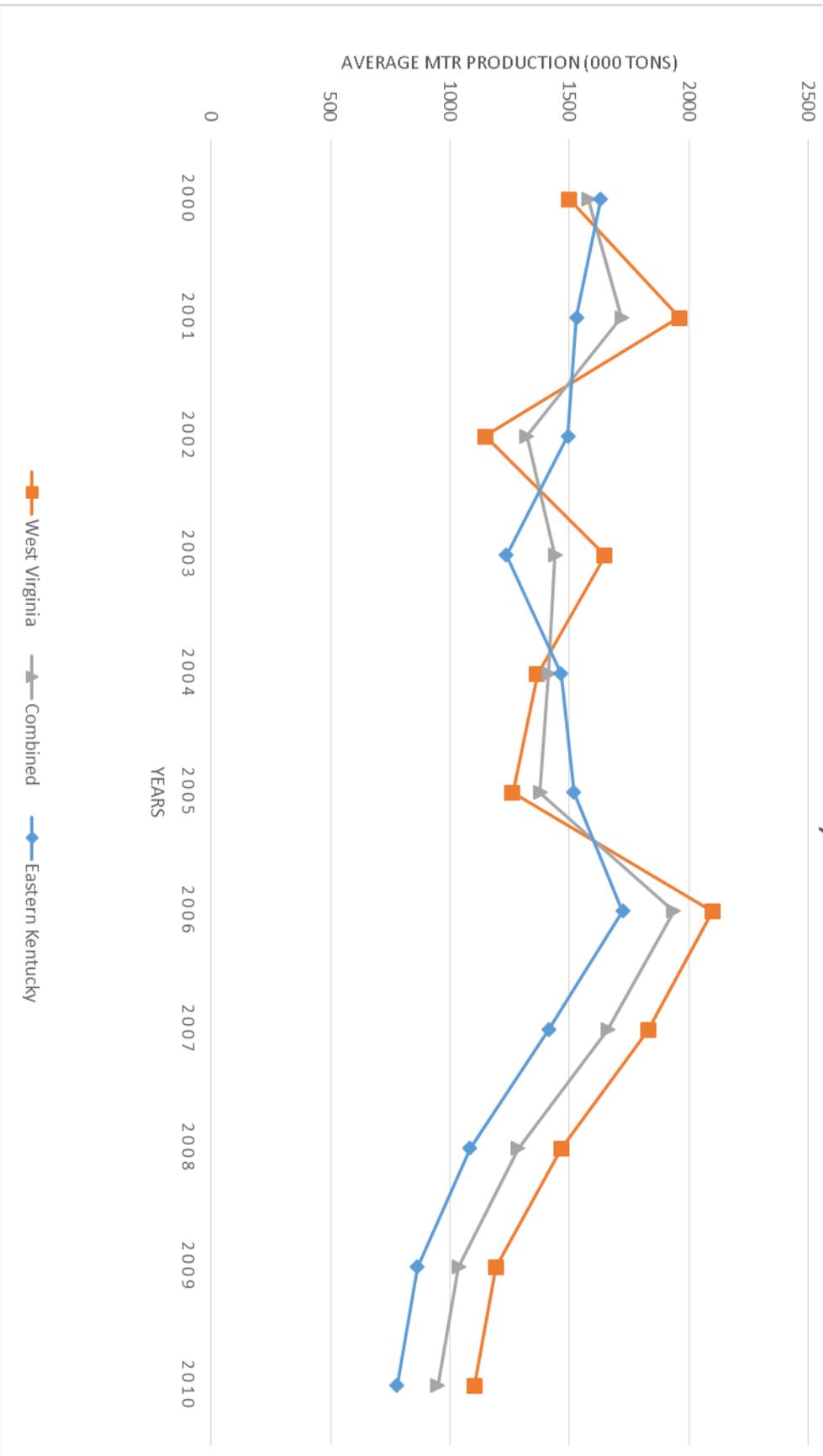
FIGURE 4: AVERAGE COUNTY-LEVEL COAL PRODUCTION IN CENTRAL APPALACHIA, 2000-2010
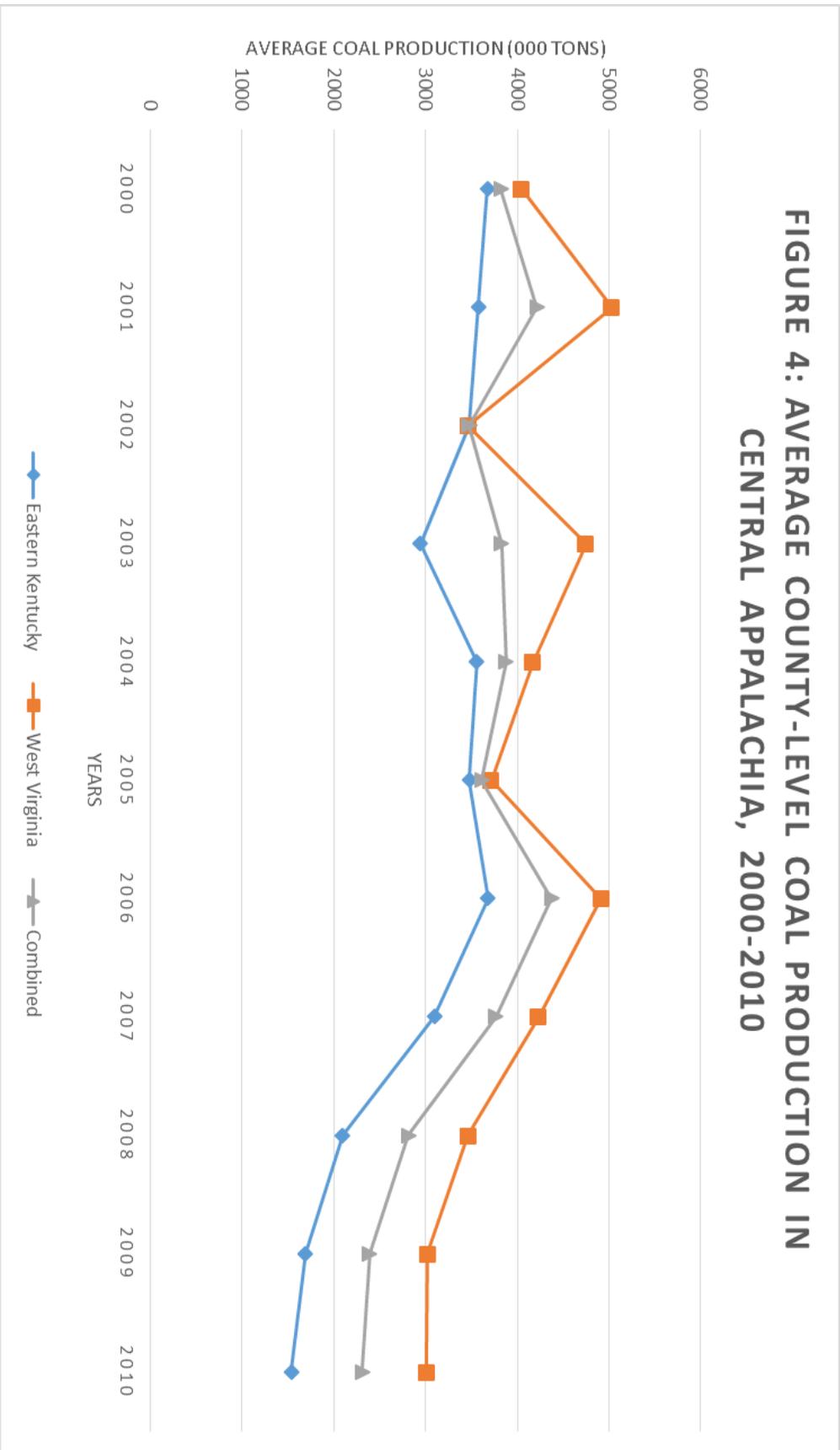
FIGURE 5: AVERAGE COUNTY-LEVEL SELF-REPORTED HEALTH STATUS IN CENTRAL APPALACHIA, 2000-2010
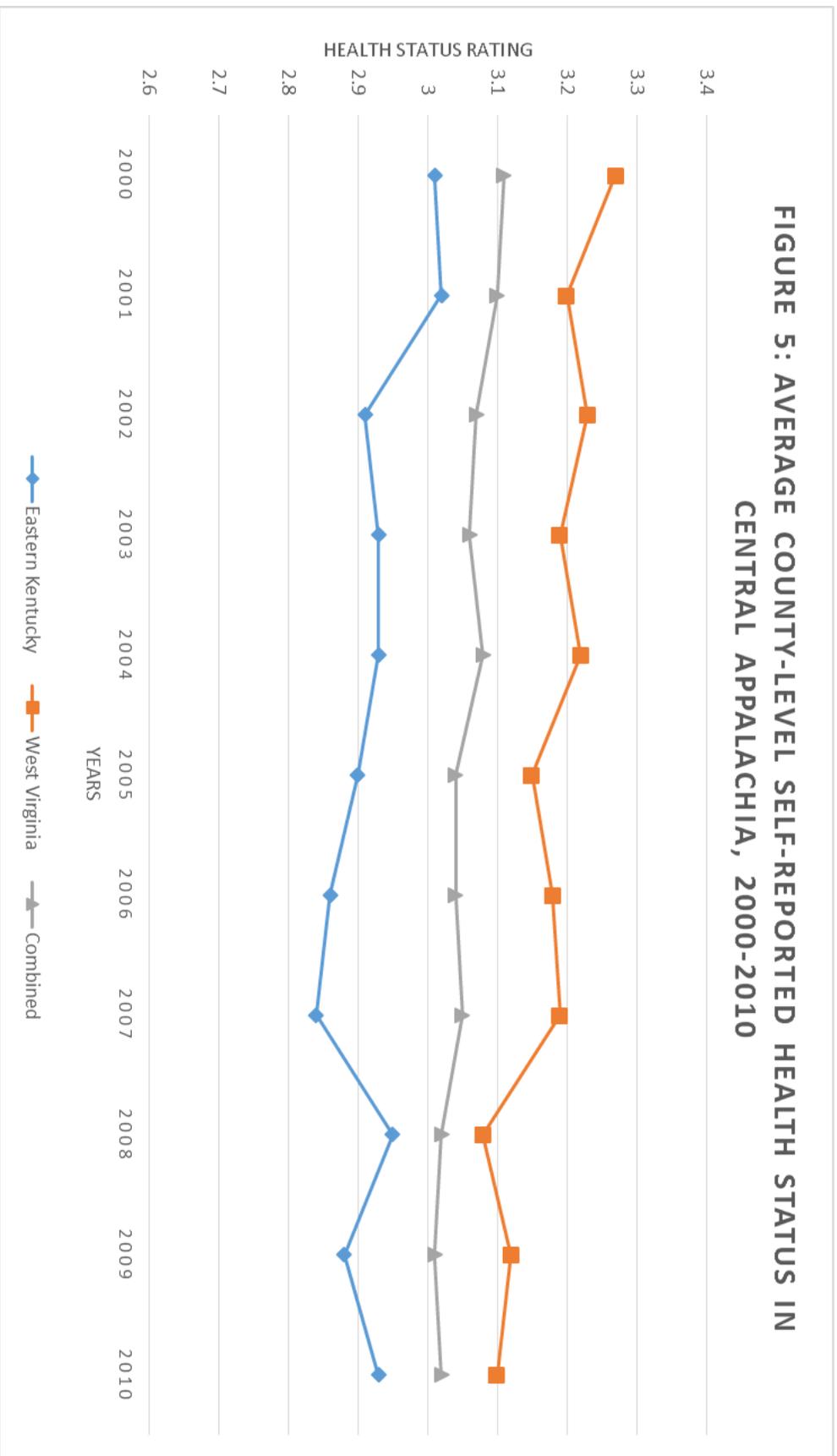
CURRICULUM VITA

NAME: James Kent Pugh

ADDRESS: Department of Sociology
            Lutz Hall 103
            University of Louisville
            Louisville, KY 40292

DOB: Mount Sterling, Kentucky – July 27, 1990

EDUCATION
& TRAINING: B.A., Sociology
                  Berea College
                  2008-2012

AWARDS: Alice Eaves Barns Award
            2014

            Dean's Citation
            2014

            Dallas and Betty Johnson Sociology Scholarship
            2012

            John B. Stephenson Scholarship for Non-Western Travel
            2011

PROFESSIONAL SOCITIES: Population Association of America
                              Appalachian Studies Association
                              Anthropologists and Sociologists of Kentucky