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# The Local Economic Impact of Coal Mine Closures

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**Abstract**

Falling natural gas prices amid the shale boom triggered a sharp decline in U.S. coal production, with over half of Appalachian mines shuttering between 2011 and 2016. In this paper, we use administrative data on mine activity and employment to measure the impact of coal mine closures on local economic outcomes. Using difference-in-differences, we find these closures significantly increased local unemployment and reduced jobs, wages, and output. We estimate a job loss multiplier of 2.0—substantially higher than in previous busts—likely driven by a rising local wage premium that amplified the impact of each lost mining job on the broader regional economy.

**Keywords:** Coal, Labor Demand, Energy Transition, Natural Resource Shock
**JEL Classification:** R11, R12, Q31, Q32, Q33

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# 1 Introduction

Economic shocks can impact regions disparately based on their geographic characteristics (Caliendo et al., 2018) and industrial composition of employment (Autor et al., 2013b; Goldsmith-Pinkham et al., 2020). Trade (Autor et al., 2013a; Choi et al., 2024) and natural resource shocks (Black et al., 2005a; Feyrer et al., 2017) quickly reveal winners and losers via local labor market outcomes, which can have downstream effects on political affiliation (Choi et al., 2024) and human capital accumulation (Smith, 2024). Beginning in the mid-2000s, the U.S. shale gas boom created winning regions such that every million dollars of fuel extracted generated $117,000 in royalty payments, $243,000 in wages, and 2.49 jobs within a 100-mile radius (Feyrer et al., 2017). However, the widespread affordability of natural gas resulting from the shale boom negatively affected demand for thermal coal as U.S. power plants switched their primary source of fuel from coal to natural gas (Watson et al., 2023). This negative demand shock led to U.S. coal production halving over the 2010s, with the Appalachian region disproportionately bearing its brunt due to its relatively low labor productivity compared to western minefields (Kolstad, 2017; Bowen et al., 2021). From 2011 to 2016, the number of active coal mines in Appalachia fell from 673 to 307 (-54 percent), and the number of coal mine employees fell from 38,573 to 16,593 (-57 percent) according to administrative data from the U.S. Energy Information Administration (EIA).

In this paper, we study the effects of coal mine closures on local output, employment, unemployment, and earnings after the 2011-2016 coal shock. Using administrative mine-level data in Appalachia from the EIA, we find that counties with coal mine closures experienced pronounced economic declines via reduced payroll employment (-4 percent), wages and salaries (-8 percent), gross domestic product (GDP) (-14 percent), and increased unemployment rates (0.9 percentage point) by the end of the shock in 2016. Additionally, these adverse economic effects worsened by 2021 across all variables except the unemployment rate, which fell due to declines in the labor force. From 2011 to 2021, we find an average job-loss multiplier effect of 2, such that 1 additional job was lost per coal job lost. This is roughly triple the 1.35 multiplier measured by Black et al. (2005a) from the 1980s coal bust, which we attribute to the increased local wage premium of U.S. coal workers, which rose from 53 percent in 1986 to 102 percent in 2011. A sectoral decomposition of employment effects suggests that job losses are primarily concentrated in mining and potentially coal-mine servicing industries (Administrative and Support and Waste Management and Remediation Services, Transportation and Warehousing, Finance and Insurance). In general, our results suggest that Appalachian coal-producing counties with coal mine closures have suffered pronounced and persistent negative economic effects from the decline in thermal coal demand induced by the shale gas boom and the subsequent energy transition.

Our research design leverages quasi-random variation in exposure to the coal shock by studying discrete coal mine closures with difference-in-differences (DiD) event study regressions. We identify our sample as the 120 Appalachian counties that contain at least one active coal mine since 2000. We find that 81 of these counties (treated counties) contained at least one mine that closed on net during the 2010s coal shock, which we match to the remaining 39 coal mining counties that experienced no net closures or increases in the number of active mines (control counties) from 2011-2016. We posit that the quasi-random variation in exposure to the coal shock across Appalachian mines depends on topographic (e.g., seam depth and width, terrain) and geologic features (e.g., sulfur and ash content of coal in mines) that determine mine productivity, extraction costs, and demand for its underlying coal (e.g., low-sulfur metallurgical coal used for steel production is not a direct competitor with natural gas) rather than characteristics of their respective encompassing local economies. Therefore, our identifying assumption is that Appalachian coal-producing counties without mine closures form a valid counterfactual for counties with mine closures after conditioning on year fixed effects and county fixed effects.

We provide support for our causal interpretation of coal mine closures on economic outcomes by demonstrating that the leads on our outcome variables in the event study DiD regressions are insignificant up to a decade before the coal shock. Additionally, we evaluate potential violations of the stable unit treatment value assumption (SUTVA) by analyzing our control counties in a spatial difference-in-differences framework. We find little evidence of spatial spillovers from treated to control counties for GDP, payroll employment, and wages, but we do find positive and significant spillovers for the unemployment rate immediately after the shock (2016), likely due to commuting patterns between treated and control counties.

We also use a continuous treatment difference-in-differences estimator that interacts treatment with the percentage of a county's pre-shock employment base in coal mining. We find that these continuous treatment DiD estimates for the mean treated county (4.7 percent of total employment in coal mining) are largely consistent with the average effects from our binary-estimate difference-in-differences models, but there are considerably larger effects for treated counties with higher employment exposure to coal. Treated counties with high coal dependence (75th percentile, or 6.9 percent of total employment) saw economic impacts roughly 50 percent higher than the average treated county.

We make contributions to several strands of the economics literature. First, we contribute to the literature on the local economic effects of natural resource extraction booms and busts in the U.S. (Black et al., 2005a,b; Matheis, 2016; Feyrer et al., 2017) and outside the U.S. (Marchand, 2012; Aragón and Rud, 2013; Kotsadam and Tolonen, 2016; Aragón et al., 2018; Frederiksen and Kadenic, 2020; Rud et al., 2024). Our contribution to this literature is to identify the local economic effects and job-loss multipliers of the 2010s coal bust in a highly exposed region. These labor market measures and job loss multiplier effects complement existing work on local financial outcomes (Blonz et al., 2026), training and government transfers (Krause, 2026a), and place-based policy design (Hanson, 2023) related to the 2010s coal bust. We demonstrate that the shock generated persistent and worsening long-term local economic effects, helping to explain the downstream effects documented in the literature. Second, we contribute to the "large plant literature" that evaluates the local economic effects of plant openings on productivity (Greenstone et al., 2010) and employment (Edmiston, 2004), as well as the regional job multiplier effects of large establishment closures (Popper and Herzog, 2003; Jofre-Monseny et al., 2018; Alexander and Richards, 2023) by estimating local economic effects for the closure of major, but often geographically isolated, plants in a tradable industry.

Lastly, we contribute to the broader literature studying the impacts of economic shocks on structural changes to local labor markets (Autor et al., 2013a,b; Choi et al., 2024). We find that shocks to industries can have disproportionately large local economic effects relative to the size of employment, depending on the local wage premium for workers in affected industries. While U.S. manufacturing workers impacted by the "China" and "NAFTA" shocks experienced relative wage stagnation in the preceding decades (Feenstra and Hanson, 1996; Katz and Autor, 1999), coal workers experienced sizable real wage increases since the 1980s, especially compared to stagnating local wages in Appalachia (Bollinger et al., 2011; Colmer et al., 2024).The near doubling in coal wages relative to average local wages likely contributed to the greater multiplier effect of coal job losses in Appalachia during the 2010s coal shock compared with the 1980s coal bust studied by Black et al. (2005a).

# 2 Background

## 2.1 The 2010s Coal Shock

Coal production has long been characterized by a boom-and-bust cycle dating back to the settlement of early Appalachian coal mining areas in the mid-nineteenth century (Matheis, 2016). Due to coal's use in industry and transportation, its production cycles were tied to industrial activity and largely mirrored the U.S. business cycle throughout much of the twentieth century (Kent, 2016). Early coal production was highly labor-intensive, and the population in mining areas (particularly in Appalachia and midwestern states) tended to be positively correlated with coal production (Matheis, 2016). Beginning in the 1970s, coal production ramped up in Western U.S. states (e.g., Wyoming, Montana), where coal is primarily mined at or near the surface (unlike deep underground Appalachian mines) in much flatter and accommodating terrain, resulting in labor productivity in mining being roughly four times as high as in eastern states (Kolstad, 2017). Increasing competition from more productive western minefields and a decline in oil prices had a tremendous negative impact on the number of coal mining jobs in Appalachia during the 1980s coal bust (Black et al., 2005a; Colmer et al., 2024), with regional coal mining employment continuing to trend down before stabilizing in the 2000s (Kolstad, 2017).

Advances in drilling methods and hydraulic fracturing technology eventually led to the shale gas boom of the mid-2000s, which resulted in a sharp drop in natural gas prices in the United States (Feyrer et al., 2017). This drop in price, along with increasing environmental regulations, led U.S. power plants to switch from coal to natural gas for electricity production, resulting in a decline in demand for thermal coal. Concurrent declines in profitability, driven by lower worker productivity and higher health and safety costs, contributed to half of Appalachia's coal mines closing since the mid-2000s, representing most of the nation's coal mine closures (Berry, 2021; Watson et al., 2023).

## 2.2 Relevant Literature

There is extensive literature covering the local economic effects of coal booms and busts. Matheis (2016) studies U.S. coal mining counties from 1870 to 1970 and finds evidence that increasing coal production positively impacted local population and manufacturing activity during the initial boom decades, despite both becoming negative in subsequent decades. Black et al. (2005a) studies the impact of the 1970s coal boom and subsequent 1980s bust on coal-producing local labor markets in Kentucky, Ohio, Pennsylvania, and West Virginia (Northern and Central Appalachia). The authors find asymmetric multiplier effects, with a larger negative impact from the bust. For every 10 coal sector jobs created during the boom, two jobs were created in the non-tradable sector (construction, retail, etc.); however, during the bust, 3.5 non-tradable jobs were lost for every 10 coal sector jobs lost. In related research, Black et al. (2005b) shows that the coal boom led to a sizable increase in the wages of low-skilled workers.

Fewer studies explicitly model the causes and local economic effects of coal mine closures. Watson et al. (2023) model U.S. coal mine closures in the 2000s as a function of expected profits using data on coal mine and power plant operations, and find that higher production costs, lower natural gas prices, and lower electricity demand were the primary causes of mine closures. Examining UK mine closures in the 1980s, Aragón et al. (2018) find evidence of lower population levels and wages, along with reallocation of employment from mining to manufacturing. Winkler (2021) studies the effects of coal mine closures in Polish municipalities from 1995-2016, and finds that the employment rates of men fall by 3 and 8 percentage points in the short- and long-terms. Mark et al. (2024) model the short-term unemployment effects of declines in the number of active mines within U.S. counties from 2002 to 2019 and find that unemployment spikes in the year of negative mining shocks recover two years later.

There is an emerging literature on the local economic effects of the 2010s coal shock in the United States. Blonz et al. (2026) study individual-level credit outcomes in Appalachia between 2011 and 2018 and find that declines in coal demand decreased credit scores and increased financial distress within two years of coal shocks. Krause (2026a) examines the effects of the coal shock on government transfers and postsecondary training investments in Appalachia, finding increases in per capita transfers but no impact on educational adjustment, unlike regions exposed to the

“China" shock (Smith, 2024). Using administrative data, Colmer et al. (2024) find that coal workers experienced large and persistent earnings shocks in the 2010s, and sectoral and regional mobility did little to mitigate these losses. Krause (2026b) finds that the coal shock was more pronounced in Appalachian counties that experienced larger declines in college-educated adults in the 1980s.

A related paper that estimates local labor market effects around the 2010s coal shock is Kraynak (2025). The author employs an instrumental variable analysis to study how shifts in local coal production from 2007-2017 impacted employment, wages, and other downstream effects (e.g., housing prices, government revenues). In contrast, our paper's identification relies on coal mine closures and the resulting mining employment losses from the 2010s coal shock. Additionally, we address the longer-term effects of the coal shock, estimate job loss multipliers, and measure the coal wage premium over several decades.

## 3 Data

We use EIA data to identify regional exposure to the 2010s coal shock. By law, each coal mining company owning a mine that produces 50,000 or more short tons of coal in the reporting year must submit an EIA-7A form for each mine it operates.[1] These data contain mine-level production totals, company information, mine location and operating status, labor hours, and the number of employees. The U.S. Mine Safety and Health Administration (MSHA) assigns each U.S. coal mine a unique MSHA ID number, which allows us to create a panel of the near-universe of U.S. coal mines that have existed since 2000. We limit the mines in our sample to those within the southern, central, or northern Appalachian Basin. Using this sample of Appalachian mines, we identify the 120 counties with at least one active mine since 2000, and aggregate panel series on mine operating status and the number of employees from the mine to the county level. We refer to the 81 counties that experienced a decline in the net number of active coal mines (i.e., at least one coal mine closure) during the 2010s coal shock (2011-2016) as *treatment counties* and the 39 counties with no change or a net increase in the number of active mines as *control counties*.

Figure 1 visualizes the number of active mines (top) and active employees (bottom) across our 120-county sample from 2000 to 2019. The vertical dashed lines indicate the respective start (2011)

[1] See here for a copy of the form: `https://www.eia.gov/survey/form/eia_7a/form.pdf`. Anthracite mines have a lower threshold at 10,000 or more short tons. Failure to comply is a criminal offense.

and end years (2016) of the 2010s coal shock, during which the number of active coal mines in the Appalachian sample fell from 673 to 307 (-54 percent) and the number of coal mine employees dropped from 38,573 to 16,593 (-57 percent). Figure 2 maps the distribution of coal closures in our sample from 2011-2016. The blue-shaded counties experienced net closures (treatment), and green-shaded counties (control) experienced no change or net increases in the number of active mines. Many of the treated counties are concentrated within the central Appalachian Basin in Eastern Kentucky and Southern West Virginia.

Data on our outcome variables come from various sources. Unemployment and labor force statistics are from the Bureau of Labor Statistics (BLS) Local Area Unemployment Statistics (LAUS) annual averages. Undisclosed county-level employment counts by detailed industry are available under a license from Lightcast and are used to measure total payroll jobs and employment by industry. Data from the U.S. Bureau of Economic Analysis (BEA) Regional Accounts are used for GDP and wages and salaries. Migration trends surrounding the coal shock are evaluated using Internal Revenue Service (IRS) migration data, while the coal mining wage premium is constructed from U.S. Census Bureau County Business Patterns (CBP) payroll and employment series.

# 4 Methods

We estimate the impact of coal mine closures on treated counties with a generalized (event-study) difference-in-differences (DiD) framework, where the dependent variable $y_{it}$ is the unemployment rate, the natural log of total payroll employment, the natural log of wages and salaries, or the natural log of gross domestic product in county $i$, $i = 1, \ldots, 120$, and year $t$, in which $t = 2001, 2006, 2011, 2016, 2021$.

$$y_{it} = \alpha_i + \delta_t + \sum_{j=2001,\, j\neq 2011}^{2021} (\text{treated}_i \times d_j) + \varepsilon_{it} \tag{1}$$

The county and year fixed effects are denoted by $\alpha_i$ and $\delta_t$, respectively. The leads and lags in equation 1 are binary variables set to one for treated counties and zero for controls. The lag effects measure how the impact of the coal mine closures varied immediately after the 2010s coal shock (2016) to five years later (2021). We can examine the lead coefficient estimates to evaluate whether the common trends assumption holds for our models. In other words, the DiD estimator requires the assumption that the treated counties' outcomes would have followed a similar path to the controls' absent the coal mine closures. Any significant lead coefficients in equation 1 would indicate a potential violation of the common trends assumption. We cluster standard errors at the county level.

# 5 Results

## 5.1 Main Results

Figure 3 captures estimates of the lead and lag effects of coal shock-era mine closures on treated counties from the generalized DiD models, as estimated by equation 1. The lead effect estimates for 2001 and 2006 are insignificant across all four variables, consistent with treated counties' economies behaving similarly to control counties in the decade before the coal shock began. Therefore, we find little evidence of a violation of the common trends assumption necessary for inference using our DiD analyses. The lag coefficients for 2016 across the four panels in Figure 3 suggest that coal mine closures in treated counties from 2011-2016 resulted in an average increase in the unemployment rate (+0.9 percentage point) and decreases in payroll employment (-4 percent), wages and salaries (-8 percent), and GDP (-14 percent). The 2021 lag coefficients broadly indicate persistent and worsening adverse economic effects five years after the end of the coal shock through decreased payroll employment (-6 percent), wages and salaries (-10 percent), and GDP (-17 percent). The one exception is for the unemployment rate, as its 2021[2] lag coefficient decreased to +0.6 percentage point and became insignificant. However, further analysis (see Appendix Figure A1) suggests that this diminishing effect of the unemployment rate is driven by a significant decrease in the labor force in treated counties from 2016 through 2021 rather than increased job finding.

## 5.2 Heterogeneity Analysis

Our main results use a binary treatment variable to measure the average effect of mine closures on counties during the 2010s coal shock. However, there is considerable heterogeneity in the number of

[2]We also estimated lag effects through 2019 to avoid the COVID-19 period and found similar results for the unemployment rate (+0.5 pp), payroll employment (-4 percent), wages and salaries (-9 percent), and GDP (-15 percent).

mine closures[3], as seen in Figure 2, and the number of coal mining jobs lost per county. We employ a continuous treatment difference-in-differences estimator to capture the heterogeneity in treatment effects across counties from 2011 through 2021.

$$y_{it} = \alpha_i + \delta_t + \gamma TI_{it} + \varepsilon_{it} \tag{2}$$

Once again, the dependent variable $y_{it}$ is the unemployment rate, the natural log of total payroll employment, the natural log of wages and salaries, or the natural log of gross domestic product in county $i$, $i = 1, \ldots, 120$, and year $t$, in which $t = 2001, 2006, 2011, 2016, 2021$. The county and year fixed effects are denoted by $\alpha_i$ and $\delta_t$, respectively. Treatment intensity $TI$ is proxied by the percentage of a treated county's total employment[4] in coal mining[5] in 2011. Therefore, $TI$ equals zero for all counties before 2016, and equals the pre-coal shock percentage of total employment in coal mining for treated counties from 2016 onward. $TI$ always equals zero for control counties. We cluster standard errors at the county level. Table 1a displays the continuous treatment estimates across our four outcome variables, which are all statistically significant at the 1 percent level. These estimates suggest that for each percentage point of a county's total employment in mining in 2011, it experienced a 0.1 percentage point increase in the unemployment rate, a 1.4 percent decrease in total employment, a 2.4 percent decrease in wages and salaries, and a 3.9 percent decrease in GDP from 2011-2021. We can use these continuous treatment estimates to calculate the closure effects for various levels of pre-treatment coal mining employment intensity, such as the median treated county (1.2 percent of total employment in coal mining in 2011), mean (4.7 percent), 75th percentile (6.9 percent), and 90th percentile (16.5 percent). The estimates for the mean treated county by pre-shock coal mining employment exposure are largely similar to the binary DiD treatment effects from section 5.1. However, treated counties at the 75th and 90th percentiles in the percentage of total employment in coal mining experienced more consequential economic effects. Treated counties highly dependent on coal mining (75th percentile of pre-shock exposure) saw 50 percent greater economic impacts from 2011-2016 mine closures than the average treated county.

[3] Across the 81 treated counties, the number of mine closures between 2011-2016 ranges from 1 to 31, with a median of 3 closures.

[4] As measured by total payroll employment across all industries from Lightcast.

[5] As measured by the administrative data from the EIA.

### 5.3 Job Loss Multiplier

We compute five- (2011-2016) and ten-year (2011-2021) job loss multipliers across treated counties based on the number of coal mining jobs in 2011 that were exposed to coal mine closures during the coal shock with Equation 3:

$$\Delta Employment_i = \alpha_i + \mu(CoalEmployment_{2011} * Treated_i) + \beta Employment_{2011} + \varepsilon_i \quad (3)$$

$\Delta Employment$ indicates the change in total employment in county $i$ from 2011-2016 or 2011-2021. $CoalEmployment_{2011}$ is the level of coal mining employment in 2011 from EIA administrative data, while $Treated_i$ equals 1 for counties with a coal mine closure from 2011-2016 and 0 otherwise. We also control for baseline level total employment in 2011 with $Employment_{2011}$ and cluster standard errors at the county level. $\mu$ is our job loss multiplier, which is estimated for both the five- and ten-year time horizons in Table 1b. We estimate statistically significant job loss multipliers of -1.6 for 2011-2016 and -2 for 2011-2021. These estimates imply that roughly 0.6 non-coal jobs were lost per coal job in treated counties from 2011 to 2016, and 1 non-coal job was lost per coal job at the 10-year time horizon from 2011 to 2021.

### 5.4 Sectoral Decomposition of Employment Effects

We further investigate the effects of coal mine closures on job losses by estimating difference-in-differences models for employment across 20 major sectors using two-digit North American Industry Classification System (NAICS) codes. We estimate the ten-year treatment effect of mine closures on sectoral employment for twenty sectors using the binary treatment DiD estimator below:

$$y_{it} = \alpha_i + \delta_t + \beta D_{it} + \varepsilon_{it} \quad (4)$$

$y_{it}$ indicates log payroll employment by industry. Area and time fixed effects are denoted by $\alpha_i$ and $\delta_t$, and the dummy variable $D_{it}$ equals one from 2016 onward for counties experiencing coal mine closures and zero otherwise. We cluster standard errors at the county level. Data on payroll employment by industry at the county level comes from Lightcast. $\beta$ coefficient estimates for employment by industry are plotted in Figure A2. Unsurprisingly, the largest employment decline occurs in NAICS 21: Mining, Quarrying, and Oil and Gas Extraction: -31 percent. The next largest set of significant effects are in potentially coal mine-servicing industries: NAICS 56: Administrative and Support and Waste Management and Remediation Services (-16 percent), NAICS 48-49: Transportation and Warehousing (-13 percent), and NAICS 52: Finance and Insurance (-9 percent). We also find a significant decline for NAICS 44-45: Retail Trade (-6 percent), which may be explained by the local demand multiplier.

### 5.5 Robustness to Spatial Spillovers

A key identification assumption for DiD estimates to be interpreted as causal is the stable unit treatment value assumption (SUTVA), which states that outcomes in one county are unaffected by treatment assignment of other counties. Since most of our control counties border treated counties, as seen in Figure 2, we investigate the plausibility of SUTVA in our research setting using a modified spatial DiD similar to those utilized by Delgado and Florax (2015) and Butts (2023). We estimate the model in equation 5 below:

$$y_{it} = \alpha_i + \delta_t + \sum_{j=2001,\, j\neq 2011}^{2021} (\text{treated}_i \times d_j) + \sum_{j=2001,\, j\neq 2011}^{2021} (w_i \times c_j) + \epsilon_{it} \tag{5}$$

where $w_i$ is the share of control county $i$'s immediate neighboring counties that are treated. For example, if a control county shares a border with 6 other counties and 3 of them are treated, then $w_i$ will be equal to $3/6 = 0.5$. In this event-study specification, the lag estimates $c_{2016}$ and $c_{2021}$ capture the indirect (or spillover) effects of coal mine closures from 2011–2016 onto the control counties in 2016 and 2021, respectively. Figure A3 captures the lead and lag indirect effect estimates from equation 5. Overall, we only find evidence of spatial spillovers onto the unemployment rate. The positive effects suggest that the unemployment rate coefficient estimates from both the event-study DiD and the continuous treatment DiD are likely biased downward and should be treated as lower bounds. This finding of spillover effects from coal mine closures in treated counties to control counties could be due to commuting patterns between counties. Unlike GDP, wages, and payroll employment, which are all calculated based on the location of the workplace, the unemployment rate is based on an employee's residence. It is plausible that many coal mine workers in treated counties who lost their jobs during the coal shock resided in adjacent control counties.

## 6 Discussion

Our findings suggest that Appalachian mine closures during the 2010s coal shock had significant negative impacts on regional economies that persisted up to five years after the shock's end. This is generally consistent with the findings from Aragón et al. (2018), which studied coal mine closures during the collapse of the United Kingdom's coal industry in the 1980s and found that negative labor market and population effects persisted about 20 years after the shock. Additionally, our results generally match the dynamic responses of local economies to coal demand cycles reported by Black et al. (2005a), which studied many of the same Appalachian counties during the 1970s coal boom and 1980s coal bust. Our spatial DiD results are consistent with the findings of spatial ripple effects of coal mine closures on local unemployment rates in Mark et al. (2024). However, their finding that local unemployment rates tend to recover 2 years after coal mine closures (with no impact on the labor force) is inconsistent with our larger and more persistent adverse labor market effects. Additionally, our finding that coal shock-induced employment losses are concentrated in mining and adjacent sectors (e.g., transportation and warehousing) is consistent with Kraynak (2025).

We report large regional economic declines following coal mine closures, despite the number of direct jobs lost in many of these treated counties being somewhat small. The median number of coal mine jobs lost across our 81 treated counties from 2011–2016 is 97 (vs. a mean of 249), with 293 and 665 mine jobs lost at the 75th and 90th percentiles, respectively. This is consistent with coal extraction becoming a highly capital-intensive industry over the past 50 years (Kolstad, 2017), which explains why our output and wage effects are several orders of magnitude higher than our employment effects.

Our average job-loss multiplier is more than twice that reported across many of the same Appalachian counties by Black et al. (2005a) during the 1980s coal bust. There are likely two reasons for this discrepancy. First, the 2010s coal shock was likely viewed as more permanent than the 1980s coal bust, despite the latter resulting in larger job losses (Krause, 2026b). As a result, the economic response may have been more pronounced during the 2010s, as capital and labor exited treated areas more rapidly and disinvestment intensified. Second, coal mine wages have increased considerably relative to local wages since the 1980s as the industry has become more capital-intensive. This is particularly true in Appalachia, where average income has stagnated compared to the rest of the country (Bollinger et al., 2011). Figure 4 shows the average coal wage premium across all U.S. counties with at least one coal employee. The local wage premium for coal workers rose from 53 percent in 1986 to 102 percent in 2011. Therefore, the effects of each coal job lost became highly consequential, as a coal job paid nearly twice the salary of a non-coal job across these counties. This is consistent with findings from Colmer et al. (2024), which found that the available replacement jobs in these regions for displaced coal workers paid much lower wages.

While we have shown that spatial spillovers to controls from mine closures are mostly confined to the unemployment rates, there is the possibility of spatial confounders due to the geography of the shale boom and treatment-induced outmigration. The shale gas boom occurred in parts of our sample area and treatment period, as the Marcellus Formation covers much of Appalachia. However, including the level of natural gas employment as a time-varying covariate in our models does not impact our results (see Appendix Figure A4). As for treatment-induced outmigration as a confounding factor, it is possible that laid-off coal workers could obtain jobs at active mines in control areas, as we do find evidence of increasing net outmigration from treated counties compared to controls after 2011 (see Appendix Figure A5). However, we conclude that these effects are likely inconsequential given the overall decline in demand for coal labor over the period. Colmer et al. (2024) use administrative data to study the outcomes of coal workers during the 2010s coal shock and find that they tended to experience large, persistent negative earnings shocks. Sectoral and regional mobility did little to mitigate these losses.

# 7 Conclusion

This paper investigates the impact of coal mine closures on their encompassing regional economies following the 2010s coal shock. We find evidence that coal mine closures negatively impacted output, wages, employment, and increased unemployment in the surrounding county. A heterogeneity analysis suggests that treated areas with higher pre-shock employment rates in coal mining tended to suffer more severe economic consequences.

The main contribution of this paper is to identify the primary economic effects for counties exposed to the 2010s coal shock through mine closures. We show that local effects of the shock are pronounced and persistent, which can explain downstream effects on household finance (Blonz et al.,

2026) and government transfers (Krause, 2026a) examined in the literature. Additionally, we show that the increasing multiplier effect from coal job losses relative to the 1980s bust may be explained by an increased wage premium for coal mine workers in the intervening decades. This dynamic contrasts with that of manufacturing workers affected by the "China" and "NAFTA" shocks (Autor et al., 2013a; Choi et al., 2024), who tended to see decreasing wage premia in preceding years.

Our results on the deep and persistent nature of local economic declines due to the coal shock have implications for public policy. There have been recent efforts to remediate the losses from coal mine closures at the state level through reallocation funds (Kent, 2016) and at the federal level through the Inflation Reduction Act, which offered place-based tax incentives for clean energy investments in communities with a coal mine or coal power plant closure (U.S. Department of Treasury, 2023). However, the extensive output, wage, and employment losses may warrant further policy actions, such as those outlined by Hanson (2023) on reinforcing the social safety net and expanding place-based policies.

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# Tables

**Table 1a: Continuous Treatment Results**

| | urate | log_jobs | log_wage | log_gdp |
|---|---|---|---|---|
| Treatment Intensity (TI) | 0.121*** | -0.014*** | -0.024*** | -0.039*** |
| | (0.016) | (0.002) | (0.003) | (0.004) |
| Observations | 600 | 600 | 600 | 600 |
| Number of fips | 120 | 120 | 120 | 120 |
| Adjusted R-squared | 0.682 | 0.517 | 0.688 | 0.407 |
| Year FE | Yes | Yes | Yes | Yes |
| County FE | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: TI is proxied by the percentage of county total employment in coal mines in 2011.

**Table 1b: Job Loss Multiplier Results**

| | jobs_11_16 | jobs_11_21 |
|---|---|---|
| coal_emp_2011 * treated | -1.58*** | -2.02*** |
| | (0.29) | (0.38) |
| Observations | 600 | 600 |
| Adjusted R-squared | 0.38 | 0.25 |

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Sources: U.S. Energy Information Administration, Lightcast, Bureau of Economic Analysis, Bureau of Labor Statistics.

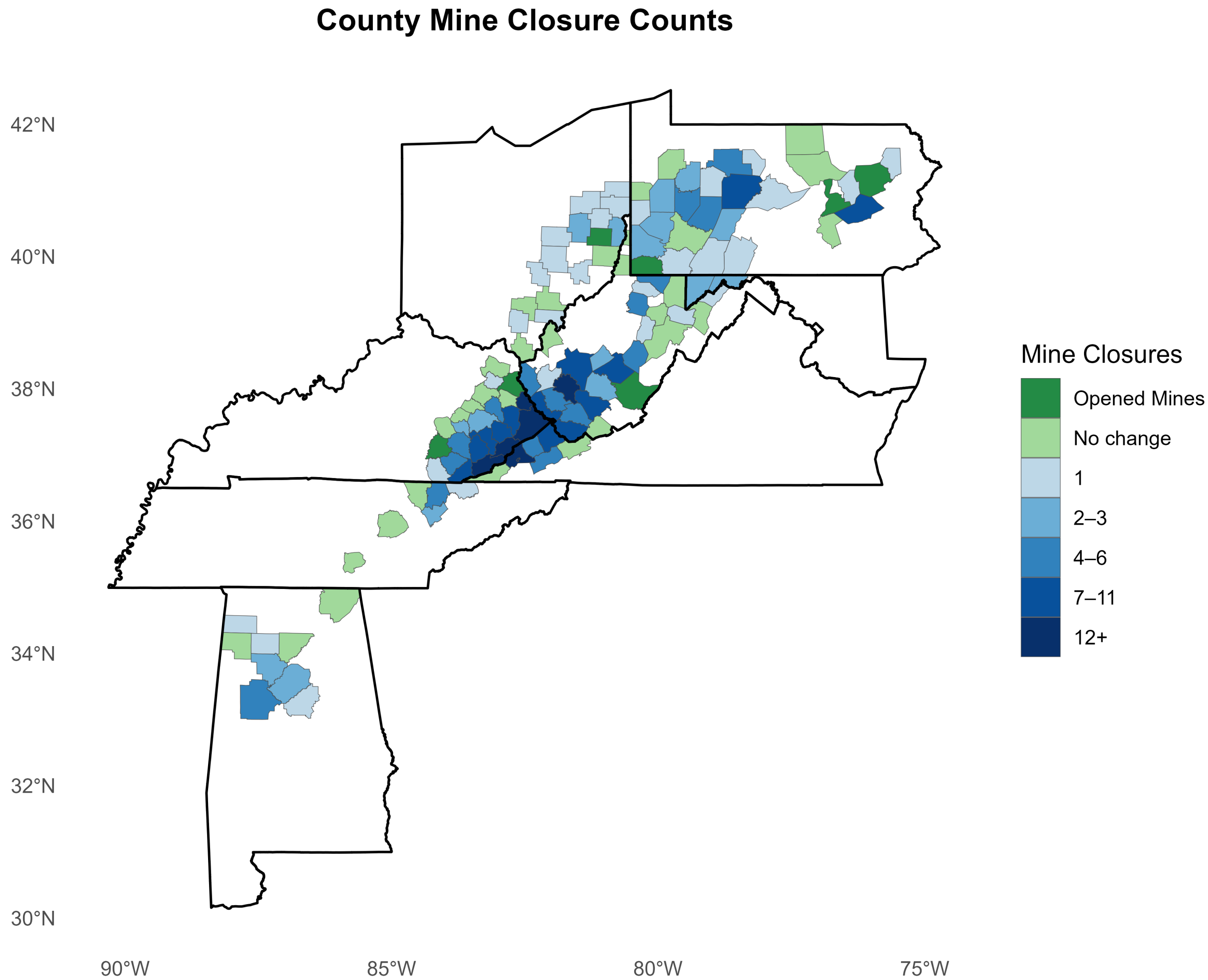
Source: Authors' calculations based on U.S. Energy Information Administration, Bureau of Labor Statistics, Lightcast, and Bureau of Economic Analysis data.

## Figures

Figure 1: Number of Active Coal Mines (top) and Coal Mine Employees (bottom) in 120 County Appalachian Sample

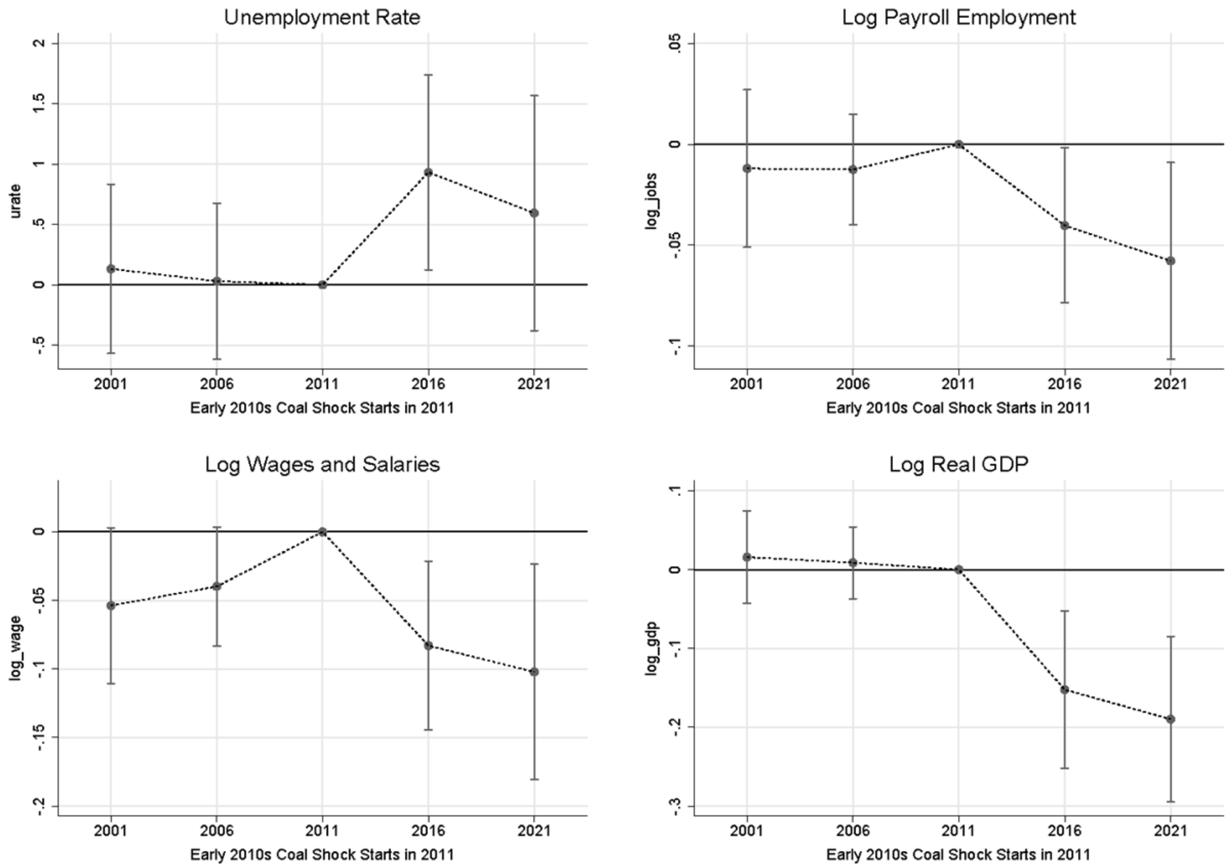

Source: Authors' calculations based on U.S. Energy Information Administration data.

Figure 2: Geographical Distribution of Coal Mine Closures 2011-2016



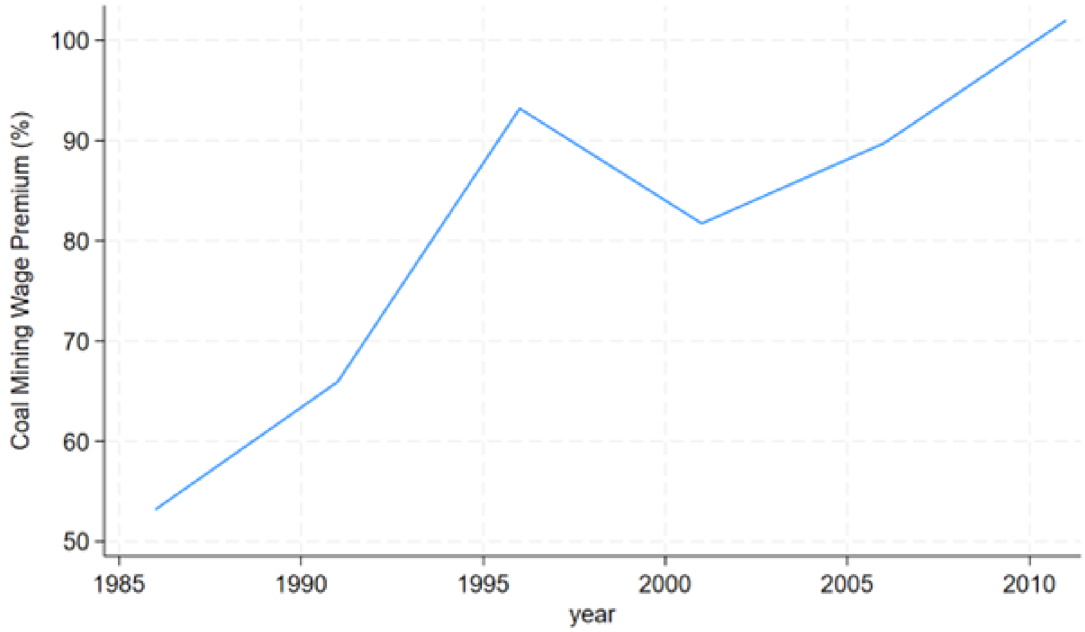

Source: Authors' calculations based on U.S. Energy Information Administration data.

Figure 3: Point estimates and 95% confidence intervals for the lead and lag effects of 2010s Coal Shock Mine Closures on treated counties' unemployment rate, payroll employment, wages and salaries, and gross domestic product




Source: Authors' calculations based on Bureau of Labor Statistics, Lightcast, and Bureau of Economic Analysis data.

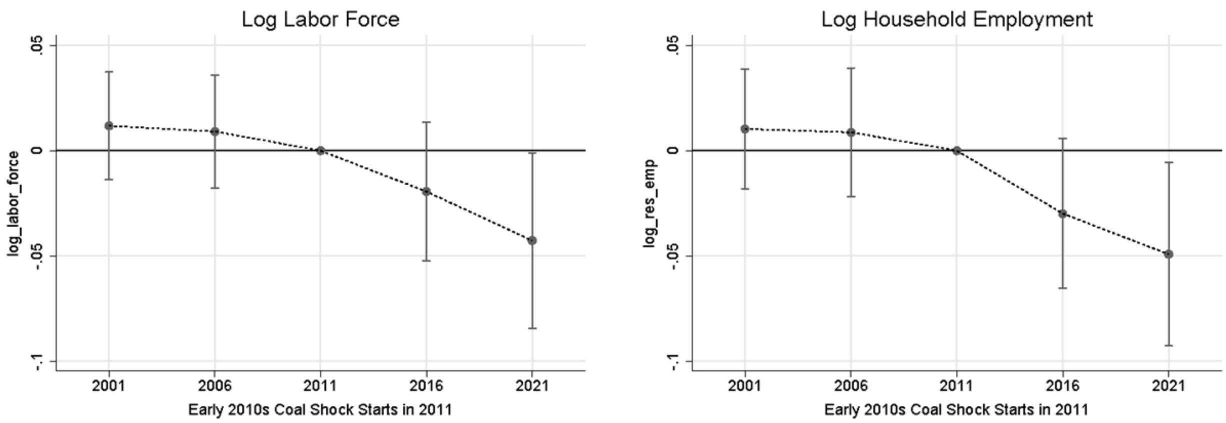
Figure 4: Coal Mining Wage Premium: 1986-2011




Source: Authors' calculations based on U.S. Census County Business Patterns data.
Note: Coal Mining Wage Premium measures the average weekly wages in the coal industry compared to the average weekly wages outside of the coal industry in U.S. counties with at least one employee in the coal industry with available data. Coal Wages computed from SIC 12 for 1986, 1991, and 1996 and from NAICS 2121 for 2001, 2006, and 2011.

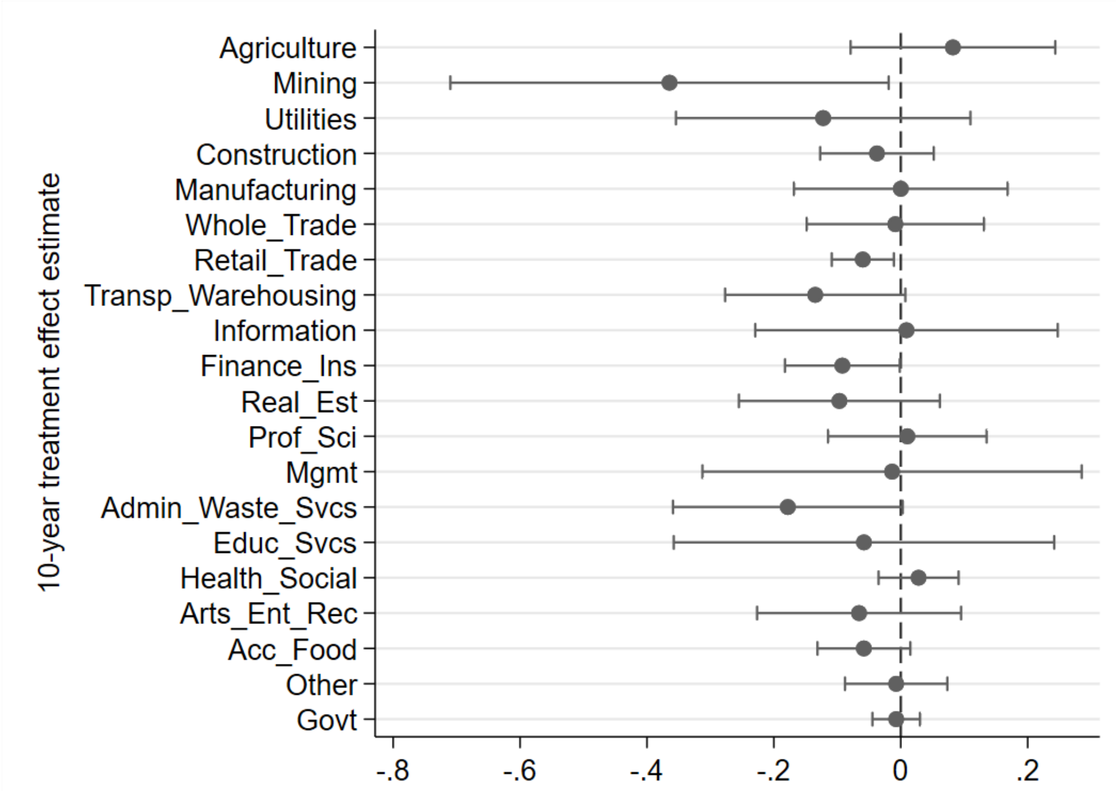
# Appendix

Figure A1: Lead and lag effects of 2010s Coal Shock Mine Closures on treated counties' labor force and household employment



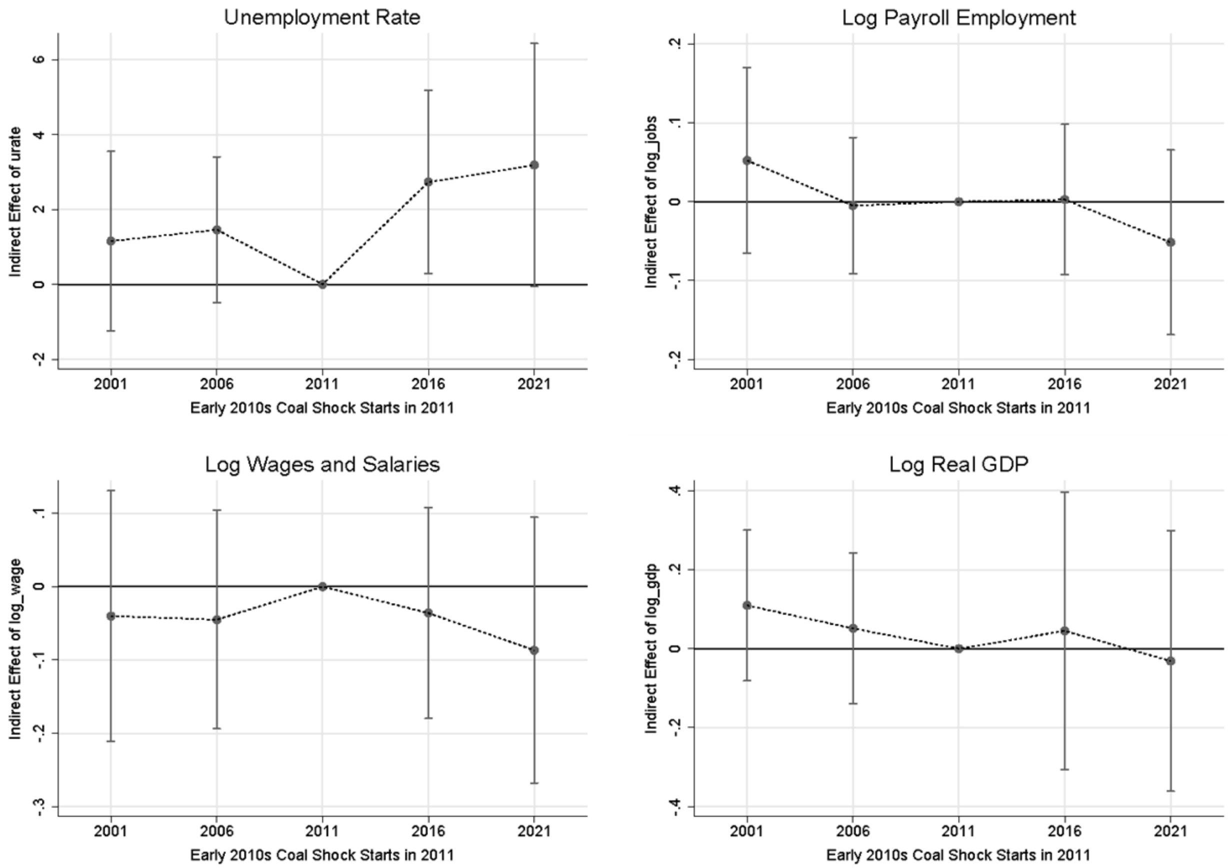

Source: Authors' calculations based on Bureau of Labor Statistics data.

Figure A2: Log Payroll Employment Results by Industry: 2011-2021



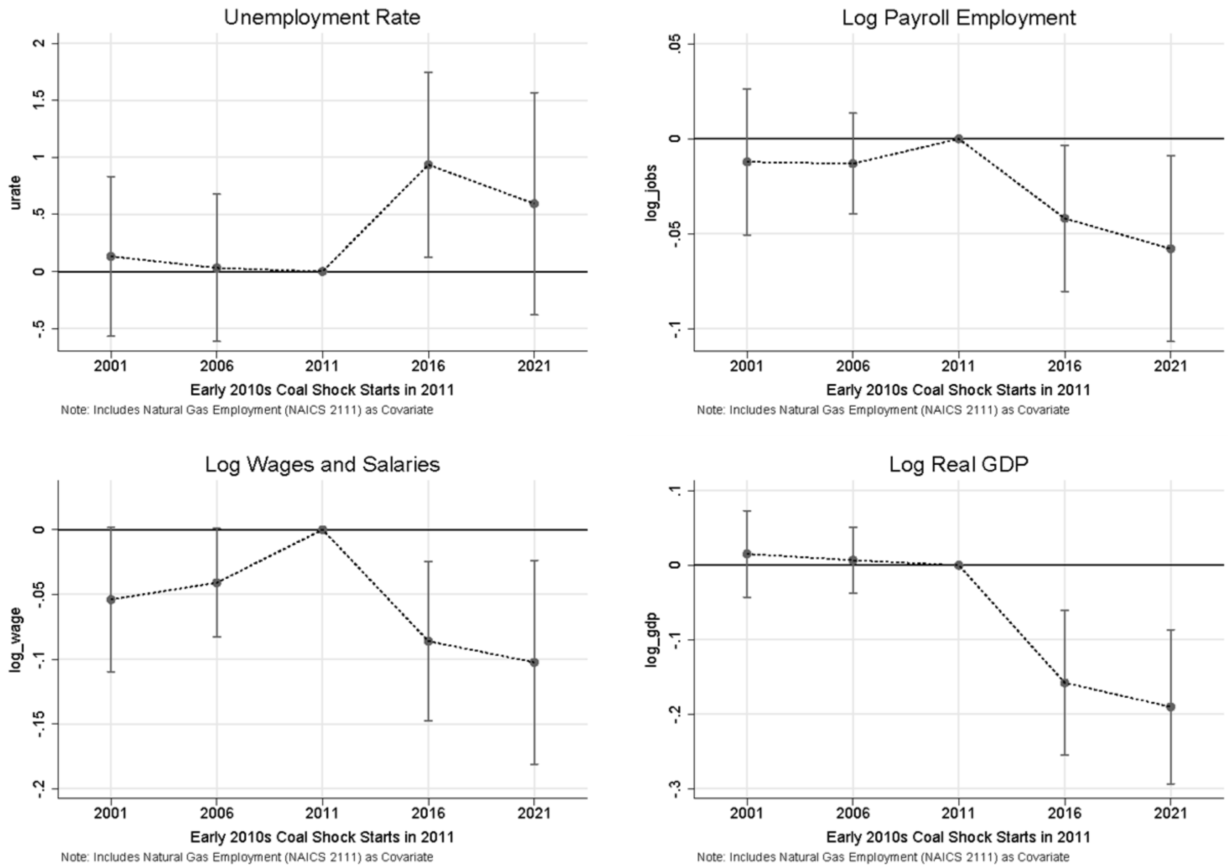

Point estimates and 95% confidence intervals for 10-year treatment effects on log payroll employment by industry. Source: Authors' calculations based on Lightcast data.
Note: The twenty sectors are based on two-digit NAICS codes groupings. For example, "Agriculture" represents employment in NAICS 11: Agriculture, Forestry, Fishing and Hunting, "Mining" represents NAICS 21: Mining, Quarrying, and Oil and Gas Extraction, and "Manufacturing" represents NAICS 31-33: Manufacturing.

Figure A3: Spatial Spillover Plots



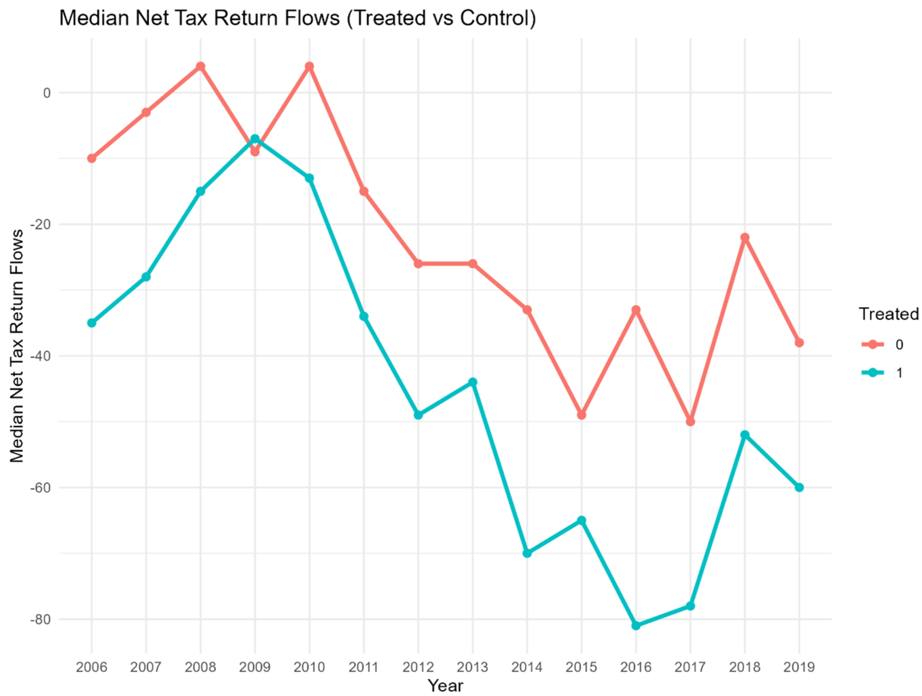

Point estimates and 95% confidence intervals for the indirect lead and lag effects of 2010s Coal Shock Mine Closures on control counties' unemployment rate, payroll employment, wages and salaries, and gross domestic product. Source: Authors' calculations based on Bureau of Labor Statistics, Lightcast, and Bureau of Economic Analysis data.

Figure A4: Shale Boom Robustness Check




Point estimates and 95% confidence intervals for the lead and lag effects of 2010s Coal Shock Mine Closures on treated counties' unemployment rate, payroll employment, wages and salaries, and gross domestic product (includes level of natural gas employment (NAICS 2111) as a covariate). Source: Authors' calculations based on Bureau of Labor Statistics, Lightcast, and Bureau of Economic Analysis data.

Figure A5: Net Migration in Median Treated vs. Median Control Counties: 2006–2019




Source: Authors' calculations based on Internal Revenue Service Migration data.