Territorial Justice in the Coal Transition: Spatial Spillovers in Medicaid Pressure Across Appalachia

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Word Count: 1796

Introduction

Decarbonisation has become a defining policy priority, yet its distributional consequences remain uneven across territories. In the United States, the coal-to-clean transition has delivered aggregate environmental benefits while imposing concentrated adjustment costs on coal dependent communities through employment losses, business closures, and weakened local public finances. These shocks are not merely local economic events: they interact with pre-existing disadvantage and health burdens, generating pressures on the social safety-net that raise questions of inclusiveness and territorial justice—central concerns for public policy assessment in the transition era.

Appalachia is a particularly informative setting for public policy assessment in the transition era. The region has historically been central to coal extraction and is characterised in many counties by persistent poverty, weaker human capital, and elevated health vulnerabilities. Importantly, Appalachian counties are linked through commuting patterns, service geographies (including healthcare access), and correlated exposure environments. Such linkages imply that transition stress may spill across administrative borders, violating the no-interference intuition often embedded in conventional policy evaluation designs. If vulnerability is spatially produced and transmitted, policy responses designed and assessed at the county level risk underestimating the breadth of transition induced hardship and misallocating compensatory support—an outcome that directly undermines territorially just decarbonisation.

This research quantifies the spatial temporal dynamics of "Medicaid pressure" across Appalachian counties from 2009–2019 and assesses whether coal-reliant counties experienced a distinct post-2015 trajectory consistent with transition era policy stress.

Objectives

Our research addresses two questions:

RQ1. What local conditions and neighbouring spillovers are associated with changes in safety-net pressure across Appalachian counties during 2009–2019?

RQ2. Did coal-reliant counties experience a systematically different post-2015 trajectory than non-coal counties, consistent with transition-era policy and market stress?

The objectives are (i) to establish whether vulnerability linked to safety-net demand is spatially clustered and interdependent; (ii) to identify the socioeconomic and environmental correlates of that vulnerability, including spillover channels; and (iii) to evaluate whether the post-2015 period marks a divergence between coal reliant and non-coal counties, interpreted as policy era stress rather than a single-policy causal isolation.

Literature Review

Federal decarbonisation policy in the U.S. has increasingly been framed not only as an emissions agenda but also as a distributive challenge with implications for equity and inclusion. The Clean Power Plan (CPP) marked a salient national intervention in power-sector regulation [1], and subsequent net-zero commitments reinforced expectations of a sustained low-carbon transition that entails broader economic and social restructuring [2][3]. Against this backdrop, just transition scholarship argues that climate policy assessment must extend beyond emissions to the adequacy of social protection in buffering concentrated adjustment costs in fossil-fuel-reliant regions [4][5][6].

The literature identifies multiple pathways through which coal dependence can raise Medicaid enrolment and safety-net reliance. Labour-market shocks from mine closures can reduce income and employer-sponsored insurance, making Medicaid a countercyclical substitute [7]. Persistent poverty and weak diversification in coal-reliant areas further elevate reliance on public coverage [8]. Health burdens linked to occupational and environmental exposure—particularly respiratory disease in Central Appalachia—provide an additional channel that may interact with transition stress, as evidenced by persistent excess illness during the COVID-19 period [9][10]. These mechanisms suggest uneven territorial incidence across Appalachian subregions.

Medicaid outcomes also vary geographically due to institutional and territorial heterogeneity. Post-Patient Protection and Affordable Care Act, states diverged in eligibility regimes following the Supreme Court decision that made Medicaid expansion optional, creating systematic differences between expansion and non-expansion states—directly relevant for Appalachia where several states remain non-expansion [11][12]. Within the region, coal reliance and socioeconomic vulnerability are spatially concentrated in Central Appalachia [13][14], while rurality and service access further shape enrolment patterns and growth [15]. This motivates empirical approaches that treat safety-net pressure as spatially embedded rather than purely local.

Methodologically, related work typically relies on either DID policy evaluation or spatial econometric modelling. DID designs leverage policy timing but can be biased under spatial dependence and spillovers [19], while spatial models capture autocorrelation and neighbour effects yet may remain associational and sensitive to omitted time-varying confounders and spatial-weights specification [20]. Empirical evidence illustrates these trade-offs: coal shocks can generate ripple effects in labour-market outcomes [16], environmental hazards are linked to poverty dynamics [17] and DID designs in other settings exploit policy rollouts to identify health impacts of clean-energy interventions [18]. These limitations motivate hybrid spatial–DID frameworks that combine policy-era validation with explicit modelling of spatial dependence to assess both local impacts and spillovers in evaluating inclusiveness and territorial justice [19][20].

Methods

We construct a harmonised county–year panel for 2009–2019 covering all counties in the Appalachian Regional Commission (ARC) definition of Appalachia (423 counties across 13 states). Data are aligned to a county–year structure via FIPS identifiers.

Outcome (Medicaid pressure proxy). A consistent county–year Medicaid enrolment series is not available for the full period. We therefore operationalise "Medicaid pressure" using the county poverty rate as an institutionally motivated proxy. Medicaid eligibility is fundamentally income tested and typically defined relative to federal poverty thresholds, so poverty captures an upstream determinant of programme reliance and thus the economic foundation of safety-net pressure. This choice supports balanced spatial panel estimation but disciplines interpretation: the research speaks to vulnerability and income linked pressure on the safety net rather than to enrolment counts or utilisation per se.

Coal dependence. County-level coal production is measured using EIA data, converted to per-capita dependence and log-transformed to address skewness. For the policy-timed

design, baseline coal exposure is defined as the pre-2015 average coal dependence (2009–2014).

Socioeconomic controls. Unemployment rates and educational attainment are taken from ARC sources and capture labour-market distress and human-capital endowments. Population density proxies' settlement structure and differences in local economic composition and service access.

Environmental risks. Ambient pollution exposures include $PM_{2.5}$ and ozone, and a composite hazardous air pollutants (HAP) index constructed from pollutant-specific lifetime cancer-risk estimates (e.g., formaldehyde, benzene, 1,3-butadiene, acetaldehyde). Missing pollutant year observations are imputed using within-county linear interpolation.

Spatial modelling strategy

We first test for spatial dependence using global spatial autocorrelation diagnostics and residual based tests from non-spatial fixed-effects benchmarks. We then estimate spatial panel fixed-effects models under a Queen-contiguity spatial weights matrix W (row-standardised). Three specifications are compared:

i. SAR-FE: allows endogenous spatial dependence in the outcome.

ii. SEM-FE: models' spatial correlation in unobservable.

iii. SDM-FE: includes both outcome dependence and spatially lagged covariates, enabling identification of spillover channels.

Model selection is guided by information criteria and spatial diagnostic performance. To avoid mechanical over parameterisation, spatial lags are included selectively for variables where cross-county transmission is most plausible (notably unemployment and environmental burdens).

Policy-timed validation: Difference-in-Difference and event study

To link spatial patterns to transition era policy timing, we implement a two-way fixed-effects DID and event-study design around 2015, using the Clean Power Plan (CPP) period as a salient decarbonisation era breakpoint. Counties in the top quartile of baseline coal reliance (pre-2015 average) are classified as coal-reliant (treated), with the remainder serving as controls. The event study tests for differential pre-trends and traces the post-2015 trajectory.

Crucially, the DID estimates are interpreted as policy-era divergence rather than a CPP-only causal effect, because 2015 coincides with overlapping structural coal decline and substantial institutional

heterogeneity in Medicaid eligibility regimes (notably Medicaid expansion versus non-expansion states).

Results

Three results stand out:

(1) Strong spatial structure in safety-net pressure. Poverty-based Medicaid pressure displays pronounced clustering across Appalachia, with hotspots concentrated in historically disadvantaged subregions. Spatial diagnostics indicate that cross-county dependence persists even after controlling for county and year fixed effects, motivating spatial specifications rather than relying on independence assumptions.

(2) Spillovers matter: vulnerability is shaped by local conditions and neighbouring contexts. In spatial fixed-effects models, unemployment is robustly associated with higher pressure, while educational attainment is associated with lower pressure, consistent with an adjustment-cost mechanism operating through labour-market distress and earnings capacity. The preferred SDM-FE specification indicates that neighbouring conditions—particularly neighbouring unemployment and neighbouring environmental burdens—are also materially associated with local vulnerability. This finding is substantively important for territorial justice: it implies that counties can absorb transition costs generated elsewhere through labour-market and service-geography linkages.

(3) Post-2015 divergence for coal-reliant counties. The event-study evidence does not indicate systematic differential pre-trends between coal-reliant and non-coal counties, while the post-2015 period exhibits a widening gap consistent with transition-era stress. The average DID estimate is positive, suggesting that coal-reliant counties experienced a larger post-2015 rise in poverty-based pressure relative to controls, conditional on fixed effects and covariates. These results align with the hypothesis that transition-era policy salience and market restructuring coincided with heightened vulnerability in coal-dependent areas, though the interpretation remains disciplined by institutional heterogeneity and the outcome proxy.

Discussion

The results support a territorial-justice interpretation with three implications.

First, vulnerability relevant to social protection is regionally produced and transmitted. The strong spatial dependence indicates that county outcomes reflect regional equilibria rather than purely local trajectories. This matters for policy assessment because it undermines the adequacy of

narrowly local interventions and cautions against evaluation strategies that treat counties as independent observational units.

Second, the most stable correlates of rising safety-net pressure are labour-market distress and human capital, pointing to an adjustment mechanism centred on employment capacity and earnings. Spillover effects strengthen this interpretation: neighbouring unemployment is associated with local vulnerability, consistent with commuting-zone linkages, displacement dynamics, and shared service geographies.

Third, the coal channel appears predominantly mediated. Coal dependence is not a stable direct predictor once spatial dependence and socioeconomic structure are modelled, suggesting that the social consequences of coal reliance manifest primarily through broader adjustment mechanisms (employment, income capacity, and regional spillovers) rather than through coal production levels. This is consistent with the idea that coal output is an imperfect measure of the shock of decline: it can proxy residual economic base where activity persists, while hardship emerges more reliably through labour-market deterioration and clustered disadvantage.

The policy-timed divergence after 2015 is interpreted as consistent with transition-era stress, but not as isolation of a single-policy causal effect. Overlapping structural decline and Medicaid eligibility heterogeneity imply that observed divergence reflects the intersection of economic stress and institutional capacity. For territorial justice, this nuance is central: a just transition is not only about exposure to decarbonisation, but also about the ability of social protection institutions to convert need into coverage rather than unmet demand.

Conclusion

By integrating spatial econometrics with a policy timed validation design, this research provides an empirically grounded account of how transition era vulnerability is spatially structured in U.S. Appalachia. The findings support a territorial justice interpretation: safety-net pressure is clustered and transmitted through regional linkages, with labour market distress and environmental burdens central to vulnerability, and with coal exposure operating primarily through mediated adjustment mechanisms. For public policy assessment in the transition era, the results imply that inclusive decarbonisation requires multi-county policy design that couples labour-market support with social protection planning and accounts for institutional heterogeneity in programme capacity.

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