Coal Mining and the Resource Curse in the Eastern United States

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Abstract:

We measure the effect of coal resource sector dependence on long run income growth using the natural experiment of coal mining in 409 U.S. counties that are selected for homogeneity. Using a panel data set (1970-2010), we find a one standard deviation increase in resource dependence is associated with an estimated 0.6 percentage point drop in annual growth rates of per capita personal income. We also measure the extent to which the resource curse operates through disincentives to education, and find significant effects, but results indicate that this education channel explains only perhaps 25% of the curse.

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1. Introduction

The "resource curse" is said to occur if a region's resource wealth detracts from the economic well-being of its people. A substantial, though controversial, empirical literature suggests that people residing in some resource-rich regions do in fact experience lower incomes and slower income growth rates than people in otherwise comparable resource-poor regions. There are many possible explanations for this phenomenon, including disincentives to human capital formation, negative interactions between extractive industries and social institutions, adverse real exchange rate effects, and economic damage from resource price volatility. Despite this extensive literature, uncertainty persists about the scale and even the existence of the resource curse, partly because it is difficult to control for variation in other factors that determine prosperity and growth among highly diverse regions. In this study we use panel data to compare growth in per-capita personal income in coal-producing counties to its growth in coal-free counties in an otherwise relatively homogeneous sample of U.S. counties over the period 1970-2010.

Most previous studies of the resource curse, including seminal work by Sachs and Warner (1995), have investigated the resource curse effect using international data. The nations of the world are extremely diverse, though, and variables that control for growth-relevant diversity among nations are often endogenous, highly correlated, mismeasured, or simply unavailable. Van der Ploeg (2011, p. 381), in a survey of the resource curse literature, recognized this problem and reasoned that the "road forward might be to exploit variation within a country where variables that might confound the relationship between resources and macroeconomic outcomes do not vary and the danger of spurious correlation is minimized." Consistent with this insight, our identification strategy begins by selecting a sample of U.S. Appalachian counties that are similar in history, culture, demography, and governance. We select our sample of 409 counties on the basis of contiguity, topography, and data on slavery from the 1860 Census, as described in detail in Douglas and Walker (2013). This mode of sample selection reduces the effects of unobservable heterogeneity, reduces potential omitted variables bias, and increases the precision of our results. Our strategy takes advantage of a natural experiment, consisting of the allocation by nature of commercially exploitable coal resources across the region. We do not, however, assume that the rate of production of coal or initial income in any given time period is exogenous, and therefore use an instrumental variables approach in our estimation.

Consistent with most of the resource curse literature, but in contrast to many previous works covering the Appalachian region (Deaton and Niman 2012, Partridge, Betz, and Lobao, 2013; Black *et al.* 2005b), we examine the effects of resource dependence on personal income growth rates rather than poverty rates, population, or employment. Each of these measures of economic wellbeing has strengths and weaknesses. Employment measures an important aspect of labor market health, but a decrease in employment may or may not indicate a decline in welfare, as it may occur simultaneously with an increase in wage rates, or a decline in the size of the workforce due to neutral or beneficial demographic shifts, such as an influx of retirees or simple aging of the resident population. Similarly, although a declining population often indicates declining welfare, it may also indicate a beneficial response to increased opportunities in other regions. An increasing poverty rate is worrisome to policy makers, but it may indicate only an increasingly uneven distribution of benefits, in which case one segment of the population may gain more than another loses. In contrast, a decline in per capita income is a less ambiguous indicator of declining general economic welfare, although (and indeed because) it is less sensitive to distributional effects than other measures. As a measure of economic welfare, per capita income shares many of the strengths and weaknesses of GDP per capita, which is the most-commonly used measure in the international studies that compose the bulk of research on the resource curse.

Another factor that distinguishes this research from related work is that our panel data set employs a relatively long time series (1970 – 2010) containing at least two distinct boom cycles. In contrast, most comparable studies use either cross-sectional data or a shorter time series. Our longer time series, plus the addition of a variable controlling for the short-run effect of energy prices on coal-county growth, allows us to distinguish cyclical from secular effects, ameliorating the bias that may arise from looking at data gathered during either the boom or the bust part of the cycle.

Our empirical analysis proceeds in two stages. First, using regressions based on the Solow growth model we find that a one standard deviation increase in the resource abundance variable is associated with a reduction in average annual growth rate by an estimated 0.6 percentage points. Second, we pair our growth regression equation with an equation describing county-level educational attainment, and find results consistent with the hypothesis that the coal industry provides incentives for less educational attainment, and that lower educational attainment levels in coal-producing counties explain part of their lower growth rates. In both sets of analyses, we consider models with and without spillover effects from neighbors.

Our results have policy implications for poor but coal-rich regions of the world. The coal industry provides employment opportunities and income, but our results suggest that those opportunities come at the price of lower overall long-term income growth. Rather than promote the coal industry whose growth and decline are largely determined by the world market for coal, our research suggests that state and local policy makers would be well-advised to capture rents during boom times and use them to implement policies that promote long-term economic diversification and accumulation of human capital.

The remainder of this paper is organized as follows. Section 2 outlines the various "channels" through which a resource curse might operate. Section 3 explains why the Appalachian region provides an especially good subject for study of the resource curse. Section 4 describes our data set and empirical model, and section 5 presents the basic empirical growth model and coefficient estimates from that model, respectively. Section 6 presents our model of the education channel and summarizes its empirical results, comparing them to the results for the basic model. Section 7 contains a discussion of conclusions and policy implications.

2. Channels through which Resource Dependence Affects Economic Growth

The resource curse literature lists several different channels through which resource abundance might negatively affect growth. Much of the recent resource curse literature focuses on institutions as the primary mechanism. For example, Mehlum, Moene, and Torvik (2006) maintain that poor institutional quality is a necessary precondition for resource abundance to retard economic growth, while Isham *et al.* (2005), Bulte *et al.* (2005), Robinson, Torvik, and Verdier (2006), Acemoglu *et al.* (2003), and Collier (2010) find that resource abundance may also cause poor institutions. Natural resource abundance has been linked to an increased risk of conflict by Collier (2010) and Ross (2004). On the other hand, Alexeev and Conrad (2009) argue that oil resources and production do not negatively affect institutions, and increase per capita GDP.

Another possible channel for the resource curse is the "Dutch Disease," described in Sachs and Warner (1995, 1997, and 2001). The Dutch Disease refers to a decline in a country's non-resource traded-goods sector caused by resource-driven appreciation of real exchange rates. At a sub-national level, where nominal exchange rates are held fixed, the Dutch Disease could occur if high wages in resource industries "crowd out" growth in the non-resource traded goods sector. Davis (2011) finds some evidence of this phenomenon using international data, though both Davis (2011) and James and James (2011) argue that most slow growth in resource-rich economies is attributable to optimally slow growth rates in the resource sector itself, constituting a "resource drag" rather than a resource curse.

The cycle of boom and bust that characterizes energy prices may also create instability that retards growth. For example, Black, McKinnish, and Sanders (2005b) examines the spillover effects on local industry of the Appalachian coal market boom and bust during the late 1970s to early 1980s. That study finds evidence of an asymmetric effect of the boom and bust cycle in the locally traded goods sector in Appalachia: For every ten mining jobs added in the boom, it estimates 1.7 additional local-sector jobs were added, but 3.5 local-sector jobs were lost ten per mining jobs lost during the industry downturn.

Another channel for the resource curse is through disincentives to education. Young people have a disincentive to continue their education when relatively well-paying unskilled employment opportunities are available in the resource sector. Papyrakis and Gerlagh (2007) find that schooling is the most important transmission channel of the resource curse in their cross-sectional study of the U.S. states. Gylfason (2001) finds that expected years of schooling for girls and secondary school enrollment rates are both negatively related to the share of natural resource wealth across countries. Black *et al.* (2005a) find that Appalachian high school enrollment rates declined substantially during the 1970s coal boom period and increased during the 1980s bust. They also find that during the coal boom the earnings of high school dropouts rose, and high school enrollment rates declined, in coal-producing counties relative to coal-free counties, and that these trends reversed during the energy price declines of the mid to late 1980s. Michaels (2011), in contrast, finds little or no effect of oil abundance on educational attainment, a result consistent with Betz et al. (2014), who also found little or no effect of coal mining on educational attainment in the Appalachian region.

3. The Appalachian Region as a Laboratory

Appalachian counties have in common a robust culture dating from settlement by Scots-Irish immigrants in the 18th century (for historical and ethnographic background, see Fischer, 1989). Topography, poor soils, poor roads, and geographic isolation precluded the Appalachian region from participating in the slave plantation culture that dominated the rest of the antebellum South, and whose legacy underlies much of the rural poverty found in the former Confederacy to this day. The integration of the Appalachian region into the industrial economy began with the exploitation of its timber resources at the end of the 19th century, which was followed by the rapid growth of the coal industry, particularly during the two world wars and during the expansion of coal-fired electric power generation in the 1960s and 1970s. That process of Appalachian integration into the wider American culture and economy is still far from complete, and the region retains a unique cultural, political, and economic character.

Besides providing a relatively homogeneous sample, the Appalachian region is attractive for this study because of the size of its coal endowment and the way that it is distributed. The coal is distributed in a north-south band that includes almost half the Appalachian counties and crosses through most of the states and climate zones in the region. Coal production in the Appalachian region currently accounts for over one third of all coal produced annually in the United States, and over half of cumulative U.S. coal production to date, according to the U.S. Energy Information Administration. The coal fields are mature, having been exploited commercially on a large scale for over 100 years, so the area of exploitation corresponds closely to the area of the exogenous geological resource endowment. Although some areas of the Appalachian coal fields have experienced a long-term decline in production since the 1950s, other areas have increased or even initiated production during the period under study. The Appalachian region and its coal endowment therefore provide an especially attractive natural laboratory for studying the resource curse.

The region is relatively poor, both within and beyond its coal fields. The poverty rate in Appalachian counties is substantially higher than in the rest of the U.S., though it fell substantially between 1965 and 2008. Economic gains over the past half-century have not been distributed evenly across the region, though, and in 2008 the Appalachian Regional Commission (ARC) classified 82 of the 420 ARC counties as "economically distressed." The majority of these distressed counties lie in the central portion of the region, primarily in eastern Kentucky and southern West Virginia, where coal mining often dominates the local economy.

[Table 1 and Figure 1 about Here]

Table 1 and figure 1 illustrate differences in per capita income and income growth rates between coal-producing and coal-free Appalachian counties since 1970, and their relationship to boom and bust cycles in coal prices. As the price of coal rose in the 1970s and again in the mid-2000s, per-capita income in coal-producing counties rose relative to income in coal-free counties. The relative income trend reversed as energy prices declined in the 1980s, and coal-producing county incomes fell far behind. During the 1990s, when real coal and other energy prices declined moderately, national prosperity brought equal growth to coal and non-coal counties. Energy prices began to increase again in 2004 and continued to do so through the 2007-09 national recession, cushioning the impact of that recession on coal-producing counties. Table 1 shows growth rates were higher in coal-producing counties in the 1970s and 2000s, but income levels were significantly lower than in coal-free counties throughout the period.

The observation that county per-capita income is lower on average in coal-producing Appalachian counties naturally leads to the question of whether a resource curse exists in the Appalachian region, and if so, what mechanisms drive it. A few other studies have addressed the question of an Appalachian resource curse from various perspectives. For example, Deaton and Niman (2012) use a panel regression to study poverty rates in 399 ARC counties, and Partridge, Betz and Lobao (2013) also find a positive but diminishing effect of coal mining on poverty rates. Betz et al. (2014) examine the relationship between coal mining employment and a variety of indicators from 1990 to 2010, finding negative effects on population growth and entrepreneurship for the Appalachian region. Black et al. (2005a, 2005b) study the effects of coal market boom and bust on employment and other indicators of health in local Appalachian labor markets. In a cross-sectional study, Santopietro (2002) discusses the role of natural resources in economic growth in the Appalachian region, but mainly focuses on the issue of income convergence. He tests for absolute convergence and finds that income levels in Appalachia are only very slowly converging, and attributes some of this slow rate of convergence to the region's reliance on natural resource industries. Kilkenny and Partridge (2009) find that export sector employment, represented in part by the share of employment in mining, fails to significantly contribute to rural economic growth.

4. Data and Empirical Growth Model

Sample Selection

In conducting our empirical work, we first define the Appalachian region in such a way that we obtain a sample of counties that is as homogeneous as possible, within which we can find control and treatment groups for the natural experiment of coal resource endowments. Many researchers, including Deaton and Niman (2012) and Partridge *et al.* (2012), define the Appalachian region as the 420 counties defined as the area of concern of the Appalachian Regional Council (ARC). The ARC includes some counties explicitly because of their poverty and slow growth rates, and it is well known that a regression sample chosen with reference to the dependent variable can yield biased and inconsistent coefficients (Heckman, 1979). Including counties that do not share the Appalachian culture and history also increases the heterogeneity of the sample, which decreases the precision of regression parameter estimates, as demonstrated by Douglas and Walker (2013). [1]

[Figure 2 about here]

We select our sample of Appalachian counties based on three exogenous criteria: topographical relief, enslaved percentage of the population in 1860, and geographic contiguity to other Appalachian counties. We draw our measure of the percentage of enslaved peoples in the county's antebellum population from the 1860 Census. The inverse correlation between slavery prevalence and mountainous terrain is readily apparent in a famous map (Hergesheimer, 1861) that was allegedly used by Abraham Lincoln to identify areas of pro-Union sentiment in the Southern Appalachians, a portion of which is reproduced here as figure 2.[2] Prevalence of slavery within a county indicates important aspects of its economic system, demography, culture, social relationships, and political loyalties. In counties where the

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1 Douglas and Walker (2013) find that using our sample of Appalachian counties rather than the ARC sample increases the precision of estimation of a model similar to those estimated in this paper, but they find no evidence of bias arising from using the ARC sample.

2 A downloadable copy of the full map and a discussion of its history are provided at the Library of Congress website, http://blogs.loc.gov/loc/2012/10/mapping-slavery/.

plantation culture prevailed, much of present-day poverty may be attributed to the legacies of African-American slavery and subsequent sharecropping and Jim Crow oppression. Because of poor soil and rough terrain, slave plantations never took hold in most of the Southern Appalachians, and consequently the demographics and dynamics of poverty in the Appalachians are distinct from those of surrounding regions. We also measure geographic relief and land topography by the set of Land Surface Form Topography Codes compiled by the U.S. Geological Survey (USGS, 1970). These codes range from 1 (Flat Plains) to 21 (High Mountains), and broadly increase in relief as the numbers increase. To further ensure homogeneity, we require our counties to form a contiguous region.

In general, our algorithm for selecting counties involves tradeoffs among the three criteria. All counties in the sample have a topography code of at least 5; all had 1860 Census enslavement rates of 30% or less, and most rates were below 15%. Overall, our sample contains only 84% of the 420 ARC counties, especially excluding counties in Mississippi and Northeast Ohio. About 14% of our sample consists of counties excluded from the ARC sample, including counties in New York State, the Allegheny Front of Virginia, and along the Ohio and Tennessee rivers.

Empirical Growth Model and Variables

We specify an empirical growth model that relies for identification primarily on the homogeneity of the counties within the data set, but also employs controls (X_{it}) for energy prices, rurality, surface mining extent, spatial spillover effects (WX_{it}), and time (ν_t) and state (μ_s) fixed effects.

$$g_{it} = \beta_1 LnY_{it} + \beta_2 NR_{it} + X_{it}\beta_3 + WX_{it}\beta_4 + \nu_t + \mu_s + \varepsilon_{it} \qquad (1)$$

The dependent variable g_{it} is the average long-run growth rate, measured as the difference in log per capita pre-tax personal income net of transfers. We annualize this ten-year growth rate by dividing by the length of the period, or $g_{it} = \left(\frac{1}{10}\right)(LnY_{i,t+10} - LnY_{it})$ for county *i* at time *t*. The data set covers four ten-year time periods from 1970 to 2010. These decades coincide with the decennial censuses, and roughly with the timing of recent boom and bust cycles in oil and other energy markets. We test the null hypothesis that resource dependence has no significant effect on income growth ($H_o: \beta_2 = 0$). A statistically significant and negative coefficient on *NR* would provide evidence for the existence of a resource curse associated with Appalachian coal production. [3]

[3] Boyce and Emery (2011) argue that a negative coefficient is insufficient evidence of a resource curse. They instead say that it may reflect a "resource drag" due to slow (but perhaps optimal) growth in the resource sector. This argument loses force where the slower-growing counties also have lower levels of income.

Table 2 contains variable descriptions, data sources, and descriptive statistics for all variables and instruments used in the study. NR_{it} is the key variable of interest, as it measures the dependence of the county's economy on income from coal production. There is a wide variation in coal dependence even among coal-producing counties, where coal revenues vary from near zero to four times county income.

[Table 2 about here]

There is some debate in the empirical resource curse literature about how best to measure resource intensity. Some studies (e.g. Brunnschweiler and Bulte 2008, Stijns 2005) find a positive resource effect employing measures based on *potential* resource wealth, i.e., measures of resource "abundance." Most studies, however, employ flow measures of resource "dependence," which capture the value of extracted resources relative to total income or total exports. Our measure of resource dependence, *NR*, is the ratio of resource revenue to pre-tax total personal income net of government transfers.[4] As such, it captures the effects of the dominance of resource extraction relative to other (non-transfer) sources of income and indicates the dependence of the county on coal mining at the beginning of the decade.

Following the economic growth and convergence literature, e.g., Temple (1999), we include log real per capita personal income during the initial year of each time period, (LnY_{it}) as a regressor in our model. A significantly negative coefficient on this term implies conditional convergence of incomes across counties to their natural growth rates. The income variable LnY_{it} and the vector of control variables X_{it} are set to the initial year of the time period, and prices are measured in year 2000 dollars.

We specify a parsimonious model with relatively few regressors advisedly, partly because of the homogeneity of our sample reduces the potential for omitted variables bias, but primarily because our focus is on persistent, medium-to-long-run effects of coal dependence on income growth rates. Some of the channels through which the resource curse is likely to operate in the Appalachian region are extremely persistent, such as institutions; others, such as human capital formation, the Dutch Disease, and economic instability, change slowly decade by decade, so much of the potential coal-dependence-induced variation in growth is likely to be cross-sectional in nature, even when viewed over a forty-year period. County-level fixed effects would eliminate all such cross-sectional variation, so we do not employ them. Indeed, all coefficients, including those for year fixed effects and oil prices, become insignificantly different from zero when county fixed effects are included in the model.

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4 We calculate resource revenue as the number of tons of coal produced in county i during the initial year of the time period, multiplied by the average real price of bituminous coal during the same year.

To provide some control for unobserved county heterogeneity induced by institutions at the state level, equation (1) contains a vector of state fixed effects, designated by the μ_s term. State fixed effects control for factors specific to each state, including income taxes, severance taxes, sales taxes, and inheritance taxes, broad policies related to infrastructure and education, the structure of the judicial system, characteristics of law enforcement (including much environmental law enforcement), and corruption, to the extent that they are affected by statewide institutions and policies. Time fixed effects control for the business cycle, the effects of energy prices on consumers, and other shocks common to all counties at a given time. To further control for heterogeneity among counties, we include variables measuring the percentage of the county's surface impacted by mountain-top removal mining (*PctMTR*) and abandoned surface mines (*PctSAML*). The mountain-top removal data vary by decade, and were obtained from shapefiles provided by the SkyTruth organization from its analysis of satellite photos from 1976, 1985, 1995, and 2005 in 59 Appalachian counties in Kentucky, Tennessee, Virginia, and West Virginia. The abandoned strip mine data were downloaded from the eAMLIS site maintained by the U.S. Office of Surface Mining and Enforcement.

Urban areas have well-known growth advantages, including agglomeration economies and superior transportation facilities, and some of the poorest counties in the Appalachian region are rural. We have therefore included variables in the vector X_{it} that control for the degree of rural isolation. These variables, derived from the USDA's Rural-Urban Continuum ("Beale") Codes, are available for 1974, 1983, 1993, and 2003, and are based primarily on data from the previous censuses, so we treat them as exogenous beginning-of-period values for their respective decades. Beale Codes are non-monotonic, so we use them to create dummy variables (*Rural, Metro*).

We also include in our control vector X_{it} an interaction variable between the ten-year percentage change in oil price *(dOilPrice)* and a dummy variable equal to one if the county produced coal during the initial year of the time period (*NRDum*). This interaction variable, *dOilprice*NRDum*, controls for the income effect of energy price cycles on coal-producing economies (Engemann, Owyang and Wall, 2013). Increases in energy prices can affect a county's growth in at least two ways. First, in all counties an energy price increase raises transportation costs and lowers disposable income net of energy expenditures. This effect is captured by the time fixed effects ν_t. Second, in energy-producing counties higher energy prices stimulate the energy industry to reduce unemployment and increase wages in the short run, and the *dOilPrice*NRDum* interaction variable captures this effect. Including this interaction variable in the regression allows the coefficient on the resource abundance variable *(NR)* to capture the long-run secular effect of natural resource abundance, net of the short-term boom and bust effects of cyclical energy price changes.

Counties are relatively small geographic units, and people often live in one county and work or shop or sell goods in the neighboring county. To control for these "spillover effects" we use a set of spatially lagged regressors each of which, for a given county, consists of a simple average of that regressor's value over that county's immediate neighbors. (To construct these variables along the border of the Appalachian region, we included all counties contiguous to but outside of the Appalachian region.) We denote these spatially lagged regressors in tables 3 and 5 by the prefix "*W**", indicating premultiplication of each variable's cross-section by a row-normalized contiguity spatial weight matrix *W*.

Because *NR* is our variable of prime interest, and growth dynamics are different in metropolitan areas, we have constructed an interaction variable *Metro*W*NR* to allow for distinct effects of coal mining neighboring on a metro county. If coal mines tend to buy machinery and other goods in neighboring urban areas more than rural areas, or if better-paid mine workers prefer to live in nearby urban areas, we'd expect a positive coefficient for this interaction variable. If, on the other hand, the impact of a mine is less incremental impact on relatively well-diversified and wealthier urban neighbors than on more rural areas, we would expect this interaction variable's coefficient to have a negative sign.

The choice of estimation method for the growth regression equation (1) depends primarily on whether or not the *NR* and *LnY* variables may be treated as exogenous. As Brunnschweiler and Bulte (2008) point out, researchers often consider resource dependence to be exogenous despite reasons to believe otherwise. Coal revenue is likely to be determined simultaneously with economic growth, particularly in coal-producing counties. Total county personal income, LnY_t, may also be endogenous given that the dependent variable is growth in personal income ($LnY_{t+1} - LnY_t$). Testing confirms that *NR* and *LnY* should be considered endogenous in equation (1); therefore we estimate the model with two-step efficient GMM using instrumental variables, and we supply OLS estimates for comparison.

We implement GMM using three instrumental variables: *Coal0, MMBTUperTonAsh*, and lagged initial income, LnY_{-1}.[5] The *Coal0* dummy variable equals one if the county has *ever* produced coal, and zero otherwise. The Appalachian coal fields have long been exploited (186 of the 193 coal counties had produced coal at some point in their past as of 1970), so *Coal0* indicates the presence of commercially

5 The BEA REIS did not collect per-capita county personal income net of transfers prior to 1969, so for the lagged 1970 income instrument we used 1959 per capita income by county from the U.S. Census.

minable coal in a county, which is presumably exogenous and positively correlated with *NR*. *MMBTUperTonAsh,* or million BTUs of heat content per ton of ash, is a measure of coal quality obtained from core sampling.[6] Like Betz et al. (2014), we found this variable to be a strong instrument for *NR*, as coals that provide more useful heat and leave less ash to dispose of tend to be mined more intensively regardless of economic conditions. Consistent with the empirical growth literature, e.g. Arellano and Bond (1991), we also instrument *LnY* with its lagged value. First stage F-tests and Hansen *J* tests support the strength and validity of all three of our instruments, as can be observed in tables 3 and 5.

5. Growth Model Estimation Results

Table 3 shows coefficient estimates for three specifications of the basic growth model, equation (1). One specification contains spatially lagged measures of spillovers, and the other two lack them. All models employ state and time fixed effects. Although OLS estimates are provided for comparison, the GMM estimates employ instrumental variables and will therefore tend to outperform OLS if the instruments are strong and exogenous. The Hansen J test does not reject exogeneity of the instruments, and the first-stage F tests provide evidence that the instruments are strong in the sense that they are well-correlated with the endogenous variables. In addition, each instrument has a significant coefficient of the expected sign in the first stage regressions (available on request).

[Table 3 about here]

Coefficient estimates for the coal mining dependence variable, *NR,* are of primary interest. In the GMM models without spillovers, the coefficient estimates suggest a negative and significant effect of coal mining dependence on income growth. The effect is larger in the model with the oil price interaction variable *dOilprice*NRdum*, which controls for short-run supply-side effects of energy market boom and bust. Estimates from the GMM models without spillovers indicate that a one standard deviation (0.5) increase in the *NR* variable is associated with a reduction in average annual growth of about 0.6%, or 1.3%, depending on the model.[7] This effect may seem small at first blush, but even an income growth rate

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6 Data come from the USGS Coal Quality database, which contains over 13,000 samples of coal and associated rocks (Bragg et al, 1998). Using ArcGIS Kriging, we interpolated a raster from these borehole points. Thanks to Seth Wiggins for preparing this data set, and for assistance with the SkyTruth GIS shapefiles as well.

7 We discuss the effect of a one standard deviation (0.50) difference in the *NR* variable instead of a unit difference because a unit increase in *NR* implies an increase of coal revenues equal to total county personal income. Note, however, that NR ranges from 0 to 3.99, so even a unit change is well within the sample.

difference of 0.6 percentage points compounded annually over 40 years would cause about a 20 percent difference in income levels at the end of the period.

Including spillover effects in the model provides a more nuanced view of the resource curse, as the, estimated income effect of coal dependence in neighboring counties (*W*NR)*, is positive and significant, though only half the magnitude of the negative effect of own-county mining. Anecdotal evidence suggests that miners and coal executives may prefer to live in in rural counties nearby, but away from the visual and environmental impact of the coal mines. Estimated spillover effects for metro areas (the sum of the coefficients on *W*NR* and *Metro*W*NR*) are practically nil, perhaps as a result of greater diversification in urban areas and fewer urban residents willing to drive for a job mining coal.

Other variables mostly have the expected signs. The estimated coefficient of the log of initial per capita income *LnY* is negative and significant in all specifications, indicating income convergence. The coefficient estimates indicate conditional income convergence rates slightly above the 2% rate usually found in the international literature according to Sala-i-Martin (1996).[8] Estimated coefficients for the oil price interaction variable in table 3 are positive and significant, consistent with the undoubtedly positive impact of higher energy prices on earnings in energy industries. This positive impact energy-price booms does not, however, counteract the long-term negative effects of dependence on coal in the Appalachian region over this time period. The estimated coefficients for the *Metro* dummy are positive as predicted and significant, while the estimated *Rural* dummy coefficients are negative but not significant.

The coefficients on mountain-top removal (*PctMTR*) and abandoned strip mine lands (*PctSAML)* as percentages of county land are perhaps a little surprising. The mountain-top removal estimate in particular is positive and significant though rather small, which tends to confirm that some county residents derive economic benefit from the practice, and reflects the growth of the mining technique over the past four decades. The magnitude of the positive effect of MTR is, however, small relative to the estimated negative impact of coal resource dependence.

We re-estimated equation (1) using several alternative measures (defined in table 4) of resource intensity, and the results indicate that our principal result is quite robust. For example, following James and Aadland (2011), measuring resource abundance as the share of total earnings in agriculture, forestry, fishing, and mining (*AFFM*) yields a negative and significant coefficient. Per-capita measures of resource intensity, such as coal revenue divided by population (*NR2*), coal production divided by population

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8 Consistent with the literature, we calculate the convergence rate $c = 1 - (1+T\beta_1)^{1/T}$ where $T = 10$.

(*NR5*), and cumulative coal production divided by population (*NR7*) all yield negative and statistically and economically significant coefficients. Using land area to scale the measure of resource (Coal revenue NR3, coal production *NR6*, and cumulative coal production *NR8*) yield negative and statistically significant coefficients as well. The *Coal0* variable is treated as exogenous for reasons given above, and so only OLS results are reported.

6. Educational Attainment as a Channel for the Appalachian Coal Resource Curse

The results reported in the previous section provide robust evidence of a curse associated with coal resource abundance in the Appalachian region. We now turn to the question of the mechanisms, or "channels," through which the Appalachian coal resource curse might work. Knowledge of these channels is required to formulate rational and effective policies to deal with the curse. All of the possible channels discussed above and others (health impacts, for example) may exist in the Appalachian region, and if so they likely interact with each other in many ways. Disentangling and illuminating all of these channels is far beyond the scope of the current essay, and our ability to do so is also limited by data availability. As a start, in this section we examine the education channel. We build on empirical work by Black *et al.* (2005a) and a large literature on incentives to human capital formation anchored by Mincer (1958) and Becker (1964). Our empirical strategy is to use a simultaneous equations model to examine whether the dependence of Appalachian county economies on coal mining may affect high school and college degree attainment of the population, and how in turn that effect on educational attainment affects income growth.

The theory of how the coal industry might create a disincentive to regional accumulation and retention of human capital is fairly simple. Many well-paying coal mining jobs do not require a high level of education; historically such jobs have not required even a high school degree. The types of jobs available for college graduates in coal-dependent counties tend to be in occupations where the returns to a college degree are lowest (natural resources, material moving, education, community service), and not in occupations where returns to a college degree are the highest (architecture and engineering, computer and math, business and financial management).[9] Where wages of less-educated resource sector workers are higher the opportunity cost of obtaining an additional year of schooling is higher as well. During periods of low resource prices the incentive for educational attainment in resource-dependent areas improves, but high unemployment during these periods also increases the incentive for out-migration, particularly for high-skilled and college-educated residents who have greater opportunities outside the region. These

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9 See Julian (2012) for a summary of 2011 synthetic work-life earnings of college graduates by sector.

disincentives for human capital accumulation and retention cause a macroeconomic decline in the regional stock of human capital. The decline in human capital causes labor productivity, technological innovation, and technological dissemination all to decline, which causes economic growth rates to fall.

A large empirical literature beginning with Barro (1991), and Mankiw, Romer and Weil (1992) confirms the importance of human capital, and in particular human capital obtained through education, to economic growth. Black *et al.* (2005a) provide empirical support for the negative interaction between Appalachian coal mining revenues and educational attainment during the 1970s to mid-1980s. Our analysis extends that of Black *et al.* (2005a) in several ways. First, we examine the long run effects of boom and bust cycles in the coal market on educational attainment, rather than examining the effects of one specific shock. Second, we explore whether or not the reduction in the fraction of individuals who have completed high school has any discernible effect on economic growth. As a robustness check, we also examine the same effects related to the completion of college.

[Figure 4 about here]

The Appalachian region lags far behind the U.S. national average in terms of both high school completion and college degree attainment. Within the Appalachian region, educational attainment in coal-producing counties lags slightly behind that of coal-free counties. Figure 3 shows average high school completion rates of residents in the United States as a whole, and for coal-producing and coal-free counties in the sample. For each year shown, the mean proportion of residents without a high school diploma is higher in coal-producing counties, with the widest margin occurring in 1990, following the 1970s boom and 1980s bust in the coal market. Similar observations obtain for attainment of college degrees.

7. Empirical Model, Data, and Estimation of the Education Channel

To estimate the magnitude of the resource curse channels some studies such as Sachs and Warner (1997 and 2001) have simply added appropriate channel metric variables to the right hand side of a growth regression. This method raises concerns of endogeneity since some channel variables are likely not exogenous in a growth regression. Several papers such as Gylfason (2001) and Papyrakis and Gerlagh (2004, 2007) use systems of equations to estimate direct and indirect effects. We use the following set of equations:

$$g_{it} = \beta_1 LnY_{it} + \beta_2 NR_{it} + X_{it}\beta_3 + WX_{it}\beta_4 + \beta_4\, Edu_{it} + \nu_t + \mu_s + \varepsilon_{it} \qquad (2.1)$$

$$Edu_{it} = \alpha_1 LnY_{it} + \alpha_2 NR_{it} + \alpha_3 EmpEdu_{it} + \alpha_4\, metro_{it} + \alpha_5\, rural_{it} + \delta_t + \gamma_s + u_{it} \qquad (2.2)$$

Equation (2.1) is a structural growth equation, similar to equation (1) but augmented with a term for educational attainment. Equation (2.2) is a reduced-form equation for educational attainment. We estimate the system twice, using two different variables for educational attainment taken from the decennial Census. The first is the share of adults age 25 and over without a high school diploma (*DropOut*), and the second is the share of adults age 25 and over with a bachelor's degree or higher (*Bach+),* both measured in the initial year of the time period. Descriptive statistics are provided in table 2.

This estimation framework allows us to estimate the magnitude of the education channel for the resource curse relative to the other channels. The education channel may be quantified as an indirect effect equal to the coefficient on the resource variable in the education equation (α_2) multiplied by the coefficient on education variable in the growth equation (β_3). We expect this indirect effect to be negative ($\alpha_2\beta_3<0$), as α_2 and β_3 are of opposite signs for both measures of educational attainment.

As with equation (1), we estimated equation (2.1) using GMM and treating natural resource dependence, initial income, and educational attainment as endogenous. We provide the same instruments for natural resource dependence and income as before. To select an instrument for educational attainment, we draw on past literature that investigates the causal link between education and earnings. Several studies including Card (1993), Uusitalo and Conneelly (1998), Higgins *et al.* (2006) and Kane and Rouse (1993) use geographic proximity of colleges to isolate exogenous variation in educational decisions, while Maluccio (1998) uses distance to high schools. Currie and Moretti (2003) use the availability of women's colleges as an instrument for maternal education. These and other studies have shown that proximity of educational institutions is strongly positively correlated with educational attainment. Since educational institutions employ local workers we use *EmplEdu*, which is the percentage of the county's workforce employed in educational services, as an instrument for educational attainment in the growth equation. The validity of using school proximity as an instrument for educational attainment relies on the assumption that school proximity affects income growth not because employment in the education sector stimulates growth directly, but because the proximity of educational institutions stimulates human capital formation. Similarly, we use the *EmplEdu* variable as an instrument in equation (2.1) on the assumption that higher employment in education at all levels reflects greater local effort toward human capital development.

Results of estimation of growth equation 2.1 using education attainment variables are presented in table 5. The estimated coefficients are identical in sign and significance to the previous growth regression coefficients presented in table 3, and are similar in magnitude as well. The signs of the two education attainment variables are as expected (indicating that more human capital implies faster growth) and both are significantly different from zero at the 5% level.

[Table 5 about here]

To estimate the effect of coal resource dependence on educational attainment, we estimate equation (2.2) using OLS and GMM. As with the other equations, state and time fixed effects are included as exogenous variables, and we employ *Coal0* and *Slavepct* as excluded instruments for the GMM estimation. In addition, we use lagged income rather than current income in equation (2.2) as a proxy for parental income. Some studies (e.g., Cohn and Huches 1994) have found that city size influences college degree attainment, so we use our *Rural* and *Metro* dummies in the vector of exogenous variables X_{it} in equation (2.2). We also include *EmplEdu* to control for the influence of local educational institutions on educational motivation and opportunity.

Our estimated coefficients on the educational attainment variables agree with Gylfason *et al.* (1999), Gylfason (2001), Black *et al.* (2005a), and Papyrakis and Gerlagh (2007), which all find a negative effect of resource abundance on schooling. Consistent with our human capital accumulation story, results reported in table 5 indicate that the negative effects of resource dependence on degree attainment are greater for high school than college. All of these results are highly statistically significant. Their practical significance is another issue. The GMM *NR* coefficients in table 5 imply that a one standard deviation (0.5 unit) increase in coal dependence increases the share of the population without a high school degree by about three percentage points, and decreases the share of the population with a college degree by more than two percentage points.

Multiplying estimates of the educational attainment variable coefficient from the growth equation (2.1) in table 5 by estimates of the *NR* coefficient from the educational attainment equation (2.2) in table 6, we estimate the indirect growth effect of coal dependence through a decrease in high school degrees to be -0.0035, which implies that a one standard deviation increase in *NR* reduces average annual income growth rates by an estimated 0.18 percentage points per year through the education channel alone. Using the *Bach+* measure of educational attainment, the estimated indirect effect of a one standard deviation increase of *NR* on growth is much less, at 0.09 percentage points per year. These results constitute, respectively, 26% and 13% of the total effect of *NR* on growth calculated from the estimates in table 5. (For comparison, Papyrakis and Gerlagh (2004) found an 11% contribution of the education channel using international data.)

Because the estimates from the two educational attainment variables are quite different, the magnitude of the education channel of the resource curse effect is difficult to determine. We cannot simply add the two coefficients, since *DropOut* and *Bach+* are highly correlated ($\hat{\rho} = -.76$). However, we can say that based on our two parameter estimates a reasonable point estimate of the true magnitude of the educational channel is somewhere between the lower of the two estimates (13%) and the sum of the two estimates (39%). Because the causal mechanism for coal mining's effect on high school completion is clearer, we expect that the true answer is near 25%, as implied by the drop-out equation. In summary, our results provide evidence that coal-producing counties have lower levels of human capital than coal-free counties, and that those lower levels of human capital significantly reduce per capita income growth over the long run. On the other hand, the results indicate that the majority of the coal resource curse of coal arises from causes other than the negative effects of the coal industry on the regional accumulation and retention of human capital.

8. Conclusions and Policy Implications

The Appalachian region defined in this paper stretches from New York to Mississippi, and it contains mature coal fields of global significance. Our results strongly suggest that the presence of coal in the Appalachian region has played a significant part in its slow pace of economic development. Our best estimates indicate that an increase of 0.5 units in the ratio of coal revenues to personal income in a county is associated with a 0.7 percentage point decrease in income growth rates. No doubt, coal mining provides opportunities for relatively high-wage employment in the region, but its effect on prosperity appears to be negative in the longer run. Our results suggest that a significant portion of that negative effect may be attributed to coal-industry disincentives to the accumulation and regional retention of human capital. Education levels in the Appalachians are low in general, though, and our estimates of the intra-regional negative effects of coal on educational attainment are relatively small, accounting for about one-fourth of the total resource curse.

Michaels (2011) takes a similar approach to ours in the sense that he studies a single resource, using county-level data, over a well-defined region of the United States. His data set covers the period 1940-1990 (with some analysis stretching back to 1890) in the oil fields of the South Central United States. He investigates the effect of oil resources on a variety of measures, including personal income and employment density in the mining, manufacturing, and agricultural sectors. In contrast to much of the rest of the empirical resource curse literature, Michaels finds a positive effect of oil resource abundance on employment density and income growth, although the benefits appear to erode over time. His paper is also similar to ours because he attempts to limit heterogeneity by drawing his sample from counties within 200 miles of the oil resource, and because he takes a longer historical perspective than most other studies. Michaels' sample is selected on exogenous criteria, but he makes no explicit effort to select counties with a uniform culture, topography, and economic history. Comparison of his results to ours suggests that the effect of oil on growth may be the opposite of coal's effect, raising the important question of why this might be so.

We take no position on whether there is a general "resource curse" that applies to most natural resource endowments, but our results strongly suggest that there is such a growth curse associated with coal in the Appalachians. Previous studies have also found indications of a resource curse in the Appalachians, and of a depressing effect of resource industries on educational attainment within the region. On the other hand, Michaels (2012), whose study resembles our own in some ways, found that the oil industry had a positive effect on development in the South Central United States. Why did the oil and coal industries have such different impacts on economic growth in their respective regions? One possibility is that government institutions are better in the oil fields, but it is not at all obvious that the government of Louisiana, for example, is less corrupt than that of, say, Pennsylvania. Another possibility is that the owners of the firms and land that produce oil are more likely to reside in the oil-producing region than are the owners of the firms and land that produce coal. A third possibility lies in the nature of the two industries themselves: for example, oil production requires refineries nearby, which are large industries themselves, add much value, and employ highly trained chemists and engineers, whereas the refinement of coal is a much less sophisticated process. Weinstein (2014) reconciles the results in Michaels (2012) with those of other studies examining the resources curse on a regional level by arguing that most of the benefits from the oil boom during the time of Michael's study were derived from a shift away from agriculture. This shift cannot be repeated, and so would not affect county growth in recent and current time periods.

On the basis of this study we can draw some tentative conclusions. Methodologically, when inquiring into the resource curse it is useful to define clearly the region and resource under study. More substantively for the Appalachian region, we have provided evidence that over-reliance on the coal industry presents some dangers to development. Some of these dangers may be averted by implementing policies that encourage educational attainment, and our study supports such policies, but we should not expect better education alone to solve the problem. The majority of the problem lies elsewhere, and we should consider other remedies. For example, the growth literature in general supports policies that reduce corruption and otherwise strengthen regional institutions. The Solow-Harwick rule states that for a nation to reap the maximum benefit from an exhaustible resources, it should use resource rents to invest in capital. If there is substitutability between produced capital and natural resources, the capital accumulation can offset the eventual slowing of growth due to declining stocks of the resource. The mechanisms by which the coal industry affects income and growth in the coal-producing regions merit more research as a foundation for future policy.

One way to avoid the resource curse would be to diversify the industrial base. Currently the Appalachian coal industry is in decline, and the Appalachian natural gas industry is growing with the implementation of hydraulic fracturing technology. Will the exploitation of the Marcellus Shale gas resource encourage or discourage long-term economic growth? The shale gas industry, like the coal industry, shows a strong tendency toward boom and bust, but then again the oil industry has a strong cyclical component to it as well. Refinement of natural gas is an important industry, but it is not on a scale with refinement of oil. On the other hand, access to a secure and low-cost natural gas supply could support growth of a variety of manufacturing industries as well as chemical and fertilizer industries that use natural gas as a feedstock. Officials in the Appalachians can perhaps look to the experience in other resource-rich regions for some guidance. A permanent trust fund financed by severance taxes is in use by Norway, as well as Alaska and several other western states. The use of such funds in the Appalachians and the other resource-rich regions of the world should be guided by a better understanding of the particular mechanisms of the resource curse within each of those regions.

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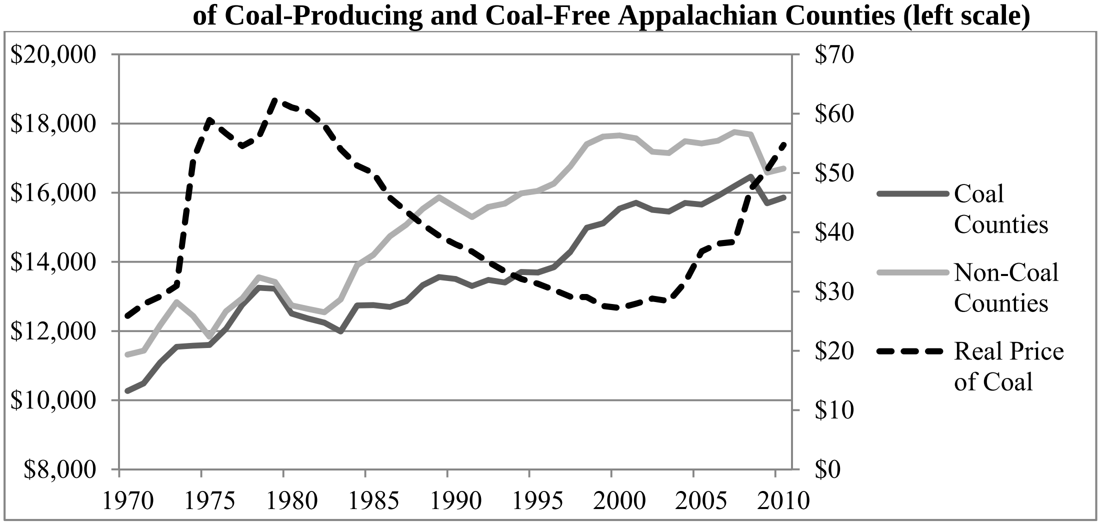
Tables and Figures

Table 1:
Real Mean Per Capita Income of Coal-Producing and Coal-Free Appalachian Counties

INCOME LEVELS:	**1970**	**1980**	**1990**	**2000**	**2010**
Coal Counties	10303	12357	13511	15478	15076
Non-coal Counties	11442	12919	16025	18478	17292
Difference (Non-coal minus coal)	1139	562	2514	2999	2226
t-stat for H_0: Coal = Non-coal	4.22	2.04	7.46	7.51	5.46
(p-value)	0.000	0.042	0.000	0.000	0.000
ANNUAL GROWTH RATE:	**1970-80**	**1980-90**	**1990-2000**	**2000-10**	
Coal Counties	1.91%	0.20%	1.22%	0.11%	
Non-coal Counties	1.27%	1.55%	1.15%	-0.37%	
Difference (Non-coal minus coal)	-0.64%	1.35%	-0.07%	-0.47%	
t, H_0: Coal = Non-coal	-5.49	13.0	-0.77	-4.53	
(p-value)	0.000	0.000	0.439	0.000	

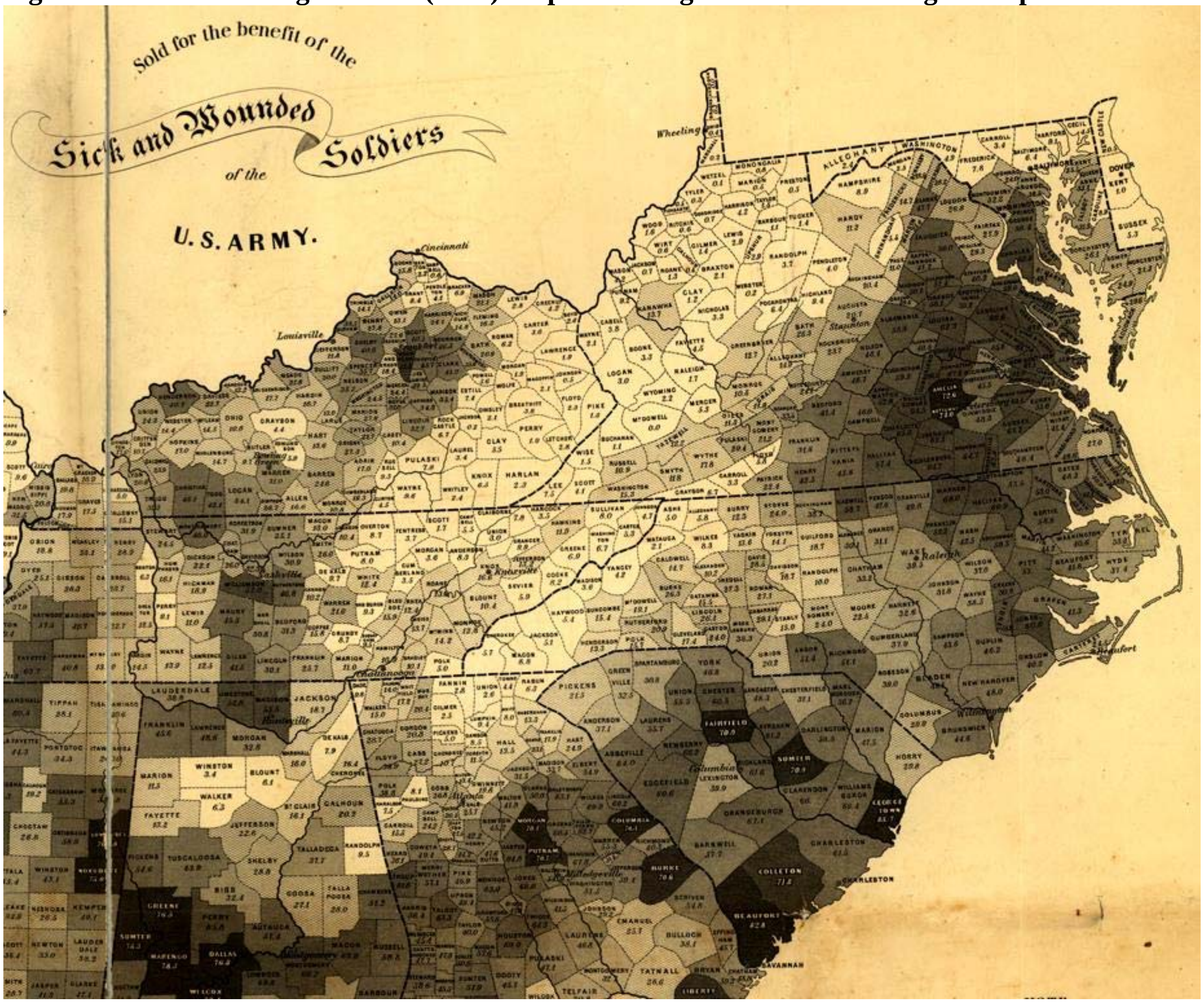
Figures show levels and annualized ten-year growth in per capita pre-tax personal income net of transfers. "Coal counties" are defined as counties producing and selling coal in the initial year of the decade. (Source: BEA. Figures may not add up due to rounding.)

Figure 1: Real Price of Bituminous Coal (right scale) and Mean Real Per Capita Personal Income of Coal-Producing and Coal-Free Appalachian Counties (left scale)



Source: Authors' calculations based on data from EIA and BEA.

Figure 2: Portion of Hergesheimer (1860) Map Indicating Enslaved Percentage of Population



Lighter colors indicate lower enslavement rates, coinciding closely with the Southern Appalachian Mountains. Source: U.S. Bureau of the Census.

Table 2: Variable Descriptions and Descriptive Statistics

Variable	Description and Source	Mean	Std. Dev.	Min	Max
Income Growth Rate git	Annualized ten-year growth rate of real per capita personal income net of transfers (BEA)	0.012	0.013	-0.033	0.093
Initial Income LnY_{it}	Beginning of period real per capita personal income: BEA.	9.493	0.304	8.322	10.463
Metro County	=1 if Beale code ≤ 3 (Metro area): BEA	0.269	0.444	0	1
Rural County	=1 if Beale code ≥ 7 (Population < 20,000, not adjacent to an urban county): BEA	0.438	0.496	0	1
NRDum	Dummy =1 if *NR* > 0: EIA, USGS	0.347	0.476	0	1
NR	County coal revenue divided by total personal income, initial year of period: EIA, USGS	0.110	0.342	0	3.997
(Oil Price Change) ∗ (NRDum)	Interaction variable, decade percent change in real oil price times *NRDum*: EIA, USGS	0.127	0.626	-0.940	1.650
Coal0	Dummy =1 if county has ever produced coal as of initial year: EIA, USGS.	0.466	0.499	0	1
MMBTUperTonAsh	Coal heat content per ton of ash created. USGS	265.8	103.7	114.8	736.7
SlavePct1860	Percent of population enslaved, 1860 Census	6.781	7.901	0	43.9
PctMTR	Percent of county surface area subject to mountaintop removal mining: SkyTruth	.379	1.44	0	13.6
PctSAML	Percent of county surface area identified as Abandoned Surface Mine Lands, 2013	1.54	2.34	0	12.4
DropOut	Percent without a high school degree	0.453	0.171	0.086	0.874
Bach+	Percent with Bachelors' degree or higher: Census	0.097	0.055	0.013	0.475
EmplEdu	Percent employed in education: Census	0.084	0.038	0.021	0.380

Table 3: Estimates of the Economic Growth Equation (1)

Dependent Variable: Average Annual Growth in Real Per Capita Personal Income net of Transfers
State and Time Fixed Effects. Sample Size: T=4 (1970-2010), N=409 Counties, total obs. = 1636

	OLS FE	GMM FE	GMM FE (Omitting Oil)	GMM FE (Spatial Spillovers)
Log Initial Income (LnY)	-0.0177***	-0.0199***	-0.0176***	-0.0235***
	(0.001)	*(0.003)*	*(0.003)*	*(0.00533)*
Metro County	0.0045***	0.0040***	0.0039***	0.00422***
	(0.001)	*(0.001)*	*(0.001)*	*(0.000983)*
Rural County	-0.0005	-0.0009	-0.0009*	-0.00106
	(0.001)	*(0.001)*	*(0.000)*	*(0.00104)*
*Oil Price Change*NRdum*	0.0064***	0.0057***		0.00203**
	(0.001)	*(0.001)*		*(0.000939)*
*W*Log Initial Income (LnY)*				0.00609
				(0.00605)
*W*Metro County*				0.00423**
				(0.00207)
*W*Rural County*				0.00371*
				(0.00210)
*W*OilPrice Change*NRdum*				0.00680***
				(0.00153)
*Metro County * W*NR*				-0.0189**
				(0.00859)
*W*NR*				0.0216**
				(0.0101)
NR	-0.0043***	-0.0256***	-0.0118*	-0.0429***
	(0.001)	*(0.009)*	*(0.007)*	*(0.0125)*
PctMTR	0.0008**	0.0041***	0.0021**	0.00550***
	(0.000)	*(0.001)*	*(0.001)*	*(0.00165)*
CntyPctSAML	-0.0002	0.0008**	0.0004	0.000529
	(0.000)	*(0.000)*	*(0.000)*	*(0.000444)*
Constant	0.1674***			
	(0.010)			
R-squared	0.403			
Hansen J test		0.589	0.772	0.035
p-value for Ho: Instruments are exogenous.		*(0.4429)*	*(0.3795)*	*(0.8507)*
First stage F test - LnY		795.37	845.99	653.21
p-value for Ho: Weak instruments.		*(0.0000)*	*(0.0000)*	*(0.0000)*
First stage F test – NR		13.96	12.85	13.40
p-value for Ho: Weak instruments.		*(0.0003)*	*(0.0005)*	*(0.0000)*

Cluster robust standard errors in parentheses.
"W" indicates spatial neighbor spillover effects; W is a row-normalized contiguity spatial weight matrix.*
*Significance levels: *** 1%, ** 5%, * 10%.*

Table 4: Estimates of the Effect of Coal Resource Intensity on Economic Growth Using Alternative measures of resource abundance

Dependent Variable: Average Annual Growth in Real Per Capita Personal Income

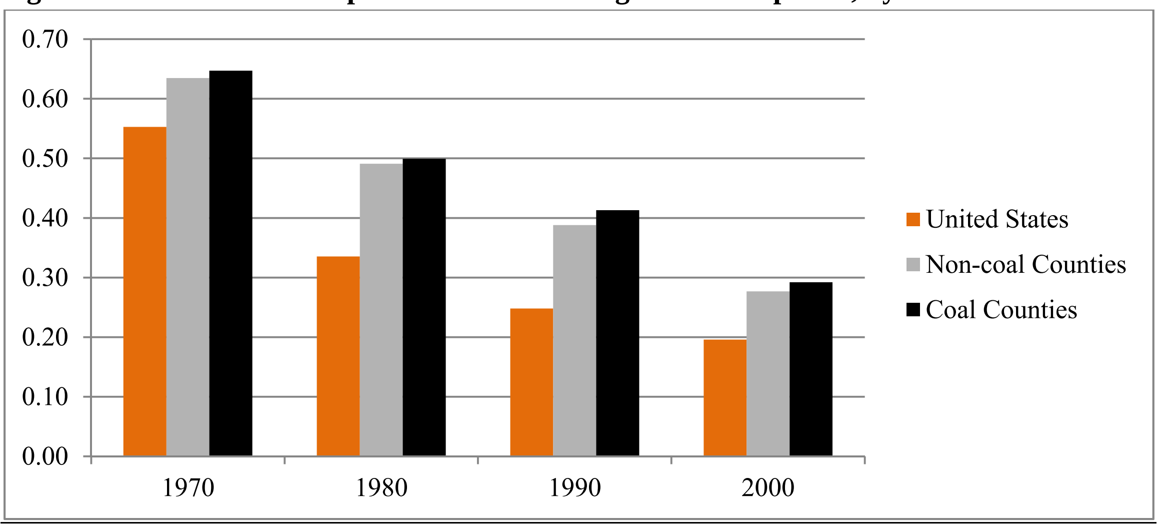
Dependent Variable: Average Annual Growth in Real Per Capita Personal Income

Sample Size: T=4 (1970-2010), N=409 Counties, total obs. = 1636

	Description	OLS FE	GMM FE (*NR* endog)
Coal0	Dummy = 1 if county has ever produced coal commercially	-.004**	--
AFFM_Share	Share of county earnings from agriculture, forestry, fishing, and mining	-0.0171***	-0.0495***
*NR2=(Price*Prod)/Population*	Coal revenue (price*production) divided by total county population	-0.0004***	-0.0021***
*NR3=(Price*Prod)/Land Area*	Coal revenue (price*production) divided by total county area (square km.)	-0.00002**	-0.00008***
NR4=(Prod)/Personal Income	Coal production divided by total county personal income	-0.0247	-1.2490***
NR5=(Prod)/Population	Coal production divided by total county population	-0.0075*	-0.1009***
NR6=(Prod)/Land Area	Coal production divided by total county area	-0.0003	-0.0039***
NR7=(Cumul.Prod)/Population	Cumulative coal production divided by total county population	-0.0001**	-0.0019***
NR8=(Cumul.Prod)/Land Area	Cumulative coal production divided by total county area	-0.0000	-0.00005***

*Significance levels: *** 1%, ** 5%, * 10%.*

Figure 3: Mean Share of Population without a High School Diploma, by Year



Source: U.S. Census Bureau

Table 5: Economic Growth and Educational Attainment (Equation 2.1)
Dependent Variable: Annual Growth in Real Per Capita Personal Income net of Transfers

	High School Dropouts GMM	FE	Bachelor's Degree or Higher GMM	FE
Log Initial Income (LnY)	-0.0359***	-0.0419***	-0.0242***	-0.0281***
	(0.008)	*(0.00986)*	*(0.004)*	*(0.00592)*
Metro County	0.0038***	0.00414***	0.0036***	0.00379***
	(0.001)	*(0.000993)*	*(0.001)*	*(0.000937)*
Rural County	-0.0005	-0.00102	-0.0008	-0.000989
	(0.001)	*(0.00108)*	*(0.001)*	*(0.00101)*
*Oil Price Change*NRdum*	0.0055***	0.00194**	0.0055***	-0.0281***
	(0.001)	*(0.000957)*	*(0.001)*	*(0.00592)*
*W*Log Initial Income (LnY)*		0.0122*		0.00830
		(0.00698)		*(0.00606)*
*W*Metro County*		0.00402*		0.00300
		(0.00212)		*(0.00200)*
*W*Rural County*		0.00460**		0.00285
		(0.00221)		*(0.00201)*
*W*OilPrice Change*NRdum*		0.00657***		0.00673***
		(0.00156)		*(0.00148)*
*Metro County * W*NR*		-0.0217**		-0.0163**
		(0.00912)		*(0.00801)*
*W*NR*		0.0260**		0.0200**
		(0.0111)		*(0.00958)*
NR	-0.0257***	-0.0446***	-0.0260***	-0.0404***
	(0.010)	*(0.0130)*	*(0.008)*	*(0.0118)*
ED_DropOut	-0.0567***	-0.0570***		
	(0.020)	*(0.0197)*		
ED_BachOver			0.0467***	0.0433***
			(0.015)	*(0.0141)*
PctMTR	0.0042***	0.00578***	0.0043***	0.00532***
	(0.001)	*(0.00173)*	*(0.001)*	*(0.00157)*
PctSAML	0.0009**	0.000523	0.0008**	0.000487
	(0.000)	*(0.000452)*	*(0.000)*	*(0.000416)*
Hansen J test	1.719		0.379	
p for Ho: Instruments exogenous	*(0.1898)*		*(0.5379)*	
First stage F test - LnY	648.32		648.32	
p for Ho: Weak instruments.	*(0.0000)*		*(0.0000)*	
First stage F test – NR	14.44		14.44	
p for Ho: Weak instruments.	*(0.0002)*		*(0.0002)*	
First stage F test –Edu	165.56		132.93	
p for Ho: Weak instruments.	*(0.0000)*		*(0.0000)*	

All estimates use State and Time fixed effects. N=409 Counties, T = 4 decades; 1636 Observations
Cluster-robust standard errors are in parentheses.
"W" indicates spatial neighbor spillover effects; W is a row-normalized contiguity spatial weight matrix.*
*Significance levels: *** 1%, ** 5%, * 10%.*

Table 6: Coal Dependence and Educational Attainment (Equation 2.2)

Dependent Variable: Population Educational Attainment (Bach+ or Dropouts) in Initial Year
State and Time fixed effects. N=409 Counties

Dependent Variable:	High School Drop Out		Bachelor's Degree or Higher	
	OLS FE	GMM FE	OLS FE	GMM FE
Log Initial Income (LnY)	-0.2326*** *(0.0117)*	-0.2308*** *(0.0114)*	0.0979*** *(0.0108)*	0.0947*** *(0.00095)*
Metro County	-0.0159*** *(0.0051)*	-0.0148*** *(0.0044)*	0.0131*** *(0.0030)*	0.0120*** *(0.0028)*
Rural County	0.0064 *(0.0051)*	0.0063 *(0.0042)*	0.0009 *(0.0024)*	0.0011 *(0.0018)*
Year 1970	0.0718*** *(0.0178)*	0.0728*** *(0.0166)*	0.0487*** *(0.0112)*	0.0458*** *(0.0107*
Year 1980	0.1347*** *(0.0054)*	0.1327*** *(0.0038)*	-0.0111** *(0.0038)*	-0.0093** *(0.0040)*
Year 1990	0.0704*** *(0.0073)*	0.0693*** *(0.0066)*	0.0033 *(0.0024)*	0.0046** *(0.0019)*
N.R.	**0.0373**** *(0.0146)*	**0.0605**** *(0.0254)*	**-0.0152***** *(0.0043)*	**-0.0436***** *(0.0110)*
EmpEdu	-0.5564*** *(0.0589)*	-0.6043*** *(0.0622)*	0.7543*** *(0.0446)*	0.7846*** *(0.0278)*
Observations	1636	1636	1636	1636
R-squared	0.92	.92	0.72	.69

State and Time fixed effects. N=409 Counties, T = 4 decades.
Robust (OLS) and State Cluster-robust (GMM) standard errors are in parentheses.
*Significance levels: *** 1%, ** 5%, * 10%.*