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Abstract

Between 2011 and 2016, coal mining employment declined by over 50 percent in Appalachia, resulting in large earnings and employment losses in coal-dependent communities. Whether these disruptions reflect temporary adjustment costs or signal more persistent decline depends in part on the extent and nature of various investment responses. This paper leverages differential Commuting Zone (CZ-) level exposure to coal's decline to estimate its impact on government transfers and postsecondary training investments. Exposed CZs experienced significant increases in government transfer payments per capita. In contrast, coal's decline produced no statistically detectable change in postsecondary degree completions, enrollment, or institutional finances. This null training response contrasts with documented effects in other settings. Given the importance of human capital in regional recovery from economic shocks, these findings suggest that distressed regions affected by the transition away from legacy energy sectors may struggle to adapt without more targeted support for postsecondary training.

Keywords: local labor markets, regional adjustment, energy transition, human capital, social insurance, postsecondary education

JEL Codes: J08, J6, J24, H5, Q4, R10

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1 Introduction

The large-scale shift away from coal has had far-reaching consequences for workers, firms, and communities traditionally reliant on the resource (Black et al., 2002, 2003, 2005a; Morris et al., 2019; Autor et al., 2021; Hanson, 2022; Blonz et al., 2023; Colmer et al., 2024). As coal regions lose their primary export industry, their long-term economic trajectories may depend on how public and private investments respond to support individuals and institutions through this transition. Despite growing policy interest in mitigating the distributional costs of decarbonization (Carley and Graff, 2020; Just Transition Fund, 2020; Lachowska et al., 2020), there remains limited evidence on whether existing tools are sufficient to promote longer-run adaptation in fossil fuel-dependent regions.

In this paper, I examine how both government transfers and postsecondary training outcomes responded to the steep contraction of the coal sector in Appalachia between 2011 and 2016. During this period, coal mining employment in the region declined by more than 50 percent. This decline, driven in large part by major advances in hydraulic fracturing technology which dramatically reduced the price of natural gas (Kolstad, 2017; Linn and McCormack, 2019; Coglianese et al., 2020), produced substantial declines in local tax revenues, employment, earnings, and a host of other adverse consequences for exposed communities and workers (Morris et al., 2019; Autor et al., 2021; Hanson, 2022; Blonz et al., 2023; Colmer et al., 2024).[1] Whether these disruptions reflect temporary adjustment costs or signal more persistent decline depends in part on the extent and nature of policy and behavioral responses. Using linked, annual data on coal employment, demographic and economic characteristics, government transfer receipt, and postsecondary training from 2003 to 2019 for all Appalachian Commuting Zones (CZs), I estimate how transfer payments and postsecondary training outcomes — including enrollment, degree

[1]Other large-scale factors, including environmental regulations and changes in international demand also contributed to declines in demand for coal during this period. In addition, long-run increases in production costs due to geological depletion — especially in Appalachia — played a role in driving this decline (Watson et al., 2023).

completions, and institutional finances — responded to coal's decline. The identification strategy exploits differential CZ-level exposure to the "coal shock" using a Bartik-style shift-share instrument (Bartik, 1991). I estimate effects over both the pre-shock period and progressively longer time horizons from 2011 to 2019 to assess how these outcomes evolved as the shock unfolded and eventually attenuated.

I find that the 2011–2016 coal shock led to a sustained increase in government transfers per capita, but no statistically detectable change in postsecondary training outcomes. A one standard deviation (SD) increase in the CZ-level coal shock increased government transfers by $150 per capita between 2011 and 2016—equivalent to about 13 percent of a standard deviation relative to 2011 levels—and this increase persisted through 2019. At the same time, I find no statistically detectable effect of the coal shock on a wide range of measures of local human capital investments, including postsecondary degree and certificate completions, enrollment, and institutional revenues and expenditures. I estimate that the coal shock produces a relatively precise null training investment response when limiting the analysis to 2-year institutions and short-term credentials, which are overwhelmingly pursued locally and thus less likely to be influenced by education-related out-migration. Additionally, the coal shock produces no statistically detectable reallocation away from mining-related credentials toward other fields. The null effect on training investments is consistent across specifications and outcome measures.

This absence of a training response contrasts with earlier evidence that educational attainment is sensitive to sectoral labor demand shocks. For example, Black et al. (2005b) show that the 1970s coal boom and subsequent bust influenced high school enrollment in affected regions, while more recent studies document that local postsecondary educational investments respond to labor demand shocks in other settings (Baker et al., 2018; Grosz, 2019; Acton, 2021). That such responses are not observed in the context of coal's recent decline in Appalachia suggests the presence of unique frictions — such as limited institutional capacity, geographic barriers, or information constraints — that may hinder adaptation. Indeed, a growing literature emphasizes the role of distance to college in shaping access and attainment in rural communities (e.g., Acton et al., 2024, 2025). While I am unable to fully separate demand- from supply-side constraints, the lack of movement away from mining-related fields indicates that supply-side frictions alone are unlikely to explain the null training response.

This paper contributes to several strands of literature. First, it contributes to research on the local adjustment costs of energy transitions. A growing body of work documents that the shift away from coal produced large reductions in population head counts, reduced employment and earnings, lower levels of public revenues, and other adverse community-level outcomes (Black et al., 2002, 2003, 2005a; Morris et al., 2019; Autor et al., 2021; Hanson, 2022). Coal's decline has also produced large transitional costs for individuals and households, reducing households' financial well-being (Blonz et al., 2023) and generating substantial earnings and employment losses among affected coal workers (Colmer et al., 2024). Together, this evidence indicates that the shift away from coal induces relatively large and scarring effects on individuals and their communities. This paper offers new insights into why these adjustment costs might be so large. While automatic transfer payments can insulate households from temporary income shocks, the negligible responsiveness of human capital investments could hinder a longer-term recovery.

Second, this paper contributes to research documenting the relationship between local economic growth and investments in human and physical capital (Moretti, 2004; Black and Sanders, 2012; Kline and Moretti, 2014; Bartik, 2020; Katz et al., 2022). While place-based investments in physical capital have a mixed record of success (Glaeser and Gottlieb, 2008), several studies have established strong market failure rationales for such investments and documented notable positive returns (Kline and Moretti, 2014; Austin et al., 2018; Jaworski and Kitchens, 2019).[2] The evidence on the return to human capital is clearer. Many studies document sizeable labor market returns to postsecondary educational investments (Jacobson et al., 2005; Jepsen et al., 2014; Grosz, 2019; Minaya and Scott-Clayton, 2022), and a robust body of research provides evidence that local human capital endowments are highly predictive of economic growth and the recovery from local shocks (Glaeser et al., 1995; Glaeser, 2005; Gennaioli et al., 2014; Islam et al., 2015; Gagliardi et al., 2023). This work implies that coal regions that can rebuild and re-skill their workforce to meet the shifting demands of the labor market and energy landscape might exhibit swifter recoveries. Given this, the muted response of training investments to coal's decline raises concerns about the pace and extent of local labor market adjustment. In the absence of increased educational attainment or shifts in skill acquisition observed in other settings, affected coal regions may struggle to respond effectively to long-run structural change. The findings highlight the potential need for more direct support to facilitate workforce adaptation in the face of declining employment opportunities in legacy industries.

Finally, this paper contributes to research on the role of automatic transfer programs in helping households weather economic shocks. Programs like unemployment insurance and Medicaid are designed to buffer short-term hardship and may also support longer-run adjustment by easing liquidity constraints or improving job match quality (Gruber, 1997; Chetty and Looney, 2006; Schmieder and Von Wachter, 2016; Finkelstein et al., 2019; Hendren and Sprung-Keyser, 2020). However, in some cases, government transfer programs may actually facilitate a permanent exit from the labor market (Black et al., 2002; Autor and Duggan, 2003; Autor et al., 2013; Charles et al., 2018b). This paper documents that while transfer receipts increase following coal's decline, there is no corresponding increase in postsecondary training activity. This pattern may help inform

[2]For example, Jaworski and Kitchens (2019) find that the transportation infrastructure built under the Appalachian Development Highway System (ADHS) generated large aggregate returns to both Appalachian and non-Appalachian counties.

what forms of additional support could aid regions undergoing large-scale labor market transitions.

The remainder of this paper is organized as follows. Data and summary statistics are presented in Section 2. Section 3 details the identification strategy. The estimated effect of the 2011–2016 coal shock on transfers and training investments is reported in Section 4. Section 5 concludes with a brief discussion of these results in light of recent place-based policies that provide assistance to coal regions.

2 Data, empirical setting, and summary statistics

2.1 Data

I combine several publicly available data sources to generate a detailed portrait of transfer payments, training investments, population and economic characteristics, and coal mining employment at the Commuting Zone (CZ) level for all years between 2003 and 2019. I include in the analysis all CZs that have at least one county in Appalachia, as defined by the regional boundaries served by the Appalachian Regional Commission (ARC). The Appalachian region includes all of West Virginia and parts of twelve other states, spanning from northern Mississippi to southern New York. Coal has long played an important role in the economy and culture of the region, particularly in Eastern Kentucky and West Virginia (Eller, 2008). This rich legacy of dependence on the coal industry coincides with high rates of persistent poverty and relatively low levels of upward economic mobility (Harrington, 1962; Eller, 2008; Ziliak, 2012; Chetty and Hendren, 2018; Blonz et al., 2023), making the region a particularly compelling setting to understand the consequences of and adjustment to the sector's collapse.[3]

I derive CZ-level coal mining employment from the mine-level statistics in the Mine

[3]Western reserves have become an increasingly important source of coal-fired electricity in the United States over the past several decades, and this region is similarly exposed to the contemporary coal shock that has disrupted labor markets across the country. The conclusions in this paper are relatively insensitive to including other coal-producing regions in the analysis.

Safety and Health Administration (MSHA)'s Mine Data Retrieval System. These mine-level statistics are aggregated to CZs based on the location in which the mine operates. Other CZ-level employment statistics are aggregated from the county-level data retrieved from the Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW). These data cover employment from workers subject to state and federal unemployment insurance (UI) programs and include most wage and salary workers.[4]

Postsecondary training characteristics include degree completions by program type (including certificates, associate degrees, bachelor's degrees, and graduate degrees), full-time-equivalent (FTE) enrollment, and institutional financial data (e.g., revenues and expenditures) retrieved from the National Center for Education Statistics (NCES)'s Integrated Postsecondary Education Data System (IPEDS).[5] IPEDS captures all institutions that participate in federal aid (Title IV) programs. I sum these training characteristics across all public and private 2- and 4-year IPEDS institutions within a CZ, although the results are qualitatively similar when differentiating between these various types of institutions. For the small share of cases in which an individual student receives two credentials (e.g., two bachelor's degrees), I retain only the IPEDS-designated "first" major to avoid double counting. In practice, this has no substantive impact on the estimates. Note that an "IPEDS institution" may be defined at different levels of aggregation. In some cases, a single IPEDS institution may refer to a main campus and its satellite campuses or a community college district. For example, the Southeast Kentucky Community and Technical College (SKCTC) has four active campuses in Southeastern Kentucky alongside its original campus in Cumberland, Kentucky. All enrollment, completions, and financial

[4]Because county-level employment counts in detailed industry categories are often withheld due to low employment counts or sparsely populated counties, I leverage the imputed industry-employment counts from Eckert et al. (2020) in limited cases in which more detailed industry-level employment counts are required. Eckert et al. (2020) impute county-level employment at the 6-digit NAICS code category for suppressed cells in the County Business Patterns (CBP) database.

[5]IPEDS includes all postsecondary certificate awards within the broader category of "certificates." This includes short-term (less than 1 academic year), moderate-term (between 1 and 2 years), and long-term (between 2 and 4 years) certificates.

data for these institutions are assigned to the Cumberland campus in the IPEDS data. All of SKCTC's active campuses are within the same CZ, so aggregating data to the CZ level will address the IPEDS institutional aggregation in this particular case. Indeed, while CZ aggregation will address this issue in most cases, institutional aggregation for certain IPEDS observations may continue to present a limitation of the underlying data.[6]

I include only degree-granting IPEDS institutions that are active in all years of the analysis (2003–2019). This produces a stable set of institutions and avoids classification errors arising from changing institutional groupings over time.[7] Training characteristics are aggregated based on the CZ in which the institution operates, as I am unable to observe the residential location of students and graduates. Empirically, most students, particularly those attending certificate and associate degree programs, attend institutions that are in very close proximity to their home, so this setup likely captures the majority of postsecondary training credentials earned by residents of affected coal regions (Hillman and Weichman, 2016; Acton et al., 2024). Importantly, these data do not capture training investments at non-IPEDS institutions and in non-credit-granting programs, such as many coding boot camps and CDL (Commercial Driver's License) programs, and thus provide an undercount of total investments in training. However, enrollment in these non-credit programs is dwarfed by enrollment in degree-granting postsecondary institutions.[8] Despite that many rural, Appalachian counties lack an institution of higher education, 92% of the 104 Appalachian CZs have at least one IPEDS-accredited postsecondary institution. While this presents an advantage of conducting the analysis at the CZ (versus county) level, this aggregation likely attenuates the estimated effects documented in

[6] The IPEDS website documentation, "Institutional Groupings in IPEDS," (available at https://nces.ed.gov/ipeds/use-the-data/institutional-groupings-in-ipeds#data-users-guidance) provides additional information on this topic.

[7] In practice, including the entire, unbalanced panel of IPEDS institutions does not alter the conclusions of this paper, although the coefficient estimates are statistically less precise.

[8] According to NCES, there were over 16 million students enrolled in degree-granting postsecondary institutions in 2019. Enrollment estimates for coding boot camps vary. The "State of the Coding Bootcamp Market Report 2020" produced by Career Karma estimated that about 34 thousand students were enrolled in bootcamps in 2019.

county-level analyses thanks to the spatial concentration of coal deposits (e.g., Black et al., 2005a; Blonz et al., 2023).

Data on government transfers by program type are based on the Bureau of Economic Analysis (BEA)'s Regional Economic Accounts. I consider various types of government transfers, including medical (Medicare and Medicaid), Social Security, various income maintenance programs, unemployment insurance (UI), and transfers related to education and training. The definitions of these program types are detailed in Appendix C.1. Because contractions in the coal industry coincided with sharp reductions in population headcounts (Krause, 2024), I normalize transfer and training outcomes to the relevant population. As government transfers of various kinds are available to all age groups and postsecondary education is typically pursued by younger adults, transfers are normalized to be expressed relative to the total population of a CZ, while training investments are normalized as a share of the CZ population ages 20–34. I refer to both normalized outcomes as "per capita."[9]

Annual population headcounts by age group are based on county-level population estimates produced by the U.S. Census. Certain CZ-level covariates, including the foreign-born share of the population, the college-educated share of the adult population (ages 25 and older), and female share of employment are based on the American Community Survey (ACS) 2009–2013 5-year estimates. All statistics that are retrieved by county are aggregated to the CZ level based on the raw sum or, for variables expressed as fractions or shares, based on the population-weighted average.

2.2 Summary statistics and Appalachia's coal shock

While only a small fraction of the overall U.S. economy, coal mining is highly spatially concentrated, providing high-paying jobs in relatively rural and remote regions

[9]Normalization allows for comparability across various transfer programs and training investments, and it avoids the confounding influence of contemporaneous changes in local population counts. The conclusions are similar when normalizing both types of outcomes to the same age group.

(Black et al., 2005a; Weber, 2020). After a period of relative stability in demand for coal in the early 21st century, coal employment declined rapidly, driven by declines in the Appalachian basin, where coal mining is much more labor-intensive than in other coal-producing regions (EIA, 2019). Figure 1 displays total coal mining employment in Appalachian CZs over the study period. Between 2011 and 2016, employment declined by over 50 percent. This sectoral collapse was largely driven by the introduction of cheap natural gas made available by hydraulic fracturing technology (Kolstad, 2017; Linn and McCormack, 2019; Coglianese et al., 2020). In 2011, natural gas production exceeded coal production for the first time in three decades, and natural gas overtook coal as the largest source of electricity generation in the U.S. in 2015.[10] Given that the electric power sector accounts for the vast majority of coal's demand in the U.S., this shift in the composition of electricity generation constituted a sizeable and largely unexpected "shock" to coal demand.[11] The empirical strategy detailed in section 3 leverages the fact that some places were relatively more exposed to this macroeconomic decline in demand for coal thanks to the spatial concentration of coal mining activity prior to the shock.

Table 1 presents summary statistics on key variables of interest for Appalachian CZs with any coal mining employment in 2011. All characteristics expressed in dollars are inflated to 2019 dollars using the CPI-U. On average, coal mining accounted for only about 1% of total employment in these CZs, though there was substantial variation across regions. The distribution of coal employment has a significant right tail: moving from the median (50th) to the 95th percentile corresponds to a 4.64 percentage point (pp) increase in the coal share of employment — an increase of nearly 4,000%. These "right-tail" CZs are heavily concentrated in Eastern Kentucky and West Virginia, as displayed in Figure 2.

The average Appalachian coal CZ awarded 61 degrees per 1,000 people ages 20–34, with half of this total (30 per 1,000) driven by bachelor's degrees. Full-time-equivalent

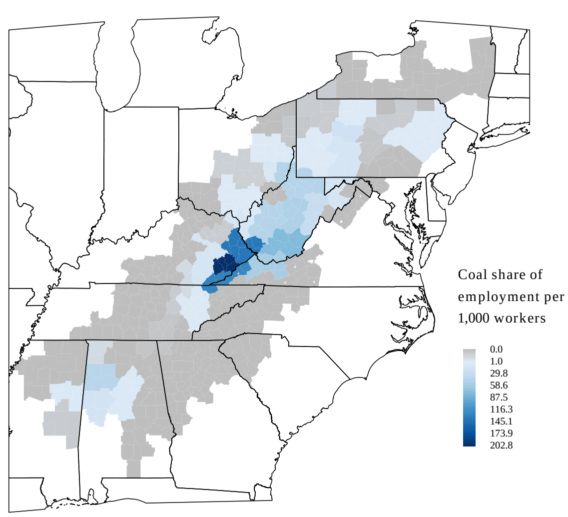
[10]See EIA (2023b).

[11]In 2011, 93 percent of coal in the U.S. was consumed by the electric power sector (EIA, 2023a).

Figure 1: Annual coal mining employment in Appalachian CZs

Notes: Figure reflects the total coal mining employment by year in Appalachian CZs, defined as all CZs with at least one county in Appalachia. Coal mining employment is based on mine-level statistics from MSHA.

Figure 2: Coal employment share in 2011, Appalachian CZs



Notes: Figure presents coal mining employment as a share of total employment in 2011 across all CZs with at least one county in Appalachia. Coal mining employment is calculated based on mine-level statistics from the MSHA, while total employment is retrieved from the QCEW.

Table 1: Summary statistics for CZ-level coal shock and 2011-level training investments and government transfers

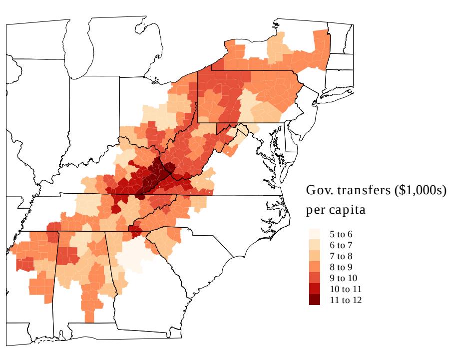
	(1) Mean	(2) SD	(3) p25	(4) p50	(5) p75	(6) p95
Coal employment variables:						
Coal share of emp, 2011	0.93	2.55	0.04	0.12	0.43	4.76
$\Delta Coal$, 2011-16	0.50	1.60	0.01	0.03	0.16	2.79
Training investments, 2011:						
Degree completions per 1000 individuals ages 20-34:						
All awards	60.80	33.28	40.91	60.86	72.04	110.41
Certificates	7.82	5.52	5.13	6.36	10.20	18.42
Associates	9.99	5.99	6.73	9.47	11.72	20.05
Bachelor's	30.11	24.04	16.44	27.20	36.29	66.29
Graduate	12.87	10.90	3.11	12.99	20.85	31.40
FTE enrollments per 1000 individuals ages 20-34:						
All institutions	233.67	116.52	166.98	228.44	259.33	458.87
2-year institutions	52.91	33.72	31.88	58.66	70.98	113.74
4-year institutions	180.76	117.99	116.92	182.96	199.45	452.71
Postsecondary institution financial characteristics ($1000s) per person ages 20–34						
Total revenues	9.99	9.85	4.47	7.68	13.88	16.68
Revenues from the federal gov.	1.30	1.23	0.41	0.65	2.08	2.75
Revenues from state & local gov.	1.53	1.53	0.52	1.18	2.08	5.80
Revenues from tuition	2.85	2.70	1.42	2.31	3.30	5.49
Revenues from other sources	4.31	5.52	1.39	2.12	5.45	9.87
Total expenditures	8.53	8.30	4.08	5.82	11.92	15.34
Government transfers ($1,000) per capita, 2011:						
All gov. transfers	9.58	1.19	8.40	9.42	10.36	11.53
Medical	4.09	0.63	3.48	4.06	4.52	4.89
Medicare	2.35	0.37	2.04	2.35	2.68	2.82
Medicaid	1.70	0.36	1.42	1.63	1.85	2.31
Social Security	3.24	0.48	3.02	3.28	3.56	3.99
Income maintenance	0.98	0.25	0.83	0.97	1.08	1.38
SNAP	0.28	0.08	0.23	0.30	0.32	0.41
SSI	0.23	0.11	0.16	0.21	0.23	0.41
EITC	0.21	0.06	0.16	0.20	0.22	0.30
Unemp. insurance	0.41	0.16	0.28	0.38	0.56	0.65
Ed. & training	0.23	0.08	0.19	0.22	0.26	0.32

All summary statistics are population-weighted and are based only on CZs with coal mining employment in 2011 (N=46). Coal variables have been multiplied by 100 for ease of interpretation. A positive $\Delta Coal$ reflects a decline in the coal share of employment. All characteristics expressed in dollars are inflated to 2019 dollars using the CPI-U. Graduate degrees include master's and doctorate degrees. Revenue from "other" sources includes revenues from sales, independent operations, investment and endowment income, and private gifts and contributions. Completion, enrollment, and revenue data are from IPEDS. Transfer receipt is based on data from the BEA. The number of coal miners is based on mine-level statistics from MSHA, and total employment from QCEW.

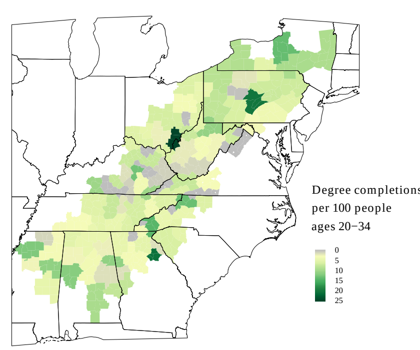
(FTE) enrollment far exceeds degree completions, with about 234 FTE enrollees per person ages 20–34 at postsecondary institutions in 2011. The majority of these students (181 per 1,000) were enrolled in 4-year institutions. On average, Appalachian coal CZs received nearly $10,000 in government transfers per person in 2011, with nearly half of this total ($4,090) composed of medical transfers, which include both Medicaid and Medicare.[12] Social Security made up the second-largest category of transfers, with coal CZs receiving, on average, $3,240 per person in Social Security benefits in 2011. The remainder of transfer programs (income maintenance programs, UI, and education and training) are relatively small components of total transfers. Like coal mining employment, there exists substantial heterogeneity in government transfer payments and degree completions across Appalachian CZs. Figure 3 displays 2011 values of government transfers ($1,000s) per capita and degree completions (all awards) per 1,000 individuals ages 20–34 across Appalachian CZs. Government transfer receipts are largest in those regions with the largest coal shares depicted in Figure 2. Degree completions are not concentrated within a single region, but degree recipiency rates are notably low in Appalachia's coal regions.

Figure 3: Transfers and degree completions in 2011, Appalachian CZs

(a) Government transfers



(b) Degree completions



Notes: Upper panel presents total government transfers (in 1,000s of 2019 dollars) per capita, while lower panel presents total degree completions per 100 people ages 20–34. Completion data are from IPEDS, while transfer receipt is based on data from the BEA.

[12] The category of Medical benefits, as defined by the BEA, includes Medicare, Public assistance medical care benefits (which is primarily Medicaid), and Military medical insurance benefits. Appendix section C.1 defines government transfer categories in greater detail.

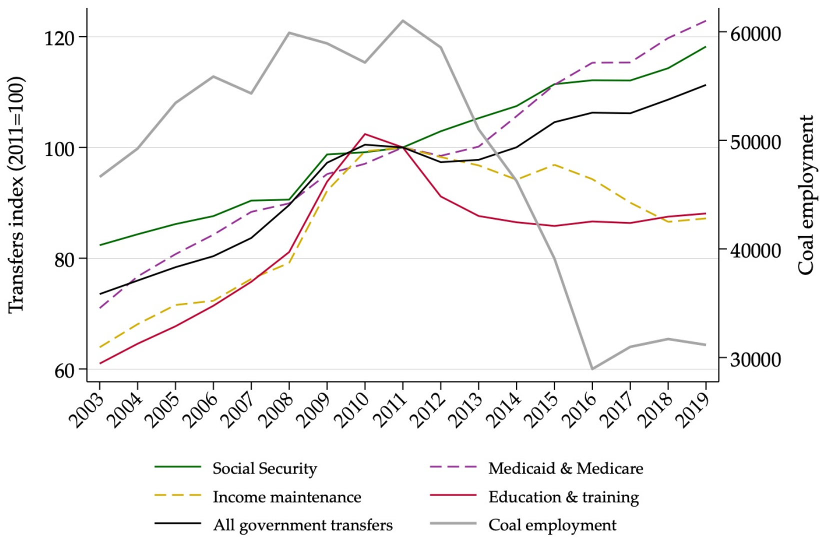
Figure 4 shows the evolution of government transfers and degree completions per capita across Appalachian coal CZs between 2003 and 2019. Coal CZs are defined as those with any coal mining employment in 2011. Both outcomes are inflation-adjusted using the CPI-U and then indexed to their 2011 levels to allow for comparison across variables. Total coal mining employment across all Appalachian CZs is indicated on the secondary axis. Government transfers of various types are displayed in the upper panel and degree completions of various types are displayed in the bottom panel.[13] In aggregate, transfers and degree completions per capita exhibit an upward trend across the study period, but there is notable variation across program types. The secular increase in government transfers per capita is driven by the persistent growth in Social Security and Medicaid and Medicare transfers per capita over the period. By 2019, Medicaid and Medicare transfers per capita were over 20 percent higher than their 2011 levels. Transfers related to income maintenance and education and training grew in the years prior to 2011 but declined following 2011. There is less variation in the growth of degree completions per person ages 20–34 across degree types. All exhibit a slight upward trend across the entire period with the exception of certificates, which peaked in 2012.

While indexing to 2011 levels allows for comparability in the growth of various transfers and training investments across time, it masks the substantial heterogeneity in the baseline size of various programs and degree types. Appendix Figure A1 displays government transfers (in the upper panel) and degree completions (in the bottom panel) by category in Appalachian coal CZs in 2003, 2011, and 2019. Consistent with the summary statistics in Table 1, Social Security and medical (Medicare and Medicaid) payments compose the majority of government transfers across the study period. In all years, bachelor's degrees contribute to about half of all degree completions. The section below details the empirical approach used to estimate the extent to which the observed change in these

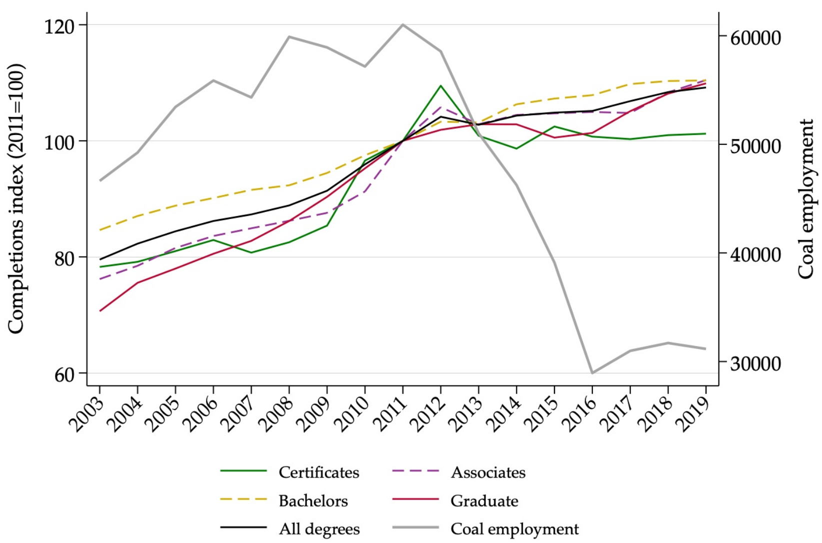
[13] Because fluctuations in UI driven by the financial crisis make it difficult to discern changes in other programs, I omit UI in Figure 4.

Figure 4: Coal employment, transfers, and training in Appalachian CZs, 2003–2019

(a) Government transfers



(b) Degree completions



Notes: The upper panel reflects the population-weighted average of government transfers per capita in the category indicated for Appalachian CZs with any coal mining employment in 2011. The bottom panel reflects the population-weighted average of degree completions per person ages 20–34 in the degree type indicated for Appalachian CZs with any coal mining employment in 2011. Graduate includes master's and doctoral degrees. Both government transfers and degree completions are indexed to 2011 values. Transfers are based on estimates released by the BEA Regional Economic Accounts, and degree completions are based on IPEDS data. Total coal employment, derived from MSHA mine-level statistics, is indicated on the secondary axis.

outcomes is attributable to the collapse of the coal industry that occurred in the latter half of this period.

3 Empirical approach

To understand how transfers and training investments respond to the 2011–2016 coal shock, I estimate a series of first-difference models over progressively longer time horizons (Autor et al., 2021; Hanson, 2022). This approach estimates the cumulative effects of a continuous treatment applied over a gradual period, following the local projections framework (Jordà, 2005, 2023). Specifically, I estimate:

$$\Delta y_{j,t+h} = \beta_0 + \beta_1 \Delta Coal_{j,\text{2011-16}} + \beta_2 \left(\mathbf{1}[Coal_{j,2011} > 0]\right) + \beta_3 \left(\mathbf{1}[College_j]\right) + \mathbb{X}_j' \gamma + \delta_r + \varepsilon_j \quad (1)$$

where $\Delta y_{j,t+h}$ is the change in outcome y in CZ j between year $t = 2011$ and $t + h$ for $h \in -8, -7, ..., 8$. The variable $\Delta Coal_{j,\text{2011-16}}$ reflects the change in coal mining employment between 2011 and 2016 in CZ j as a share of the CZ's total employment in 2011.[14] This variable is multiplied by -1, such that a higher value reflects a larger decline, or larger coal shock. As indicated in Table 1, the population-weighted average coal shock $\Delta Coal_{j,\text{2011-16}}$ across Appalachian coal CZs was a decline of 0.5pp (σ=1.6).

Rather than use the observed change in the coal share of employment $\Delta Coal_{j,\text{2011-16}}$ directly when estimating equation 1, I instrument for the observed change using a single-industry Bartik shift-share variable (Bartik, 1991).[15] This approach isolates the decline in local coal mining employment that is driven by differential exposure to the macroeconomic coal shock. I instrument for $\Delta Coal_{j,\text{2011-16}}$ with the following (Bartik, 1991; Autor

[14] I divide the change in coal employment by a constant (2011) employment level rather than the change in employment to avoid the confounding influence of simultaneous changes in overall CZ employment.

[15] Bartik-style instruments have been widely used to study local labor demand shocks in a variety of settings (Bartik, 1991; Blanchard and Katz, 1992; Charles et al., 2019; Notowidigdo, 2020).

et al., 2021; Hanson, 2022):

$$\widehat{\Delta Coal}_{j,2011\text{-}16} = -1 \times \frac{L_{cj,2011}}{L_{j,2011}} \times \left(\frac{L^{j'}_{c,2016} - L^{j'}_{c,2011}}{L^{j'}_{c,2011}} \right) \tag{2}$$

where $\frac{L_{cj,2011}}{L_{j,2011}}$ is the coal mining share of employment in CZ j in 2011. Figure 2 displays the regional variation in the coal employment share. This value is multiplied by the term in parentheses in equation 2, which reflects the percent change in coal mining employment between 2011 and 2016 in all CZs except for CZ j. I include all CZs (including those outside of Appalachia) in the construction of $\widehat{\Delta Coal}_{j,2011\text{-}16}$. This is a relatively standard shift-share instrument that leverages differential CZ-level exposure to the national shock to coal demand (Goldsmith-Pinkham et al., 2020; Autor et al., 2021; Borusyak et al., 2022). While the shock is macroeconomic in nature, certain regions have a comparative advantage in the industry based on the spatial concentration of coal deposits and are thus more exposed to the sector's collapse. Below, I detail how the estimation strategy offers a natural placebo check to test the exogeneity of the instrument.

In equation 1, I control for a rich set of CZ-level covariates $\mathbb{X}'_j$ that control for factors influencing a region's organic movement in and out of government transfer and training programs, independent of the coal shock. This includes the baseline (2011) college-educated share of adults (ages 25 and older), foreign-born share of the population, female share of employment, manufacturing share of employment, population share under 20, population share ages 20–34, population share 65 and older, and a variable capturing the CZ's exposure to the Great Recession, described below.[16] These controls capture key population and employment characteristics that may influence eligibility for means-tested/old-age transfer programs and changes in postsecondary training investments that may also be correlated with exposure to the coal shock.[17] Equation 1 also

[16]Year 2011 population characteristics (college share, foreign-born share, and female share) are derived from the ACS 5-year (2009-2013) sample. The manufacturing share is derived from the CBP-imputed data for 2011 provided by Eckert et al. (2020).

[17]For instance, coal communities tend to have relatively older populations. Controlling for the age com-

includes dummy variables $\mathbf{1}[Coal_{j,2011} > 0]$ and $\mathbf{1}[College_j]$ indicating whether the CZ had any coal mining employment in 2011 or postsecondary institution during the study period, respectively. These dummies control for baseline differences across coal versus non-coal and college versus non-college CZs. While most CZs include an institution of higher education, the inclusion of $\mathbf{1}[College_j]$ accounts for zeros in training responses that result from the absence of an institution. I also include Census region fixed effects, δ_r, to flexibly account for regional differences in underlying changes over the analysis period.[18] All regressions are weighted by 2011-level population counts.

Coal's recent collapse began on the heels of the recovery from the Great Recession, which had differential effects on different regions of the United States (Charles et al., 2018a; Yagan, 2019; Autor et al., 2021). Both transfer payments and postsecondary training investments were greatly affected by this major economic event. To avoid the potentially confounding effects of the Recession and the subsequent policy efforts intended to mollify its consequences, I include in the vector of covariates a control that captures differential exposure to the Great Recession, following the logic in Yagan (2019). This variable ϕ_j for county j is defined as:

$$\phi_j = \sum_k \frac{L_{jk2000}}{L_{j2000}} \times \left(\frac{L^{j'}_{k2009} - L^{j'}_{k2006}}{L^{j'}_{k2006}} \right) \tag{3}$$

where $\frac{L_{jk2000}}{L_{j2000}}$ is the share of employment in 4-digit industry k in county j in year 2000.[19] Each industry share is multiplied by the shift in employment in that industry in all counties except j between 2006 and 2009, $\frac{L^{j'}_{k2009} - L^{j'}_{k2006}}{L^{j'}_{k2006}}$. I sum this value for all industries k in each county j, such that ϕ_j reflects each county's exposure to the employment effects of the Great Recession, based on an industrial composition determined well before the

position of the population ensures that variation in government transfers related to aging populations is absorbed by the control, rather than attributed to the coal shock itself.

[18]The results are robust to omitting these fixed effects as well as using alternative levels of geographic controls.

[19]Annual county-level employment at the detailed 4-digit NAICS code was retrieved from the imputed data set produced by Eckert et al. (2020).

Recession unfolded. I then aggregate this value to the CZ level by taking the population-weighted mean of ϕ_j across counties in a given CZ.

Appendix Table A1 reports first-stage regression estimates of the relationship between the shift-share instrument defined in equation 2 and changes in the coal share of employment across CZs from 2011 to 2016. In the central specification reported in column 3, which includes Census region fixed effects and full CZ-level controls, the coefficient on the instrument is 1.20, indicating that a one percentage point predicted decline in coal employment is associated with a 1.2 percentage point decline in the observed coal share of employment across CZs. The corresponding first-stage F-statistic is 68.7, exceeding standard weak instrument thresholds.

I estimate equation 1 separately for each time horizon between 2003–2011 and 2011-2019. This amounts to a series of long-difference regressions of differing lengths that end or begin in year 2011. In all cases, β_1 reflects the effect of the 2011–2016 coal shock on the outcome of interest over the period specified. This approach reveals how long it takes for the full effects of the coal shock to manifest, with pre-shock regressions serving as a natural placebo check on the exogeneity of the coal shock to expected outcomes (Autor et al., 2021; Borusyak et al., 2022). Estimates from time periods after the coal shock subsided reveal whether the impacts of the shock attenuate or persist beyond 2016.

A related concern is that the coal shock variable might also capture endogenous, contemporaneous local shocks. Specifically, because natural gas made available by hydraulic fracturing was one of the main drivers of the decline in demand for coal over this period, spatial overlap of these two resources (and associated jobs) could confound the interpretation of the coal shock. If places that lost greater numbers of coal workers were the same places that gained greater numbers of natural gas workers, the primary independent variable might muddle these two forces. Appendix Figure A2 provides a heat map of natural gas production per capita in 2011 across the Appalachian CZs, demonstrating that natural gas extraction occurs in regions where coal is relatively less concentrated. Natural gas production was heavily concentrated in Pennsylvania, while the sharpest coal losses occurred in Eastern Kentucky and West Virginia. To limit the influence of differences between coal and non-coal areas, I include a dummy variable indicating whether a CZ had any coal mining employment in 2011. This approach leverages variation in the intensity of coal dependence across coal areas, rather than between coal and non-coal regions. In supplemental analyses, I control directly for CZ-level natural gas production. The inclusion of this control has no substantive impact on the estimated effects of the coal shock.

4 Results: Transfers and training response to the coal shock

How did government transfers and training investments respond to coal's collapse in Appalachia? In sections 4.1 and 4.2, I present the central point estimates revealing the investment response to the 2011–2016 coal shock along both transfer and training margins, respectively.

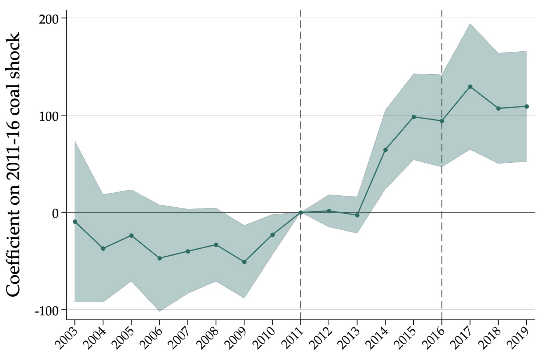
4.1 Government transfers and the coal shock

Figure 5 presents the coefficient estimates of β_1 in equation 1, where the outcome is defined as the change in government transfers per capita for the program type indicated. Each marker reflects the point estimate from a separate regression where the outcome is defined over each time horizon from 2003–2011 to 2011–2019. In all regressions, the coal shock is defined over the 2011–2016 period. The shaded areas reflect the 95 percent confidence intervals. The y-axis scales are consistent within the top two panels (total transfers and medical transfers) and within the bottom four panels (social security, income maintenance, UI, and education and training). For visibility, the scales are not consistent across these two groups. Each panel includes a dashed line indicating 2011 and 2016.

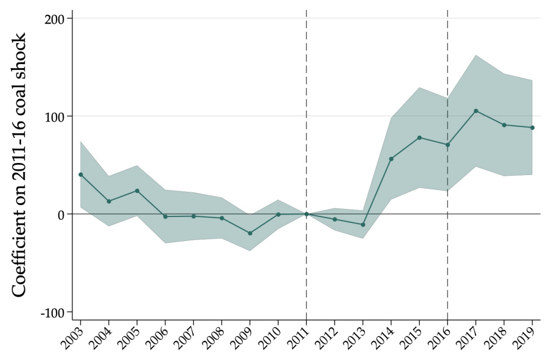
While impossible to test for explicitly, the central identification assumption in this IV strategy is that CZ-level exposure to the coal shock, captured by the shift-share instru-

Figure 5: Effect of the 2011–2016 coal shock on government transfers ($'s) per capita

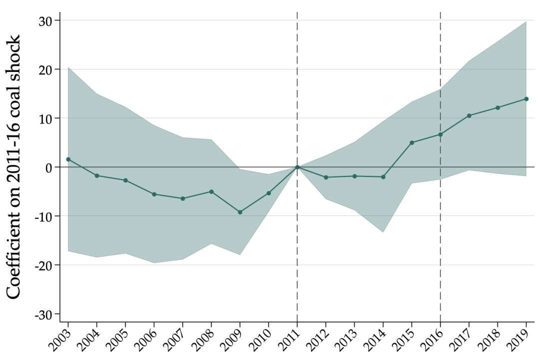
(a) Total government transfers/capita



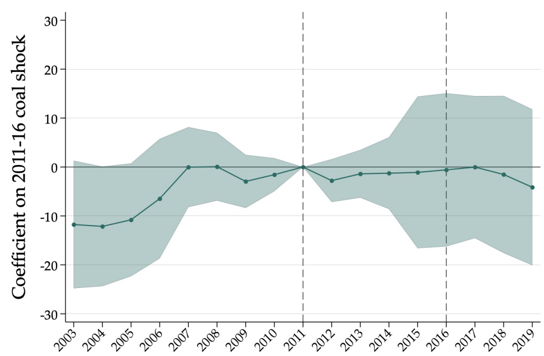
(b) Medical transfers/capita



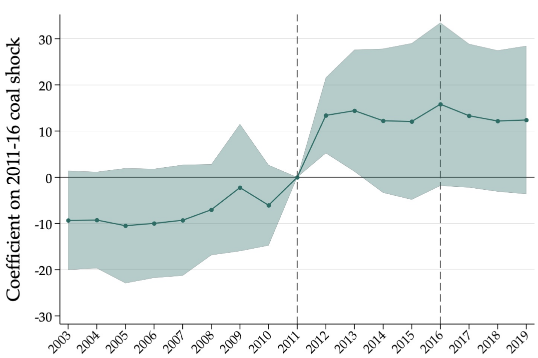
(c) Social security transfers/capita



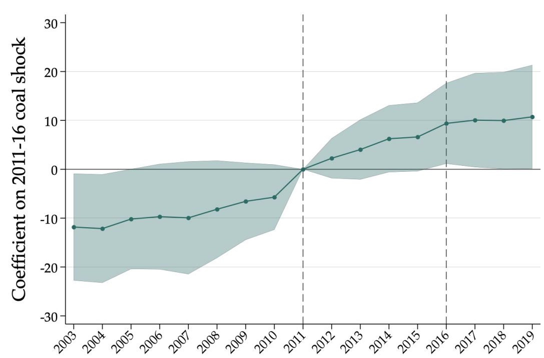
(d) Income maintenance transfers/capita



(e) UI transfers/capita



(f) Education & training transfers/capita



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in government transfers per capita for the program type indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

ment, only influences outcomes of interest via the macroeconomic shift in demand for coal that transpired over the 2011–2016 period. Across the various panels in Figure 5, the coal shock has little substantive impact on changes in transfer receipt during pre-shock time horizons. These pre-shock long-difference regressions test whether the instrumented coal shock predicts outcomes during these placebo periods, when demand for coal was relatively stable. The statistically weak, negative coefficients in the years prior to 2011 indicate the possibility of modest declines in transfers per capita during these pre-shock periods, or a slight reverse pre-trend. This could be explained by the slight uptick in coal employment during this pre-shock period (Figure 1). However, the standard errors typically bound a null effect, supporting the notion that the instrument isolates exogenous CZ-level exposure to the macroeconomic shock to coal demand.

The point estimate for year 2016 in panel a (total government transfers) is 94.2, implying that a 1-unit increase in the 2011–2016 coal shock (a 1pp decline in the coal share of employment) yields a $94 increase in government transfers per capita over the 2011–2016 period. The estimate grows modestly in subsequent years to reach 109.1 in 2019, indicating a $109 increase in government transfers per capita over the 2011–2019 time frame. To contextualize the magnitude of this effect, consider the impact of a 1-SD increase in the coal shock (1.6pp): A 1-SD increase in the coal shock reflects a $150 increase in transfers per capita (1.6×94), or an increase of 12.6% of a standard deviation in government transfers per capita based on 2011 values ($1,190).[20] The increase in total transfers is almost entirely attributable to an increase in medical (Medicaid and Medicare) transfers. The coefficient for 2011–2016 in panel b (70.8) suggests that 75% of the coal-shock-induced increase in government transfers per capita over the 2011–2016 period is attributable to the increase in medical transfers. A 1-SD increase in the coal shock thus yields a $113 increase in medical transfers per capita, or 18% of a standard deviation in medical transfers per

[20] Appendix Figure A3 demonstrates that these patterns are robust to the inclusion of alternative geographic controls (division fixed effects or no fixed effects) and a control for CZ-level natural gas production.

capita based on 2011 values ($630). Appendix Figure A4 separately evaluates the effect of the coal shock on Medicaid and Medicare, demonstrating that the increase in medical transfers is entirely attributable to Medicaid transfers. The point estimate on 2016 in panel c is 64, indicating that a 1pp decline in the coal share yields a $64 increase in Medicaid transfers per capita over the 2011–2016 period.[21]

Other transfer programs appear less responsive to the 2011–2016 coal shock, though the standard errors for certain programs are relatively large. The point estimates for Social Security (panel c of Figure 5) suggest a modest upward trend throughout the coal shock period, but the confidence intervals bound zero. Due to the relatively large footprint of the program, I can rule out that the effect on Social Security is as large as the effect on total government transfers.[22] Given that Social Security includes both retirement and disability programs, this null result contrasts with other research documenting relatively large impacts of labor demand shocks on program uptake (e.g., Black et al., 2002; Charles et al., 2018b). It aligns more closely with Hanson (2022), who finds limited impacts of the long-run decline in coal on Social Security receipt nationally.

Income maintenance programs (panel d of Figure 5) show similarly muted responsiveness, but several well-defined programs are included in this category that may respond differentially. Appendix Figure A5 decomposes these effects across three programs in this category. The y-axis is adjusted to reflect their smaller scale. Earned Income Tax Credit (EITC) transfers per capita increase modestly and remain elevated throughout the

[21] The four largest coal-producing states in Appalachia (Kentucky, West Virginia, Ohio, and Pennsylvania) all adopted the Affordable Care Act's (ACA) Medicaid expansion to adults with incomes up to 138 percent of the Federal Poverty Level, with Kentucky, West Virginia, and Ohio implementing expansion in January 2014 and Pennsylvania implementing expansion in January 2015. Because CZs cross state boundaries, I do not include state fixed effects in the central empirical specification. However, assigning CZs to states based on the state in which most of the population resides and adding state fixed effects to the regression specification does not alter the conclusions. Such a specification will absorb the effect of state-level policies implemented during the study period, such as Medicaid expansion.

[22] Given the SD in Social Security transfers per capita in 2011 ($480), the coefficient on the 2011–2016 coal shock would need to be 37.8 for the 2011–2016 outcome period in order for the shock to produce the same-sized effect as for total transfers ($480 \times 0.126/1.6$).

shock.[23] The EITC is a refundable tax credit designed to support lower-income workers, offering larger credits to workers with children. Single mothers have historically composed the largest group of taxpayers eligible for the EITC (Eissa and Liebman, 1996). I am unable to distinguish the degree to which the observed uptick in EITC receipt is driven by an increase in parenthood, an increase in single parenthood (i.e., divorce), a decline in the average income of parents, or a combination of all of these (and possibly other) factors. At the same time, Supplemental Security Income (SSI) and Supplemental Nutrition Assistance Program (SNAP) transfers appear largely unresponsive to the coal shock. Together, these patterns indicate that the coal shock influenced receipt of some income support programs, such as the EITC, but had limited impact on others, including SSI and SNAP.

The final two panels of Figure 5 consider transfers related to unemployment insurance (panel e) and education and training (panel f). UI exhibits an immediate increase in the initial years of the shock, followed by a weakly significant stabilization. This response is consistent with the fact that the coal shock was not a one-time mass-layoff event, but rather a longer-run contraction unfolding steadily throughout the period. Government transfers related to education and training, primarily reflecting financial assistance for students attending postsecondary institutions (e.g., via Pell Grants or interest payments on student loans), increased by \$9.4 per capita over the 2011–2016 period in response to the coal shock. While this effect is modest, with confidence intervals spanning zero for much of the observation window, it highlights a limited set of financial aid programs rather than direct involvement in training initiatives. Notably, the BEA estimates of county-level assistance for education and training may be less accurate than other programs discussed in this paper, as these values are sometimes derived from state or national data and allocated to counties in proportion to household population, rather than

[23] The point estimate for the 2011–2016 period in panel c is 3.0. Thus, a 1-SD increase in the coal shock produces a \$4.8 increase in EITC transfers per capita over the 2011–2016 period, or an increase of 8% of a SD based on 2011 values.

based on actual county-level values (BEA, 2024). In the section that follows, I investigate a more comprehensive set of metrics capturing training investments.

An important limitation in interpreting these results is the inability to disentangle the channels through which the coal shock affects transfer receipt. Increases in per capita transfers may reflect mechanical changes in population composition (e.g., out-migration of residents not receiving transfers), changes in eligibility (e.g., declining incomes increasing program participation), or changes in spending per recipient (e.g., rising healthcare needs among Medicare and Medicaid enrollees). Prior work shows that coal-related job loss alters the age and educational composition of affected regions, yielding an older, less-educated, and lower-income population (Hanson, 2022; Krause, 2024). These shifts likely account for some portion of the observed increase in transfer receipt.

Appendix Section B explores this issue by examining how the coal shock affects local age distributions and adjusting transfer outcomes by age-specific population groups most likely to receive each program. This analysis yields similar conclusions, suggesting that the effects are not solely driven by demographic shifts. Nonetheless, I cannot separately identify whether the coal shock affects the number of beneficiaries or average spending per enrollee. It is possible, for example, that the null point estimates reported above, particularly for income maintenance programs, reflect a combination of increased program eligibility alongside barriers to program enrollment. Still, the large and persistent increase in total transfers per capita indicates that transfers become a more important component of the overall economy as a result of the coal shock. That is, the relatively immobile residents who do remain in exposed communities are, on average, more reliant on government support programs.

4.2 Training investments and the coal shock

Several existing studies document a relationship between labor demand shocks and subsequent investments in educational credentials (Black et al., 2005b; Charles et al., 2018a; Foote and Grosz, 2020; Acton, 2021). Consistent with the predictions from classic theories of human capital (Mincer, 1958; Becker, 1964), these studies tend to find that educational investments — as proxied by local enrollment counts and postsecondary degree and program choices — respond to local labor market conditions. In this setting, the collapse of coal sharply reduced the returns to entering the coal industry, which historically offered high wages to workers with relatively low levels of educational attainment (Colmer et al., 2024). As a result, one would expect coal's decline to incentivize investments in higher levels of educational attainment and shift program choices away from fields affected by the demand shock. In this section, I explore how such educational investments in Appalachia responded to the sharp decline in demand for coal.

Figure 6 shows the coefficient estimates of β_1 in equation 1, where the outcome is defined as the change in the number of degrees completed per 1,000 individuals ages 20–34 in the degree type indicated. Again, each marker reflects the estimate (and its 95 percent confidence interval) from a separate regression for each time horizon between 2003-–2011 through 2011—2019. Across all types of credentials, point estimates in the pre-shock period are very near zero, indicating no pre-shock trend in degree completions. As the coal shock unfolds, there are no statistically discernible impacts on degree completions in any program type.

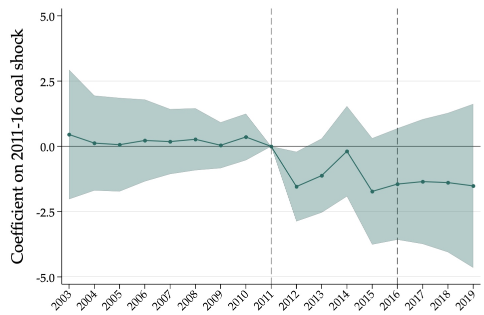
The point estimates for all awards (panel a) indicate a weak decline in degree completions, but a null effect is within standard confidence intervals.[24] I can rule out effect sizes comparable to the observed effect on government transfers. For a 1-SD increase in the coal shock to produce an increase in the rate of overall degree completions of the same magnitude as the effect on transfer receipt, the point estimate in panel a for the 2011–2016 period would need to be 2.6, which is well outside of the 95% confidence interval.[25]

[24] Appendix Figure A6 shows that these results are similar under alternative geographic specifications and when controlling for local natural gas production, suggesting that the central estimates are not sensitive to regional fixed effect assumptions or other contemporaneous shocks.

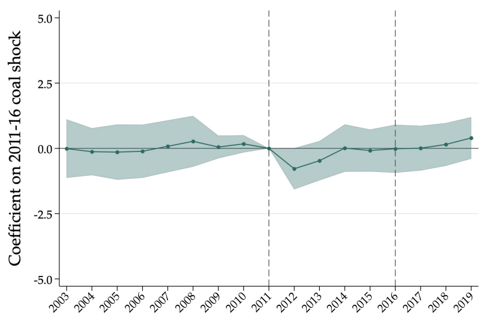
[25] The SD in degree completions in 2011 was 33 degrees per 1,000 people ages 20–34. Thus, for a 1-SD increase in the coal shock to produce the same-sized effect on degree completions as for total transfers (12.6%

Figure 6: Effect of the 2011–2016 coal shock on degree completions per 1,000 people ages 20–34

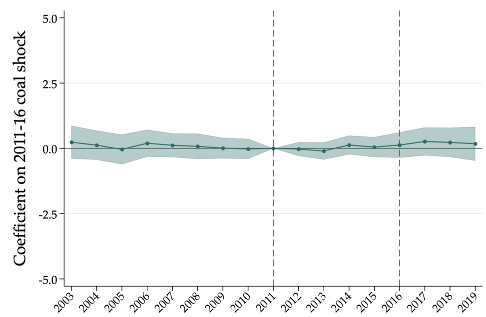
(a) All awards



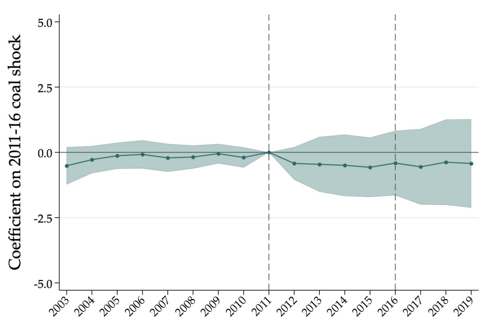
(b) Certificates



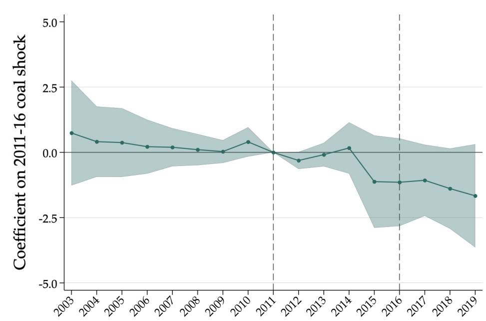
(c) Associate degrees



(d) Bachelor's degrees



(e) Graduate degrees



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in degree completions per 1,000 people ages 20–34 for the degree type indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011–2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the CZ-level variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

The negative point estimates for "all awards" are driven by statistically insignificant declines in bachelor's and graduate degree completions (panels c and d), which together composed 70% of all degrees awarded in 2011. While these estimates are not statistically distinguishable from zero, I can rule out economically meaningful positive effects.[26] Though bachelor's and graduate degrees take longer to complete and often involve longer-distance enrollment, the absence of even modest gains suggests that coal's decline did not trigger an increase in pursuit of these degrees within the time frame examined.

Shorter-term credentials may offer a more informative measure of localized educational response in this setting. Certificates and associate degrees can typically be completed within two years and are overwhelmingly pursued at institutions located within the student's local labor market (Hillman and Weichman, 2016). As a result, patterns in these credentials are less likely to be confounded by education-related migration and more likely to reflect local adaptation. However, the point estimates for certificate and associate degree completions (panels b and c) are consistently close to zero and show no statistically detectable increase following the coal shock.[27] Across all degree types, the coal shock produces a precise null training investment response.

Certificates and associate degree completions may still exhibit some lag in responsiveness if programs take multiple years to complete. However, delayed completion cannot fully account for the null effects on degree attainment. Figure 7 shows the enrollment analog to the degree completion results. Because IPEDS enrollment data are not available by degree type, the outcome reflects full-time-equivalent (FTE) enrollment across all program types. FTE enrollment is calculated as full-time enrollment plus 0.392857 times

of a standard deviation), the point estimate for the 2011–2016 period would need to be 2.6 (33×0.126/1.6).

[26]For the coal shock to produce the same effect on bachelor's degrees as for total government transfers, the coefficient would need to be 1.9 (24×.126/1.6). For graduate degrees, it would need to be 0.86 (10.9×.126/1.6).

[27]This analysis combines degree completions at both public and private and 2- and 4-year institutions. Restricting to certificate and associate degrees received only at 2-year institutions produces nearly identical results.

part-time enrollment, following the weighting scheme used by the Digest of Education Statistics. Panel a shows the change in FTE enrollment per 1,000 individuals ages 20–34 across both 2- and 4-year institutions. Panels b and c disaggregate this to FTE enrollment at 2-year and 4-year institutions, respectively.[28] As with degree completions, the coal shock yields no statistically detectable effect on enrollment across institution types, and I can rule out substantial positive effects.[29]

The evidence above indicates that the training response to the coal shock — in terms of postsecondary enrollment and credentials earned — is statistically indistinguishable from zero. However, it is possible that demand for training increased, but supply was constrained by institutional limitations. Economic downturns may restrict revenues from local sources, and federal funding streams are not always designed to respond to localized shocks. For example, the Trade Adjustment Assistance Community College and Career Training (TAACCCT) program, launched in 2011, provided $1.9 billion in grants between 2011 and 2014 to expand and improve workforce-aligned programs at community colleges.[30] Although designed to support training for in-demand jobs, TAACCCT distributed funding broadly: every state was guaranteed at least 0.5 percent of each year's appropriated funds. The program was not intended to target specific regional downturns but instead offered geographically dispersed support to institutions aligned with local or regional business needs.

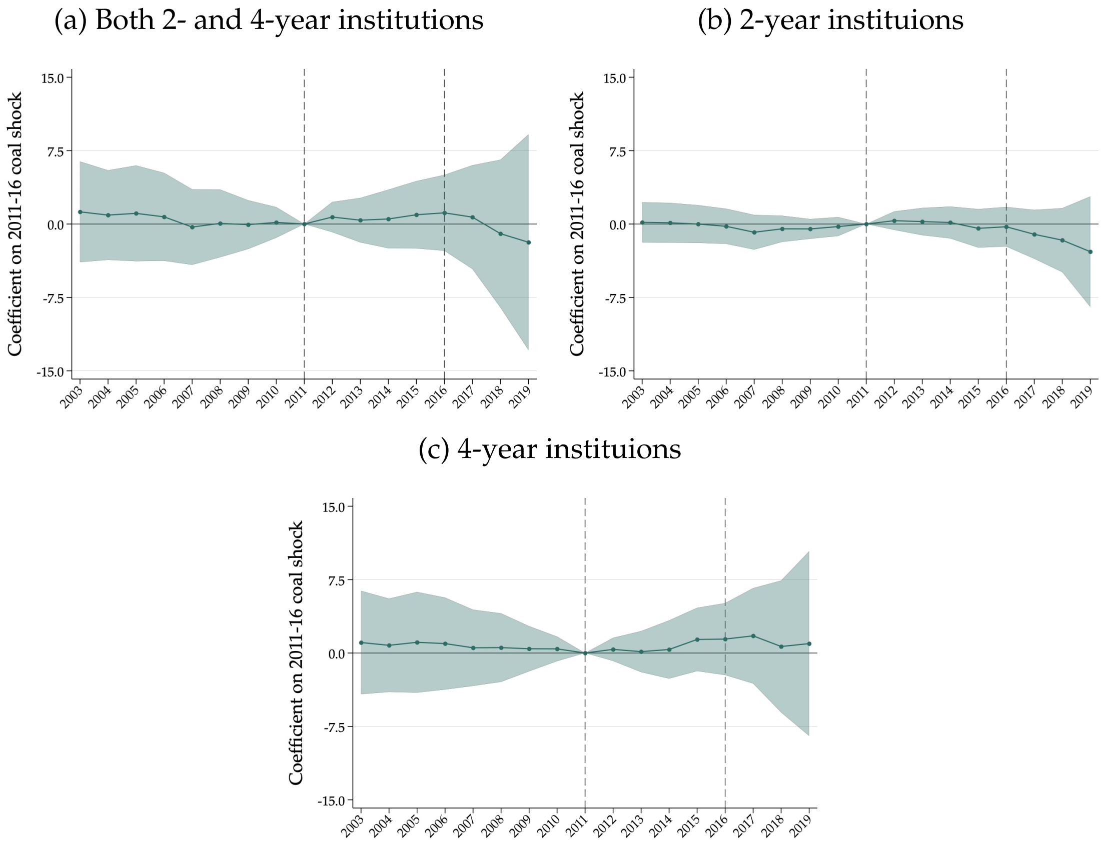
This logic previews the lack of responsiveness in institutional finances to the 2011–2016 coal shock. Appendix Figure A7 reports estimates from equation 1, where the outcome is the change in institutional revenues or expenditures (in $1,000s) per person ages 20–34. Panels a and b show that the coal shock has no statistically detectable effect on total rev-

[28] Defining the outcome as the change in the natural log of total enrollees yields qualitatively similar results.

[29] The SD in the FTE enrollment rate in 2011 was 116.5. Thus, for a 1-SD increase in the coal shock to produce the same-sized effect on enrollments as it did on transfers, the coefficient for 2011–2016 would need to be 9.2 ($116.5 \times 0.126/1.6$).

[30] TAACCCT was authorized under the American Recovery and Reinvestment Act (ARRA) of 2009 and funded through the Health Care and Education Reconciliation Act.

Figure 7: Effect of the 2011–2016 coal shock on FTE enrollment at postsecondary institutions per person ages 20–34



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in full-time-equivalent (FTE) enrollees per person ages 20–34 at the institution type indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

enues or total expenditures. As local economic conditions deteriorate, one might expect lower revenues from state and local sources. Panels c and d distinguish between revenues from the federal government and revenues from state and local government, respectively. Both indicate stable, statistically indetectable responses to the coal shock. Likewise, the coal shock yields no distinguishable effect on revenues from tuition (panel e). Revenues from "other" sources (panel f), which include revenues from sales, independent operations, investment and endowment income, and private gifts and contributions, further exhibit a negligible response. Given TAACCCT's focus on community colleges — which primarily serve local students and are less affected by education-related migration — Appendix Figure A8 restricts the analysis to 2-year institutions. These estimates are more precisely estimated around zero, indicating no detectable changes in financial inputs to the subset of institutions most likely to have been affected. Taken together, these results suggest that the coal shock did not generate a discernible financial response in the post-secondary institutions serving affected Appalachian communities.

While many government transfer programs are explicitly intended to react to income or employment shocks, policy-driven investments in educational institutions are rarely specifically linked to local economic conditions. If the supply of postsecondary training is unresponsive to deteriorating local labor market conditions in Appalachia, this may inhibit a detectable quantity response in terms of total completions. Still, students may shift their program choices in response to local shocks at the same time that overall degree completions are limited by supply constraints. Other work has documented that students' educational program choices are responsive to new information about labor market returns to different program types (Baker et al., 2018; Grosz, 2019; Acton, 2021).[31] Did the decline of coal cause a shift in students' educational program choices?

To answer this question, I consider whether the decline in coal produced changes in degrees awarded in mining-related training programs. I focus on the composition of certificate and associate degree completions which, because of the length of the programs, have greater capacity to respond to labor demand shifts in the near term. Further, these programs are typically completed at 2-year institutions, where almost all students enroll locally. Building on Acton (2021), I match each educational program's Classification of Instructional Program (CIP) code to the associated Standard Occupation Classification

[31] Acton (2021) shows that exogenous declines in local employment in Michigan reduce the share of high school graduates enrolling in related community college programs the following year, at the same time that it increases the share enrolling in other vocationally oriented programs.

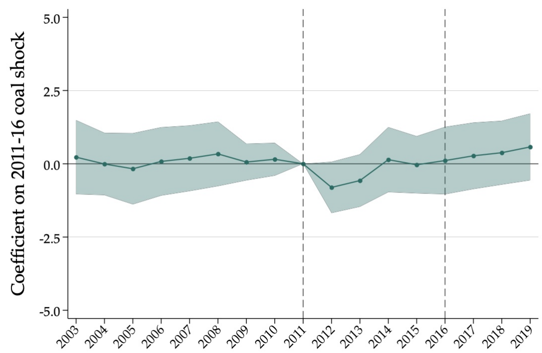
(SOC) code using the crosswalk built by the Bureau of Labor Statistics (BLS) and the National Center for Education Statistics (NCES). CIP codes are matched to SOC codes if the educational programs offer the specific skills and knowledge required by the occupations to be successful. I define "mining-related" programs as those associated with a SOC code that includes the term mining. Appendix Table C2 details the 6-digit CIP and SOC titles included in this categorization. I then aggregate these 6-digit CIP codes to the 2-digit level, yielding three 2-digit CIP code categories that include mining-related training: 14 (engineering), 15 (engineering technologies and technicians), and 49 (transportation and materials moving).[32]

Figure 8 shows the coefficient estimates of β_1 in equation 1, where the outcome is again defined as the change in the number of degrees completed per 1,000 individuals ages 20–34 in the degree type indicated, as in Figure 6. The outcome in panel a includes the change in all certificates and associate degree completions between 2011 and the year indicated on the horizontal axis. The outcome in panel b includes only those degrees awarded in mining-related CIP codes, while the outcome in panel c includes degrees awarded in all other CIP codes. The coefficients for each time difference in panels b and c sum to those in panel a, as they are exhaustive of all program types. If students reacted to shifting labor market opportunities in the local coal mining sector by switching away from mining-related programs, the point estimates for the post-2011 period in panel b should be negative, and those in panel c positive. Instead, the time pattern of the coefficients potentially suggests a short-run decline in non-mining completions immediately following the shock, which runs counter to the evidence in Acton (2021) in the context of mass layoffs in Michigan. While these early declines are not precisely estimated, they provide no support for a reallocation of students toward non-mining fields. I omit the full set of point estimates here, but find that the 2011–2016 coal shock had negligible effects

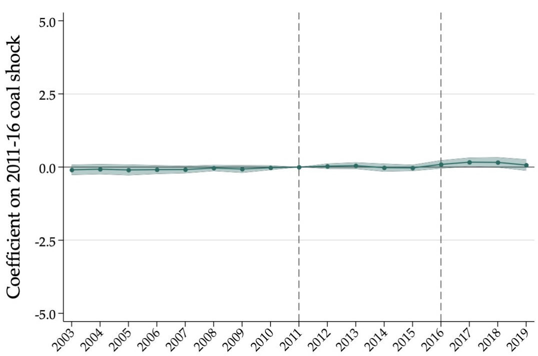
[32] I define mining-related programs at the 2-digit CIP code level because the training data are retrieved at this level of aggregation

Figure 8: Effect of the 2011–2016 coal shock on certificate and associate degree completions per 1,000 people ages 20–34

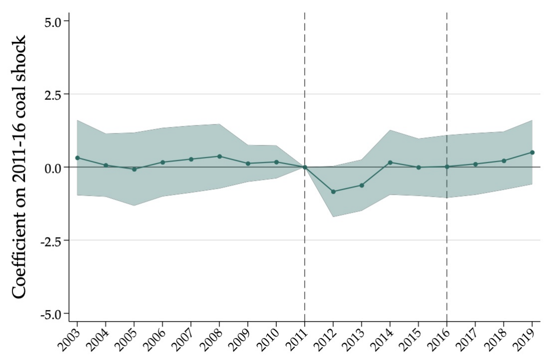
(a) All certificate & associate degrees



(b) Degrees in mining-related CIP codes



(c) Degrees in all other CIP codes



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in certificate and associate degree completions per 1,000 people ages 20–34 between 2011 and the year on the horizontal axis. Mining-related CIP codes are defined as CIP codes 14, 15, and 49. The coal shock is defined as the 2011–2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the CZ-level variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

on degree completions in all 2-digit CIP codes, including the largest category of certificate and degree programs, "Health professions and related programs" (CIP code 51). Across all program types, postsecondary program decisions do not appear responsive to the nature of the local labor demand shock.

The evidence presented in this section indicates that the sectoral collapse of coal produced negligible impacts on training investments in affected Appalachian regions. This null result contrasts with earlier research documenting that educational investments often respond to local labor market shocks. For instance, Black et al. (2005b) show that high school enrollment rates increased in coal-producing counties during the 1980s coal bust, when job losses disproportionately affected workers without high school diplomas. In the more recent period, the vast majority of coal miners have at least a high school degree (Krause, 2024), and the returns to postsecondary education have grown substantially.[33] As a result, the analog hypothesis in the contemporary setting is that coal's decline should influence postsecondary training. That the 2011–2016 coal shock produces no detectable increase in postsecondary enrollment, and negligible effects across a variety of other training investment measures, may reflect a range of constraints. Unlike high school, postsecondary education is not universally accessible. Prospective students may face financial constraints, informational barriers, or lack academic preparation (Dynarski et al., 2023). Institutions themselves may also lack the resources to expand capacity in response to rising local demand (Bound and Turner, 2007). These challenges are likely compounded by declines in household income (Blonz et al., 2023) and public revenue (Morris et al., 2019) following coal's collapse. Geographic proximity to higher education may also play a role. While most Appalachian CZs have at least one college, many rural communities are still relatively distant from these institutions, and many studies document that geographic proximity plays an important role in influencing students' college-going decisions (e.g.,

[33] Krause (2024) shows that while 40% of Appalachian coal miners had less than a high school degree in the 1980 Census, over 86% had a high school degree or more based on data from the 2005–2009 ACS.

Rouse, 1995; Reber and Smith, 2023; Acton et al., 2024). As discussed above, institutional financial constraints may also limit the supply of postsecondary education. Each of these frictions may prevent prospective students from pursuing higher education even as local labor market shocks change the expected returns to schooling.

One limitation of this analysis is that I am unable to distinguish the residential location of enrollees and degree recipients. If a dislocated coal worker commutes across CZ lines to enroll in a certificate program in another labor market, their enrollment will be assigned to the market in which the institution operates, rather than their affected coal community. However, given that students tend to enroll in institutions very close to their home residences (Hillman and Weichman, 2016), and because CZs are constructed to capture the range of typical commuting flows, it is unlikely that accounting for education-related migration would substantially alter the conclusions. With this caveat in mind, I consistently find that the training response to the 2011–2016 coal shock is statistically indistinguishable from zero across a wide range of postsecondary training outcomes. In most cases, null effects are precise enough to rule out sizeable positive effects on the order of the transfer response documented above. While important to protecting households from the temporary financial consequences of local labor demand shocks, transfer payments alone are likely insufficient in supporting individuals and their communities to adapt to new economic challenges. Substantial research points to a combination of the increasing skill demands of the broader labor force and sluggish educational attainment in certain regions as explanations for persistent regional income disparities (Katz and Murphy, 1992; Juhn et al., 1993; Goldin and Katz, 2008; Autor et al., 2008; Bollinger et al., 2011; Moretti, 2013). Thus, reskilling residents and retaining or attracting skilled workers will likely be necessary to promote longer-term economic recovery in coal regions.

5 Conclusion and discussion

The large-scale transition away from coal as the major source of electricity in the United States has dramatically altered the labor market opportunities available to residents in historically coal-dependent regions. The long-term economic trajectories of these regions will depend in part on how individuals, institutions, and policy systems facilitate adaptation to these structural shifts. Evaluating the investment response to coal's decline provides broader insights into how regions adjust to energy transitions, particularly the extent to which workers and communities reallocate resources in response to large shifts in labor demand.

This paper examines how government transfers and postsecondary training investments responded to the sharp contraction of the coal industry in Appalachia between 2011 and 2016. Exploiting regional variation in exposure to the coal shock, I find that government transfer payments increased substantially, driven by a rise in Medicaid payments per capita, a temporary increase in UI, and a modest increase in EITC receipt. This transfer response could be the result of various mechanisms, including selective out-migration, an increase in eligibility among the incumbent population, or an increase in utilization. All of these mechanisms are consistent with an increased dependency of the average resident on transfer receipt. In contrast, I find no statistically detectable response across a wide set of postsecondary training measures, including degree completions, enrollments, program composition, and institutional finances. This null response persists even when limiting the analysis to short-term credentials and community colleges, where educational migration is less likely to confound local effects. Across a range of outcomes, I find no evidence of increased postsecondary training investments in response to Appalachia's coal shock.

This null training response contrasts to prior research showing that students often adjust educational investments in response to labor market shocks (e.g., Black et al., 2005b; Foote and Grosz, 2020; Acton, 2021). The lack of responsiveness in this setting suggests that unique barriers may limit human capital accumulation in the relatively rural and distressed regions impacted by coal's decline. Both demand- and supply-side constraints likely play a role. The financial cost of attendance, limited geographic proximity to institutions, informational barriers, and low levels of academic preparation may depress educational demand. At the same time, institutional capacity constraints and the structure of federal training programs may limit supply. Many federal education and training programs are allocated through competitive grants rather than responsive to local economic conditions, leaving the most distressed areas potentially under-resourced relative to their needs.

While inconsistent with prior research on educational investment responses to local shocks, the patterns documented in this paper align with broader features of U.S. policy toward economically distressed households and regions. Transfer programs like Medicaid and UI are designed to respond automatically to individual-level changes in income or employment, whereas federal investments in training and education typically rely on discretionary grants that are not explicitly tied to local economic conditions. Recent policy efforts largely reinforce this structure. For example, the Inflation Reduction Act (IRA) provides production and investment tax credits for clean energy development in designated "energy communities" but does not include direct investments in postsecondary education or workforce training (Bistline et al., 2023a,b; Clarke et al., 2024). While these tax credits are designed to be place-based, the broad criteria for classification mean that nearly half of the U.S. land area qualifies (Raimi et al., 2022), directing subsidies toward both deeply distressed regions and those that already present favorable conditions for clean energy investment. Programs like the POWER Initiative and the Assistance to Coal Communities (ACC) aim to support diversification and workforce development but rely on competitive processes that exclude many eligible communities in a given funding cycle (Shelton et al., 2022). The regions most affected by structural decline — those with weaker administrative capacity and declining human capital — may be least equipped to access and implement these resources effectively (Roemer and Haggerty, 2021).

The findings in this paper have important implications for how economists and policymakers evaluate efforts to promote regional adjustment to the ongoing energy transition. Human capital is a critical determinant of economic growth and regional recovery from labor demand shocks (Gennaioli et al., 2014; Gagliardi et al., 2023). If residents in structurally declining regions face persistent barriers to accessing postsecondary education — and if institutions serving those areas lack the resources to expand training — then market-based reallocation may be insufficient to support long-term adaptation. While place-based investments in physical capital and infrastructure may foster some development, they are unlikely to produce durable recovery without complementary investments in human capital. If financial, geographic, or institutional constraints inhibit training investment, targeted policies may be necessary to facilitate skill acquisition and workforce transitions in response to large-scale employment declines in distressed regions.

References

Acton, Riley K., "Community College Program Choices in the Wake of Local Job Losses," *Journal of Labor Economics*, October 2021, *39* (4), 1129–1154.

_ , Kalena Cortes, and Camila Morales, "Distance to Opportunity: Higher Education Deserts and College Enrollment Choices," *NBER*, October 2024.

_ , _ , Lois Miller, and Camila Morales, "Distance to Degrees: How College Proximity Shapes Students' Enrollment Choices and Attainment Across Race-Ethnicity and Socioeconomic Status," *NBER*, January 2025.

Austin, Benjamin, Edward L. Glaeser, and Lawrence H. Summers, "Jobs for the Heartland: Place-Based Policies in 21st-Century America," *Brookings Papers on Economic Activity*, 2018, *Spring*, 151–255.

Autor, D. H. and M. G. Duggan, "The Rise in the Disability Rolls and the Decline in Unemployment," *The Quarterly Journal of Economics*, February 2003, *118* (1), 157–206.

Autor, David H., David Dorn, and Gordon H. Hanson, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, October 2013, *103* (6), 2121–2168.

_ , _ , and _ , "On the Persistence of the China Shock," *Brookings Papers on Economic Activity*, 2021, pp. 381–447.

_ , Lawrence F. Katz, and Melissa S. Kearney, "Trends in U.S. Wage Inequality: Revising the Revisionists," *Review of Economics and Statistics*, May 2008, *90* (2), 300–323.

Baker, Rachel, Eric Bettinger, Brian Jacob, and Ioana Marinescu, "The Effect of Labor Market Information on Community College Students' Major Choice," *Economics of Education Review*, August 2018, *65*, 18–30.

Bartik, Timothy J., *Who benefits from state and local economic development policies?*, Kalamazoo, Mich: W.E. Upjohn Institute for Employment Research, 1991.

_ , "Using Place-Based Jobs Policies to Help Distressed Communities," *Journal of Economic Perspectives*, August 2020, *34* (3), 99–127.

BEA, "Local Area Personal Income and Employment: Concepts and Methods," Technical Report, U.S. Department of Commerce 2024. https://www.bea.gov/system/files/methodologies/BEA-Local-Area-Personal-Income-and-Employment-Concepts-and-Methods.pdf.

Becker, Gary S., *Human capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, New York: Columbia University Press, 1964.

Bistline, John, Geoffrey Blanford, Maxwell Brown, Dallas Burtraw, Maya Domeshek, Jamil Farbes, Allen Fawcett, Anne Hamilton, Jesse Jenkins, Ryan Jones, Ben King, Hannah Kolus, John Larsen, Amanda Levin, Megan Mahajan, Cara Marcy, Erin Mayfield, James McFarland, Haewon McJeon, Robbie Orvis, Neha Patankar, Kevin Ren-

nert, Christopher Roney, Nicholas Roy, Greg Schivley, Daniel Steinberg, Nadejda Victor, Shelley Wenzel, John Weyant, Ryan Wiser, Mei Yuan, and Alicia Zhao, "Emissions and Energy Impacts of the Inflation Reduction Act," *Science*, June 2023, *380* (6652), 1324–1327. Publisher: American Association for the Advancement of Science.

_ , Neil Mehrotra, and Catherine Wolfram, "Economic Implications of the Climate Provisions of the Inflation Reduction A," *NBER*, 2023.

Black, D. and Seth Sanders, "Inequality and Human Capital in Appalachia: 1960-2000," in "Appalachian Legacy: Economic Opportunity after the War on Poverty," Washington: Brookings Institution Press, 2012, pp. 45–80. James P. Ziliak (editor).

Black, Dan A., Kermit Daniel, and Seth G. Sanders, "The Impact of Economic Conditions on Participation in Disability Programs: Evidence from the Coal Boom and Bust," *American Economic Review*, February 2002, *92* (1), 27–50.

_ , Terra G. McKinnish, and Seth G. Sanders, "Does the availability of high-wage jobs for low-skilled men affect welfare expenditures? Evidence from shocks to the steel and coal industries," *Journal of Public Economics*, September 2003, *87* (9-10), 1921–1942.

_ , _ , and _ , "The Economic Impact of the Coal Boom and Bust," *The Economic Journal*, 2005, *115* (503), 449–476. Publisher: [Royal Economic Society, Wiley].

_ , _ , and _ , "Tight Labor Markets and the Demand for Education: Evidence from the Coal Boom and Bust," *ILR Review*, October 2005, *59* (1), 3–16. Publisher: SAGE Publications Inc.

Blanchard, Olivier Jean and Lawrence F. Katz, "Regional Evolutions," *Brookings Papers on Economic Activity*, 1992, pp. 1–75.

Blonz, Joshua, Brigitte Roth Tran, and Erin Troland, "The Canary in the Coal Decline: Appalachian Household Finance and the Transition from Fossil Fuels," *NBER*, 2023.

Bollinger, Christopher, James P. Ziliak, and Kenneth R. Troske, "Down from the Mountain: Skill Upgrading and Wages in Appalachia," *Journal of Labor Economics*, October 2011, *29* (4), 819–857.

Borusyak, Kirill, Peter Hull, and Xavier Jaravel, "Quasi-Experimental Shift-Share Research Designs," *The Review of Economic Studies*, January 2022, *89* (1), 181–213.

Bound, John and Harry J Holzer, "Demand Shifts, Population Adjustments, and Labor Market Outcomes during the 1980s," *Journal of Labor Economics*, 2000, *18* (1), 20–54.

_ and Sarah Turner, "Cohort crowding: How resources affect collegiate attainment," *Journal of Public Economics*, June 2007, *91* (5), 877–899.

Carley, Sanya and Michelle Graff, "A just U.S. energy transition," in David M. Konisky, ed., *Handbook of U.S. Environmental Policy*, Edward Elgar Publishing, April 2020.

Charles, Kerwin Kofi, Erik Hurst, and Mariel Schwartz, "The Transformation of Manufacturing and the Decline in US Employment," *NBER Macroeconomics Annual*, 2019, *33*, 307–372.

_ , _ , and Matthew J. Notowidigdo, "Housing Booms and Busts, Labor Market Opportunities, and College Attendance," *American Economic Review*, October 2018, *108* (10), 2947–2994.

_ , Yiming Li, and Melvin Stephens, "Disability Benefit Take-Up and Local Labor Market Conditions," *The Review of Economics and Statistics*, July 2018, *100* (3), 416–423.

Chetty, Raj and Adam Looney, "Consumption smoothing and the welfare consequences of social insurance in developing economies," *Journal of Public Economics*, December 2006, *90* (12), 2351–2356.

_ and Nathaniel Hendren, "The Impacts of Neighborhoods on Intergenerational Mobility II: County-Level Estimates," *The Quarterly Journal of Economics*, August 2018, *133* (3), 1163–1228.

Clarke, Leon, Mark Curtis, Ann Eisenberg, Emily Grubert, Julia Hobson Haggerty, Alexander James, Nathan Jensen, Noah Kaufman, Eleanor Krause, Daniel Raimi, Dustin Tingley, and Jeremy Weber, "A research agenda for economic resilience in fossil fuel–dependent communities," *Environmental Research: Energy*, August 2024.

Coglianese, John, Todd D. Gerarden, and James H. Stock, "The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008-2016," *The Energy Journal*, January 2020, *41* (1).

Colmer, Jonathan, Eleanor Krause, Eva Lyubich, and John Voorheis, "Transitional Costs and the Decline of Coal: Worker-Level Evidence," *Working Paper*, 2024.

Dynarski, Susan, Aizat Nurshatayeva, Lindsay C Page, and Judith Scott-Clayton, "Addressing Non-Financial Barriers to College Access and Success: Evidence and Policy Implications," *NBER*, 2023.

Eckert, Fabian, Teresa Fort, Peter Schott, and Natalie Yang, "Imputing Missing Values in the US Census Bureau's County Business Patterns," Technical Report w26632, National Bureau of Economic Research, Cambridge, MA January 2020.

EIA, U.S. Energy Information Administration, "U.S. coal production employment has fallen 42% since 2011," 2019. https://www.eia.gov/todayinenergy/detail.php?id=42275.

_ , "Coal Explained," 2023. www.eia.gov/energyexplained/coal/use-of-coal.php.

_ , "Monthly Energy Review," Technical Report, Washington, DC November 2023. www.eia.gov/mer.

Eissa, Nada and Jeffrey B. Liebman, "Labor Supply Response to the Earned Income Tax Credit," *The Quarterly Journal of Economics*, 1996, *111* (2), 605–637. Publisher: Oxford University Press.

Eller, Ronald D., *Uneven Ground: Appalachia Since 1945*, Lexington: University of Kentucky Press, 2008.

Finkelstein, Amy, Nathaniel Hendren, and Erzo F P Luttmer, "The Value of Medicaid: Interpreting Results from the Oregon Health Insurance Experiment," *Journal of Political Economy*, 2019, *127* (6), 2836–2874.

Foote, Andrew and Michel Grosz, "The Effect of Local Labor Market Downturns on Postsecondary Enrollment and Program Choice," *Education Finance and Policy*, October 2020, *15* (4), 593–622.

Gagliardi, Luisa, Enrico Moretti, and Michel Serafinelli, "The World's Rust Belts: The Heterogeneous Effects of Deindustrialization on 1,993 Cities in Six Countries," *Working Paper*, 2023.

Gennaioli, Nicola, Rafael La Porta, Florencio Lopez De Silanes, and Andrei Shleifer, "Growth in regions," *Journal of Economic Growth*, 2014, *19* (3), 259–309. Publisher: Springer.

Glaeser, Edward L., "Reinventing Boston: 1630–2003," *Journal of Economic Geography*, 2005, *5* (2), 119–153. Publisher: Oxford University Press.

— **and Joshua D. Gottlieb**, "The Economics of Place-Making Policies," *Brookings Papers on Economic Activity*, 2008, *Spring*, 155–253.

Glaeser, Edward L, José A. Scheinkman, and Andrei Shleifer, "Economic growth in a cross-section of cities," *Journal of Monetary Economics*, 1995, *36*, 117–143.

Goldin, Claudia and Lawrence F. Katz, "The Race between Education and Technology," in "The Race between Education and Technology," Harvard University Press, 2008, pp. 287–323.

Goldsmith-Pinkham, Paul, Isaac Sorkin, and Henry Swift, "Bartik Instruments: What, When, Why, and How," *American Economic Review*, August 2020, *110* (8), 2586–2624.

Grosz, Michel, "Do Postsecondary Training Programs Respond to Changes in the Labor Market?," *Bureau of Economics, Federal Trade Commission*, 2019, *Working Paper no. 343.*

Gruber, Jonathan, "The Consumption Smoothing Benefits of Unemployment Insurance," *The American Economic Review*, 1997, *87* (1), 192–205.

Hanson, Gordon H., "Local Labor Market Impacts of the Energy Transition: Prospects and Policies," in "Economic Policy in a More Uncertain World," Washington, DC: The Aspen Institute, 2022, pp. 155–199.

Harrington, Michael, *The Other America: Poverty in the United States*, New York: Macmillan, 1962.

Hendren, Nathaniel and Ben Sprung-Keyser, "A Unified Welfare Analysis of Government Policies*," *The Quarterly Journal of Economics*, August 2020, *135* (3), 1209–1318.

Hillman, Nicholas and Taylor Weichman, "Education Deserts: The Continued Significance of "Place" in the Twenty-First Century," Technical Report, American Council on Education, Washington, D.C. 2016.

Islam, T. M. Tonmoy, Jenny Minier, and James P. Ziliak, "On Persistent Poverty in a Rich Country," *Southern Economic Journal*, 2015, *81* (3), 653–678.

Jacobson, Louis, Robert LaLonde, and Daniel G. Sullivan, "Estimating the returns to community college schooling for displaced workers," *Journal of Econometrics*, March 2005, *125* (1-2), 271–304.

Jaworski, Taylor and Carl T. Kitchens, "National Policy for Regional Development: Historical Evidence from Appalachian Highways," *The Review of Economics and Statistics*, December 2019, *101* (5), 777–790.

Jepsen, Christopher, Kenneth Troske, and Paul Coomes, "The Labor-Market Returns to Community College Degrees, Diplomas, and Certificates," *Journal of Labor Economics*, January 2014, *32* (1), 95–121.

Jordà, Oscar, "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, February 2005, *95* (1), 161–182.

_ , "Local Projections for Applied Economics," *Federal Reserve Bank of San Francisco, Working Paper Series*, July 2023, *2023* (16), 01–35.

Juhn, Chinhui, Kevin M. Murphy, and Brooks Pierce, "Wage Inequality and the Rise in Returns to Skill," *Journal of Political Economy*, 1993, *101* (3), 410–442. Publisher: University of Chicago Press.

Just Transition Fund, "National Economic Transition Platform," Technical Report 2020. http://nationaleconomictransition.org/platform/.

Katz, Lawrence F. and Kevin M. Murphy, "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *The Quarterly Journal of Economics*, 1992, *107* (1), 35–78. Publisher: Oxford University Press.

_ , Jonathan Roth, Richard Hendra, and Kelsey Schaberg, "Why Do Sectoral Employment Programs Work? Lessons from WorkAdvance," *Journal of Labor Economics*, April 2022, *40* (S1), S249–S291. Publisher: The University of Chicago Press.

Kline, Patrick and Enrico Moretti, "Local Economic Development, Agglomeration Economies, and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority," *The Quarterly Journal of Economics*, February 2014, *129* (1), 275–331.

Kolstad, Charles D., "What Is Killing the US Coal Industry?," Technical Report, Stanford Institute for Economic Policy Research 2017.

Krause, Eleanor, "Job loss, selective migration, and the accumulation of disadvantage: Evidence from Appalachia's coal country." Working Paper, Harvard University, Cambridge, MA 2024.

Lachowska, Marta, Alexandre Mas, and Stephen A. Woodbury, "Sources of Displaced Workers' Long-Term Earnings Losses," *American Economic Review*, October 2020, *110* (10), 3231–3266.

Linn, Joshua and Kristen McCormack, "The roles of energy markets and environmental regulation in reducing coal-fired plant profits and electricity sector emissions," *The RAND Journal of Economics*, 2019, *50* (4), 733–767.

Minaya, Veronica and Judith Scott-Clayton, "Labor Market Trajectories for Community College Graduates: How Returns to Certificates and Associate's Degrees Evolve Over Time," *Education Finance and Policy*, January 2022, *17* (1), 53–80.

Mincer, Jacob, "Investment in Human Capital and Personal Income Distribution," *Journal of Political Economy*, 1958, *66* (4), 281–302. Publisher: University of Chicago Press.

Moretti, Enrico, "Estimating the social return to higher education: evidence from longitudinal and repeated cross-sectional data," *Journal of Econometrics*, July 2004, *121* (1-2), 175–212.

_ , "Real Wage Inequality," *American Economic Journal: Applied Economics*, January 2013, *5* (1), 65–103.

Morris, Adele C, Noah Kaufman, and Siddhi Doshi, "The risk of fiscal collapse in coal-reliant communities," *Columbia University SIPA and The Brookings Institution*, 2019, pp. 1–56.

Notowidigdo, Matthew J, "The Incidence of Local Labor Demand Shocks," *Journal of Labor Economics*, 2020, *38* (3), 687–725.

Raimi, Daniel, Sanya Carley, and David Konisky, "Mapping county-level vulnerability to the energy transition in US fossil fuel communities," *Scientific Reports*, September 2022, *12* (1), 15748.

Reber, Sarah and Ember Smith, "College Enrollment Disparities," Technical Report, The Brookings Institution, Washington, D.C. 2023.

Roemer, Kelli F. and Julia H. Haggerty, "Coal communities and the U.S. energy transition: A policy corridors assessment," *Energy Policy*, April 2021, *151*, 112112.

Rouse, Cecilia Elena, "Democratization or Diversion? The Effect of Community Colleges on Educational Attainment," *Journal of Business & Economic Statistics*, 1995, *13* (2), 217–224. Publisher: [American Statistical Association, Taylor & Francis, Ltd.].

Schmieder, Johannes F. and Till Von Wachter, "The Effects of Unemployment Insurance Benefits: New Evidence and Interpretation," *Annual Review of Economics*, October 2016, *8* (1), 547–581.

Shelton, Rebecca, Wesley Look, Joey James, Evan Fedorko, Sophie Pesek, Dan Mazzone, and Aurora Barone, "Investment in Coal Communities through the Partnerships for Opportunity and Workforce and Economic Revitalization (POWER) Initiative," *Resources for the Future*, 2022, *22* (7).

Topel, Robert H., "Local Labor Markets," *Journal of Political Economy*, 1986, *94* (3), S111–S143.

Watson, Brett, Ian Lange, and Joshua Linn, "Coal demand, market forces, and U.S. coal mine closures," *Economic Inquiry*, 2023, *61* (1), 35–57. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ecin.13108.

Weber, Jeremy G, "How Should We Think about Environmental Policy and Jobs? An Analogy with Trade Policy and an Illustration from U.S. Coal Mining," *Review of Environmental Economics and Policy*, January 2020, *14* (1), 44–66.

Wozniak, Abigail, "Are College Graduates More Responsive to Distant Labor Market Opportunities?," *The Journal of Human Resources*, 2010, *45* (4), 944–970.

Yagan, Danny, "Employment Hysteresis from the Great Recession," *Journal of Political Economy*, 2019, *127* (5), 2505–2558.

Ziliak, James Patrick, *Appalachian Legacy: Economic Opportunity after the War on Poverty*, Washington, D.C.: Brookings Institution Press, 2012.

A Appendix Tables and Figures

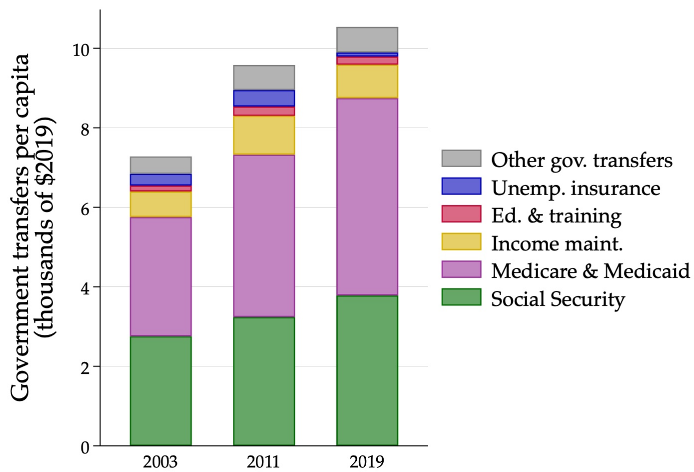
Table A1: First-stage estimates for instrumented coal employment shock

	(1)	(2)	(3)
	Change in coal share of employment		
$\widehat{\Delta Coal}_{j,2011\text{-}16}$	1.12***	1.12***	1.20***
	(0.12)	(0.12)	(0.14)
Region FE	-	✓	✓
CZ covariates	-	-	✓
R-squared	0.91	0.91	0.93
F-stat on $\widehat{\Delta Coal}_{j,2011\text{-}16}$	89.48	86.96	68.67
Observations	104	104	104

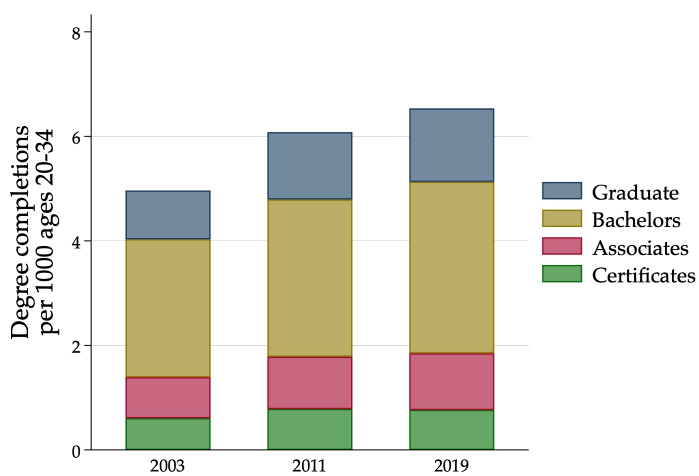
Regressions are weighted by 2011 CZ population. The outcome variable is the CZ-level change in the coal share of total employment over the 2011–2016 period. The variable $\widehat{\Delta Coal}_{j,2011\text{-}16}$ is the predicted change in the coal share of employment, based on a single-industry shift-share instrument. Columns 2 and 3 include Census region fixed effects. Column 3 additionally controls for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.
*** p<0.01, ** p<0.05, * p<0.1

Figure A1: Coal employment, transfers, and training in Appalachian CZs, 2003–2019

(a) Government transfers

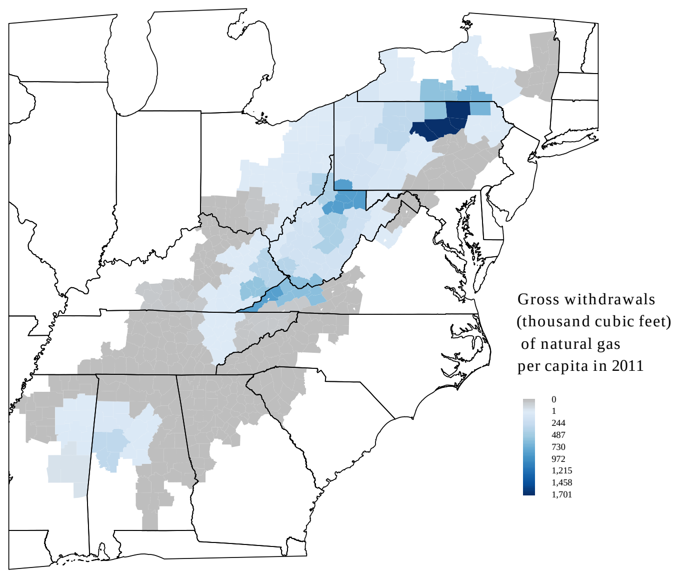


(b) Degree completions



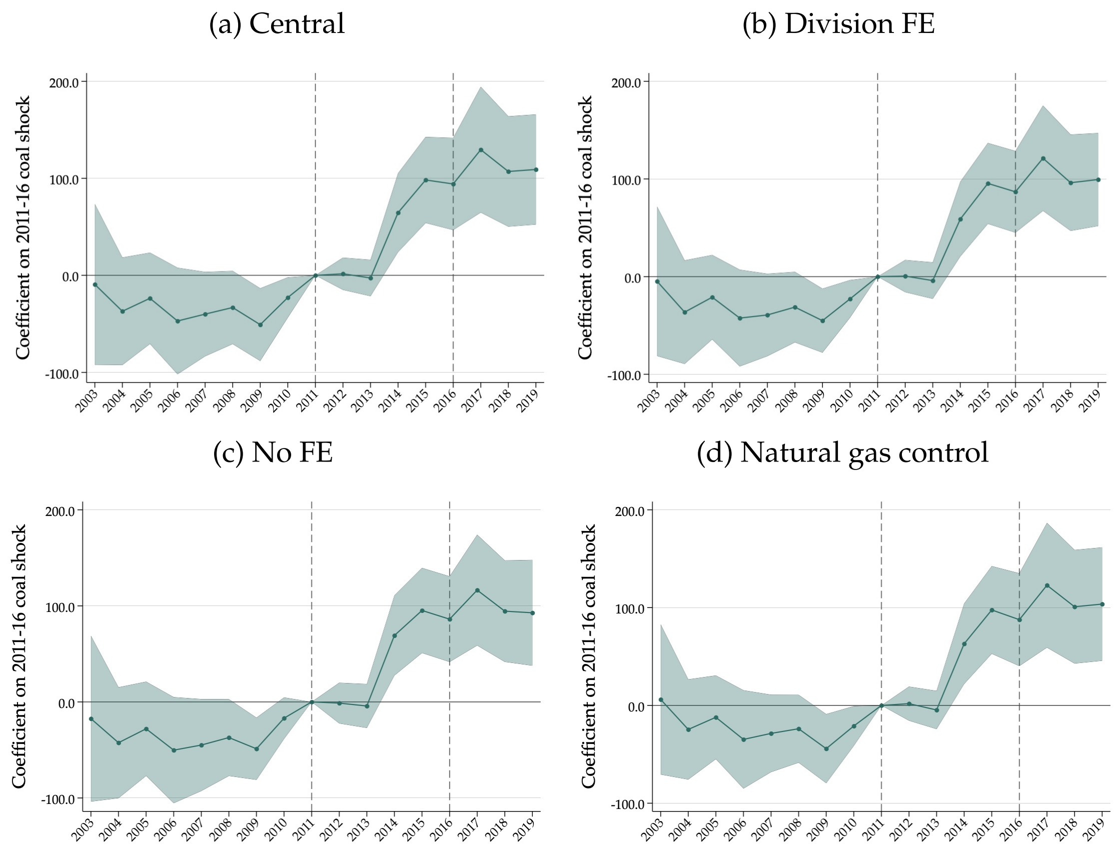
Notes: Upper panel presents total government transfers per capita (in thousands of 2019 dollars) in each of the categories specified for Appalachian CZs with any coal mining employment in 2011. Bottom panel presents degree completions per 1,000 residents ages 20–34 in each of the categories specified for the same group of Appalachian CZs. Data on government transfers were retrieved from the BEA. Data on completions were retrieved from the National Center for Education Statistics (NCES)'s Integrated Postsecondary Education Data System (IPEDS). Graduate includes master's and doctoral degrees.

Figure A2: Natural gas production per capita, in 2011



Notes: Figure presents gross withdrawals of natural gas (in thousands of cubic feet) as a share of CZ population in 2011. Natural gas production was retrieved from the USDA's Economic Research Service (ERS).

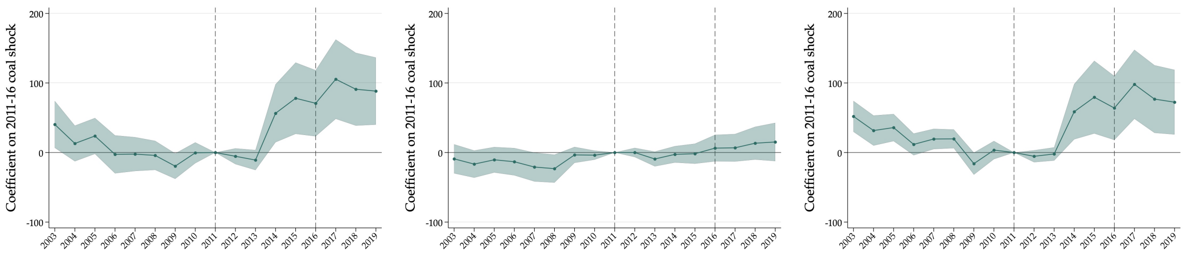
Figure A3: Effect of the 2011–2016 coal shock on government transfers: Robustness



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in government transfers per capita between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population. Panel a reflects the main specification, which controls for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period. In panel b, division fixed effects replace region fixed effects. Panel c includes no regional controls. Panel d replicates the main specification with an additional control for CZ natural gas withdrawals as a share of CZ population in 2011.

Figure A4: Effect of the 2011–2016 coal shock on Medicaid and Medicare transfers ($'s) per capita

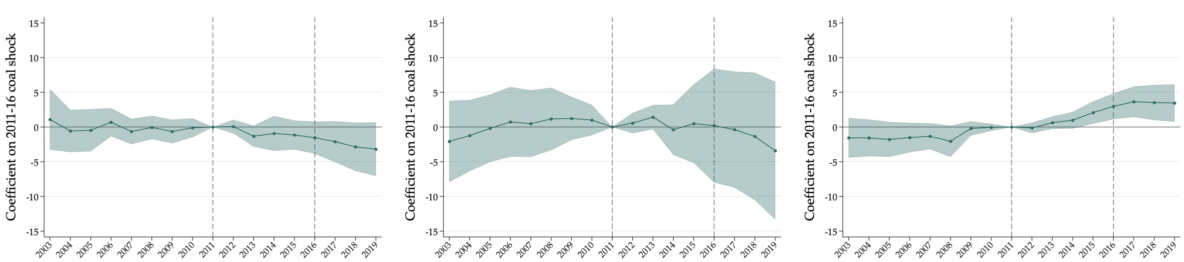
(a) Medical (b) Medicare transfers/capita (c) Medicaid transfers/capita



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in government transfers per capita for the program type indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

Figure A5: Effect of the 2011–2016 coal shock on income maintenance programs

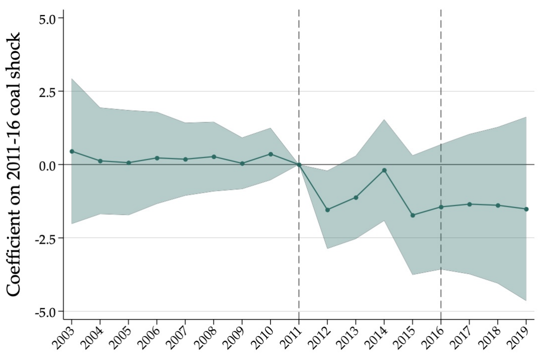
(a) SSI transfers/capita (b) SNAP transfers/capita (c) EITC transfers/capita



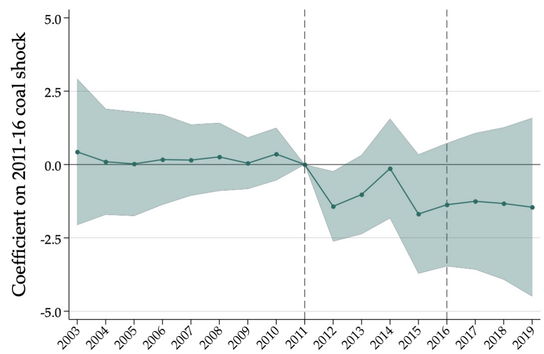
Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in government transfers per capita for the program type indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

Figure A6: Effect of the 2011–2016 coal shock on postsecondary degree completions: Robustness

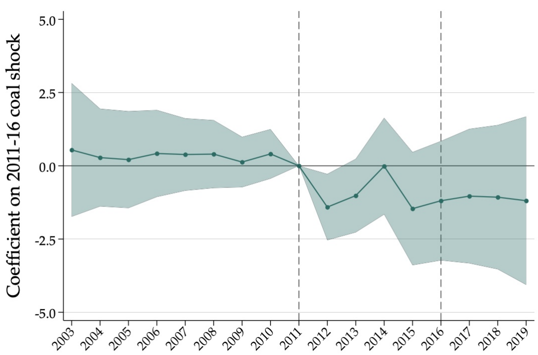
(a) Central



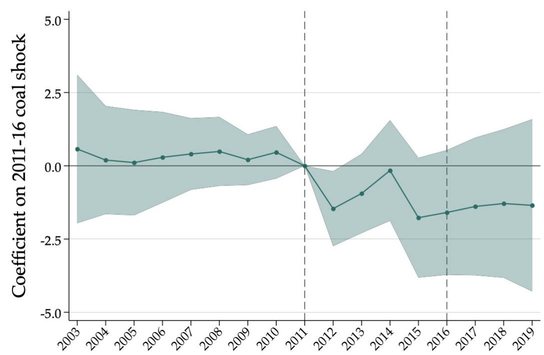
(b) Division FE



(c) No FE

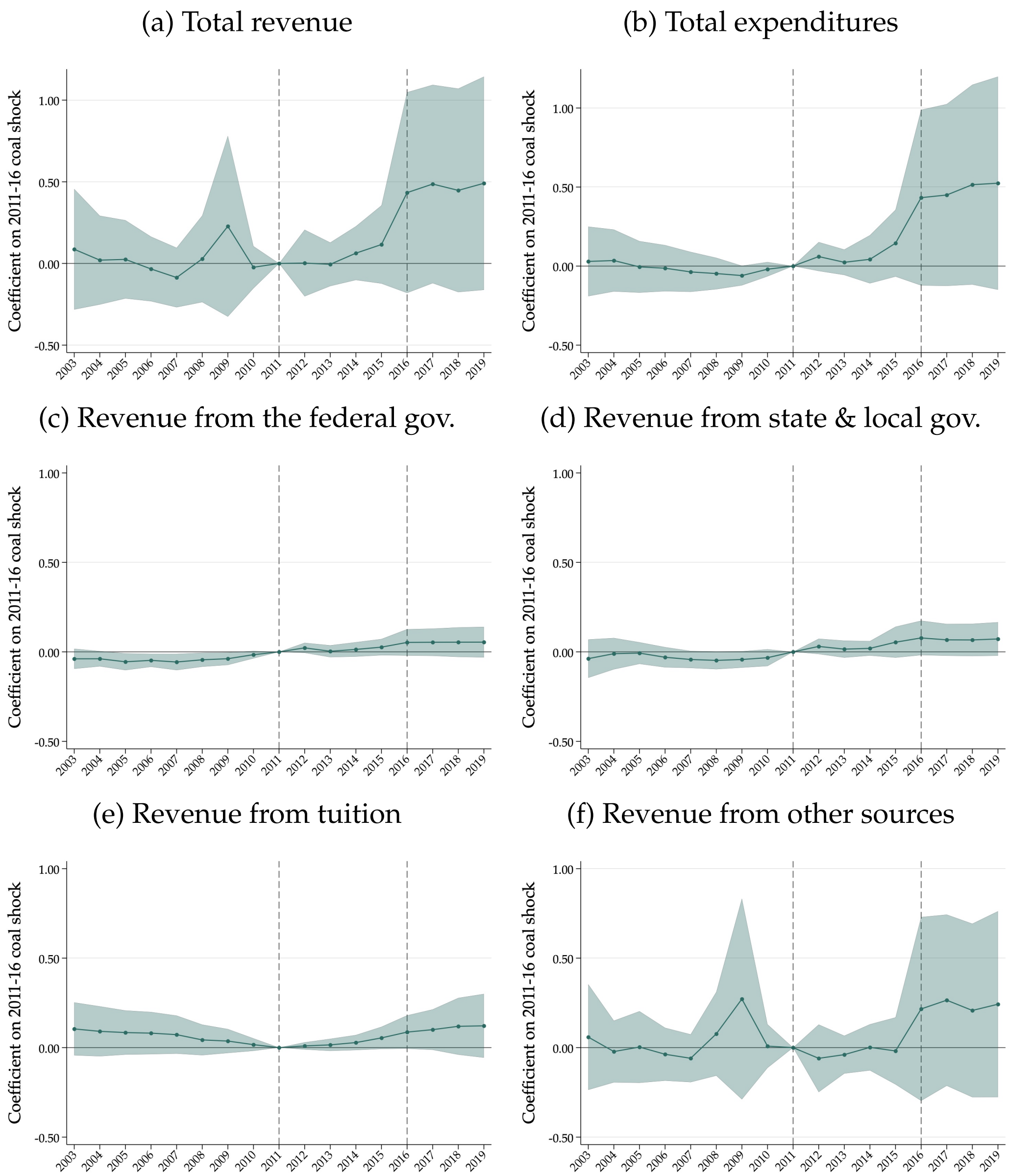


(d) Natural gas control



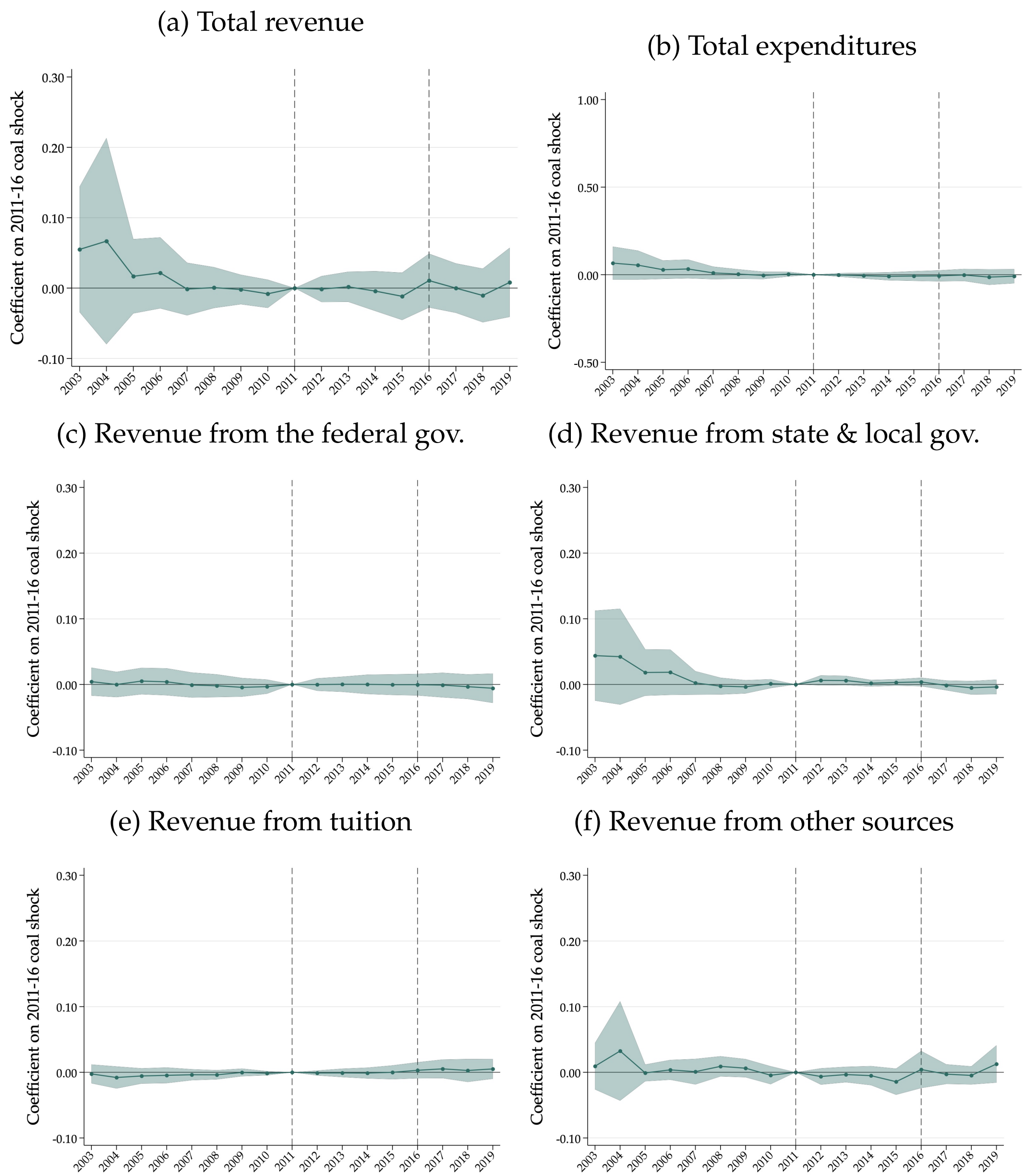
Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in degree completions per 1,000 people ages 20–34 (all award types) between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population. Panel a reflects the main specification, which controls for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period. In panel b, division fixed effects replace region fixed effects. Panel c includes no regional fixed effects. Panel d replicates the main specification with an additional control for CZ natural gas withdrawals as a share of CZ population in 2011.

Figure A7: Effect of the 2011–2016 coal shock on institutional finances ($1,000s) per person ages 20–34



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in institutional finances of the type indicated (in $1,000s) per person ages 20–34 between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011–2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the CZ-level variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

Figure A8: Effect of the 2011–2016 coal shock on 2-year institutions' finances ($1,000s) per person ages 20–34



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in 2-year institutions' finances of the type indicated (in $1,000s) per person ages 20–34 between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011–2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the CZ-level variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

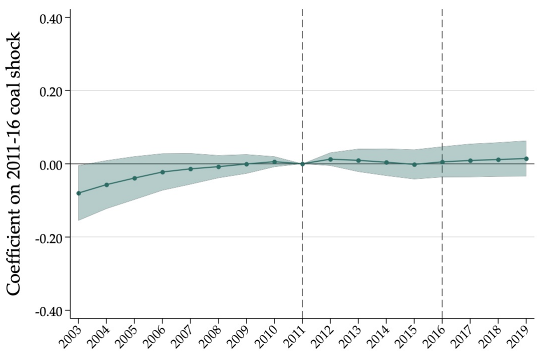
B Transfer response by age group

The central specification examining the effect of the 2011–2016 coal shock on government transfers normalizes the outcome variable by the total population. While the government transfers, broadly defined, flow to all age groups, specific programs are explicitly targeted to certain age or income groups. Medicare and certain components of Social Security (old age) are targeted to older members of the population, while unemployment insurance is available to working-age individuals and thus is unavailable to children. Other research documents that population migration is highly selective, such that shocks may shift the underlying composition of the population (Topel, 1986; Bound and Holzer, 2000; Wozniak, 2010; Autor et al., 2021; Hanson, 2022). I examine how the 2011–2016 coal shock influences the age distribution of the population in Figure B9, which shows the coefficient estimates of β_1 in equation 1, where the dependent variable is defined as the change in the share of the CZ population in a given age group between 2011 and the year indicated on the horizontal axis.

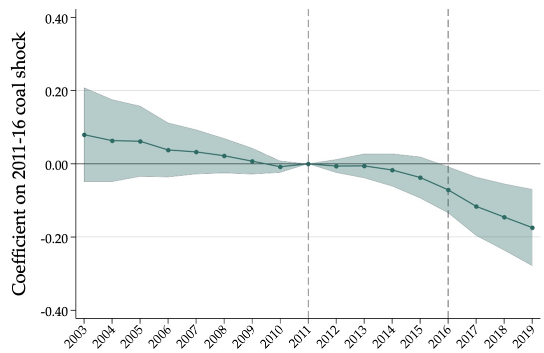
The point estimates in Figure B9 indicate very small shifts in the age composition resulting from the coal shock. The shock has a relatively precisely estimated null effect on the share of the population under 20 years old (panel a). It produces a relatively small decline in the working-age adult share of the population (ages 20–64) and a modest increase in the share of the population that is 65 and older, but these effects are not statistically distinguishable until later in the outcome period. Social Security and Medicare, the two largest programs targeted at seniors, exhibited negligible responsiveness to the coal shock even before accounting for shifts in the eligible beneficiary share. Thus, it is unlikely that accounting for a shifting age distribution would fundamentally alter the conclusions reported in the main text. At the same time, other transfer programs, like those related to education and training, are primarily targeted to young adults, while UI typically flows to working-age adults. Some programs like Medicaid have no specific age eligibility, but

Figure B9: Effect of the 2011–2016 coal shock on the age distribution of the population

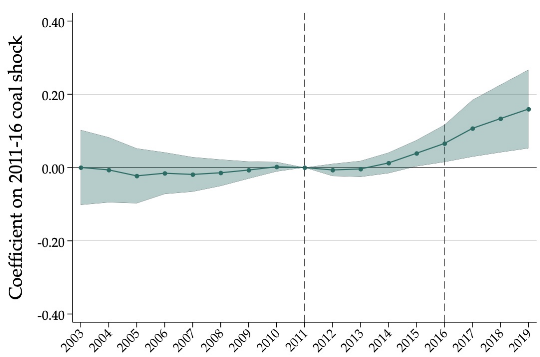
(a) Share of the population ages 0–19



(b) Share of the population ages 20–64



(c) Share of the population ages 65 and older



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in the share of the population in the age group indicated between 2011 and the year on the horizontal axis. The coal shock is defined as the 2011-2016 change in coal mining employment as a share of CZ employment in 2011, and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

certain age groups receive a disproportionately large share of total payments.

To account for underlying shifts in the age distribution, I re-estimate equation 1 as before, but I age-adjust the outcome variable (the change in government transfers per capita) to reflect the primary age group targeted by the program. For some programs, defining the targeted age group is relatively straightforward. For example, for Medicare, I define the outcome variable as the change in total Medicare payments per person ages 65 and older. Many programs do not have specific age eligibility thresholds but generally target working-age adults, which I define as the population ages 20 to 64 (e.g., unemployment insurance and various income maintenance programs). Other program types (Social Security and Medicaid) are relatively less straightforward, as benefits flow to all age groups. The BEA regional economic accounts do not distinguish between Social Security transfers for old-age, survivors, and disability. About three-quarters of Social Security beneficiaries receive old-age (retirement) benefits, which target the elderly population. While disabled worker benefits flow to individuals of all working ages (i.e., under 66), about 75 percent of beneficiaries are over age 50. A small fraction of children and younger working-age individuals receive Social Security benefits as dependents or survivors (e.g., widowers and children).[34] Given that old-age and disability are the largest categories of beneficiaries, and that these individuals are broadly of retirement age or older working-age adults, I adjust Social Security benefits to the population ages 45 and older. Medicaid benefits similarly flow to all age groups, although certain age groups compose a disproportionate number of enrollees. Thus, I index Medicaid transfers according to the national age distribution of enrollees, as reported by the Kaiser Family Foundation (KFF).[35] This places greater weight on younger than older age groups, as the former make up a larger share

[34]The age distribution of Social Security beneficiaries for every program type are available at "Social Security Beneficiary Statistics" from the Social Security Administration's website, available here here.

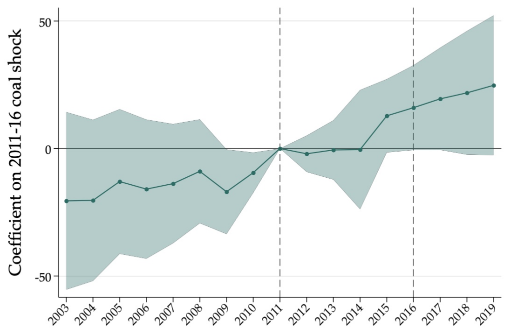
[35]See "Medicaid Enrollment by Age" by KFF, available here. KFF reports the following age distribution of Medicaid enrollees in 2019: 0-18 (40%), 19-26 (12%), 27-44 (22%), 45-64 (17%), 65 and older (10%). As I only have annual, county-level population estimates for larger bins of age groups, I age-adjust the population for Medicaid transfers according to the following: 0-19 (39%), 20-44 (34%), 45-64 (17%), 65 and older (10%).

of Medicaid enrollees.

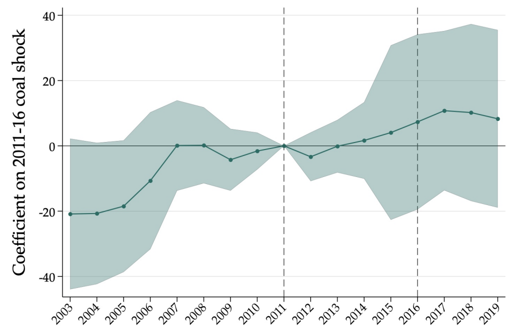
Figure B10 reports these results. The direction of the coefficient estimates can be compared to that in Figure 5 (Social Security, income maintenance, unemployment insurance, and education and training) and A4 (Medicaid and Medicare). However, the magnitude of the coefficient estimates is not comparable across figures or program types, as they are indexed to different age groups that differ in size. For this reason, the y-axis scales differ across figures and program types. I omit total government transfers and medical transfers in Figure B10, as these broad categories are not targeted to a specific age group. In general, the conclusions drawn from Figures B10 and 5 are largely consistent, though the point estimates are more statistically imprecise when transfers are normalized by age group. This increased imprecision may stem from the population estimates by age category produced by the Census, which are themselves subject to some error. Nonetheless, the evidence suggests that adjusting for age composition does not significantly change the key findings from the primary analysis.

Figure B10: Effect of the 2011–2016 coal shock on government transfers ($'s) per person in specified age group

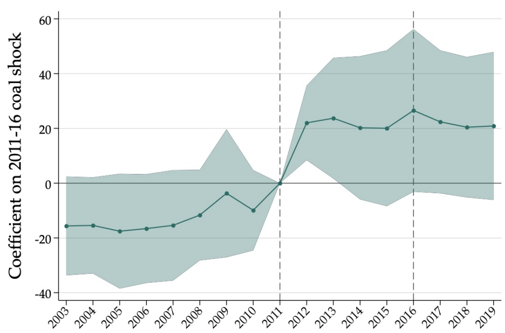
(a) Social security/ages 45+



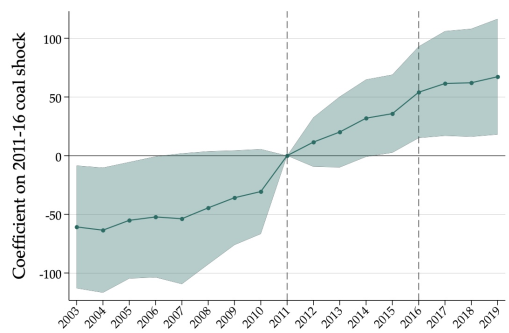
(b) Income maintenance/ages 20–64



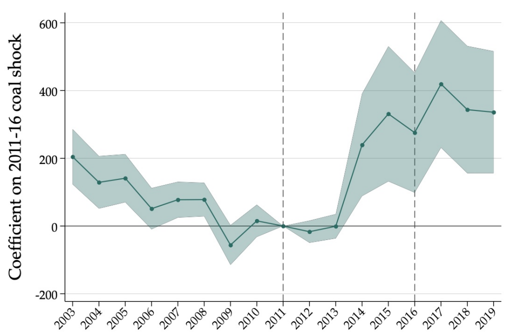
(c) Unemployment insurance/ages 20–64



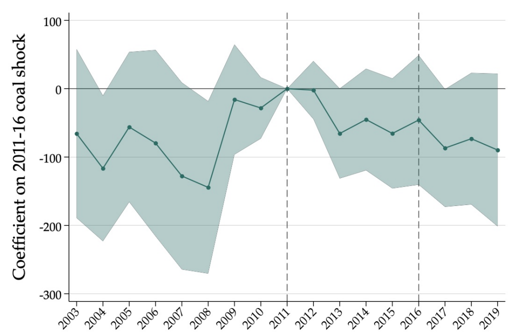
(d) Education and training/ages 20–34



(e) Medicaid/weighted age groups



(f) Medicare/ages 65+



Notes: Figure reflects the IV coefficient estimates of β_1 in equation 1 and 95 percent confidence intervals for 16 separate regressions for each time difference between 2003–2011 and 2011–2019. The dependent variable is the change in government transfers per person in the age group specified for the program type indicated between 2011 and the year on the horizontal axis. Medicaid transfers per person are weighted according to the following: 0-19 (39%), 20-44 (34%), 45-64 (17%), 65 and older (10%). The coal shock is defined as the 2011-2016 change in coal mining employment as a share of county employment in 2011 and is instrumented with the variable defined in equation 2. All regressions are weighted by the 2011 population and control for the 2011 college-educated share of adults, foreign-born share, female share of employment, manufacturing share of employment, exposure to the Great Recession defined in equation 3, population share under 20, 20–34, and 65 and older, Census region fixed effects, and dummy variables indicating whether the CZ had any coal employment in 2011 and whether the CZ hosted a postsecondary institution throughout the 2003–2019 period.

C Data Appendix

C.1 Government transfer definitions

County-level government transfers are retrieved from the BEA's Regional Economic Accounts (CAINC35 Personal current transfer receipts). The definitions of the specific categories of transfer receipt are detailed below. Many of these definitions are copied verbatim from the BEA website.

- **Total government transfers** consist of retirement and disability insurance benefits, medical benefits, income maintenance benefits, unemployment insurance compensation, veterans' benefits, education and training assistance, and other transfer receipts of individuals from governments.
- **Medical** transfers include Medicare benefits, public assistance medical care, and military medical insurance benefits. I consider two of these categories independently:
  - **Medicare** transfers are federal government payments made through intermediaries to beneficiaries for the care provided to individuals under the provisions of the Medicare program.
  - **Medicaid** transfers – i.e., Public assistance medical care benefits – consists of Medicaid and other medical vendor payments.
- **Social Security** transfers (old-age, survivors, and disability insurance benefits) are primarily monthly benefits received by retired and disabled workers, dependents, and survivors and lump-sum payments received by survivors.
- **Income maintenance** benefits include Supplemental Security Income (SSI) benefits, Earned Income Tax Credit (EITC), Additional Child Tax Credit, Supplemental Nutrition Assistance Program (SNAP) benefits, family assistance, and other income

maintenance benefits, including general assistance. I consider several of these categories specifically:

  - **SNAP** payments are issued to qualifying low-income individuals in order to supplement their ability to purchase food. BEA's state estimates are based on tabulations from the Department of Agriculture and are allocated to counties based on payment data from the various state departments of social services. When payment data are not available, data on the number of SNAP recipients from the Census Bureau's Small Area Income and Poverty Estimates program are used to extrapolate or interpolate.
  - **SSI** benefits are received by low-income persons who are aged, blind, or disabled from both the federal government and state governments. BEA's state estimates are based on Social Security Administration (SSA) tabulations of annual disbursements, and county estimates are based on payment data from the SSA.
  - **EITC** benefits are federal income tax credits for low-income workers, mainly those who have minor children.

- **Unemployment insurance (UI)** benefits include state unemployment compensation, unemployment compensation of Federal civilian employees, unemployment compensation of railroad employees, unemployment compensation of veterans, and trade adjustment assistance (TAA) payments.
- **Education and training** assistance includes federal fellowships (e.g., National Science Foundation grants), higher education student assistance (Pell Grants), Job Corps payments, interest payments on guaranteed student loans, and state educational assistance, which consist of educational assistance provided by states to individuals for tuition and other educational expenses not including loans.

C.2 CIP-SOC crosswalk

Table C2: CIP code to SOC code mapping for mining-related occupations

CIP code	CIP Title	SOC code	SOC Title
14.0802	Geotechnical and Geoenvironmental Engineering	17-2151	Mining and Geological Engineers, Including Mining Safety Engineers
14.1401	Environmental/Environmental Health Engineering	17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors
14.2101	Mining and Mineral Engineering	17-2151	Mining and Geological Engineers, Including Mining Safety Engineers
14.3901	Geological/Geophysical Engineering	17-2151	Mining and Geological Engineers, Including Mining Safety Engineers
15.0901	Mining Technology/Technician	47-5013	Service Unit Operators, Oil, Gas, and Mining
49.0202	Construction/Heavy Equipment/ Earthmoving Equipment Operation	47-5041	Continuous Mining Machine Operators
49.0202	Construction/Heavy Equipment/ Earthmoving Equipment Operation	47-5042	Mine Cutting and Channeling Machine Operators
49.0202	Construction/Heavy Equipment/ Earthmoving Equipment Operation	47-5049	Mining Machine Operators, All Other

This table reports all 2010 CIP codes matched to 2010 SOC codes with “mining” in the title. The CIP SOC crosswalk was created by the Bureau of Labor Statistics and the National Center for Education Statistics.