The Death of King Coal and the Scars of Deindustrialization*

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Abstract

This paper investigates the human cost of industrial decline. We focus on the largest contraction of the coal industry in the UK. Using longitudinal data following two cohorts born in 1958 and 1970, we estimate the lifelong effects of being exposed to pit closures during childhood on health and economic outcomes. Those exposed to the shock as children have worse health throughout life, and this effect transmits over generations. They are also raised in less privileged economic conditions and accumulate less wealth as adults. We also uncover that migration is an imperfect mitigation strategy. The longitudinal data structure allows us to account for different trajectories in the effects across locations and cohorts. We also verify that outcomes are identical in levels before the shock. Results are robust to a battery of robustness checks. These findings highlight that in the absence of any support, industrial decline has long-lasting consequences imperfectly mitigated by access to better opportunities. Few people move, and those who do keep a scar.

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1 Introduction

This paper investigates the human cost of industrial decline. We focus on the demise of the coal industry in the United Kingdom during the second half of the twentieth century. Using longitudinal data, we document the effects of mine closures over generations. In particular, we uncover negative economic, anthropometric, and health outcomes that persist throughout life and are transmitted over generations.

The collapse of the coal industry in Britain is one of the most dramatic episodes of industrial decline of the twentieth century. The Industrial Revolution was fueled by coal. Economic historians have even argued that coal was necessary to spark industrialization (Pomeranz, 2000; Allen, 2009; Wrigley, 2010; Fernihough and O'Rourke, 2021, among others). Coal was still the dominant energy source by the 1950s when it powered more than 90% of Britain's energy consumption (see Figure 1.A), and predominantly sourced domestically (1.B). At the end of the 1950s, the coal mining sector employed more than 700,000 people (see Figure 2). However, that number was halved within a decade, and waves of closures would continue to shape the industry until the end of the century.

The energy transition out of coal was underway, driven in part by the availability of alternative energy sources and concerns about pollution. Today, decades after, the former coalfields still rank among the most deprived areas in Britain (Foden et al., 2014; Rud et al., 2024). Public concern has been large enough to grant the formation of an all-party parliamentary research group working on policies to "level up" these regions (All-Party Parliamentary Group on Coalfield Communities, 2023). In this paper, we provide the first empirical evidence tying this deprivation to the collapse of the industry, with an exploration of the mechanisms explaining the persistence of the effect. In doing so, we bring insights of contemporary relevance to the many countries that are seeking to phase out the production of coal to meet climate targets.

We hypothesize that industrial decline can persistently affect development through its impact on the lifelong health of those who are exposed to it as children. We posit that this effect can carry on to future generations, as adults who grew up in worse health may earn and save less over their life, which may in turn impact the health of their children.

We use the time and location of mine closures to estimate the effect of growing up in times of industrial decline on living standards. We leverage longitudinal data from the UK following all children born during a week in 1958 and 1970. These data allow us to estimate the effect of being exposed to mine closures during childhood on individual outcomes throughout life. Their longitudinal nature permits accounting for fixed effects that capture time-invariant county-specific patterns of individual development as well as cohort-specific shocks shared across counties. Therefore, our identifying assumption is that unobservable factors that may have affected mine closures were either time-varying but shared across counties or varying across counties but time-invariant. In other words, unobserved determinants of health varying over both time and counties do not correlate with closure decisions in the nationalized mining industry. The most intuitive determinants of anthropometric and health trends are arguably shared nationally or time-invariant. For instance, all counties would have benefited from improved medical technology, in particular through the National Health Service and would thus be captured by time fixed effects. Similarly, broad aggregate regional disparities in development, in particular in regional GDP per capita were relatively stable from 1960s to the 1980s (Geary and Stark, 2016).[1] These ex-ante broad regional inequalities would thus be captured by county fixed effects.

Historical evidence supports the assumption that pre-existing socioeconomic trends did not determine mine closures. They were mostly decided based on geological factors that affected profitability and localities affected were not targeted by specific public investment in the aftermath of the shock (see section 2). Empirically, we test the plausibility of the identifying assumption in four main ways. First, we establish independence regarding the treatment in characteristics observed before the shock. In particular, the levels of health outcomes at birth and parental socioeconomic characteristics do not depend on the treatment before it occurs. Second, we propose an instrumental variable for exposure to mine closure based on the age of the pits in the county. Third, we rule out possible alternative explanations, such as the possibility that the effects are explained away by selective attrition and migration. Finally, we confirm that results are not driven by pre-existing development trends specific to the coalfields.

Our estimates show that exposure to mine closures in childhood has significant negative effects throughout life. In particular, height is lower throughout adolescence (up to 6% of a standard deviation) and, despite some catching up, remains significantly lower throughout life. We also observe adverse effects on BMI, with increases towards the extremes (overweight and underweight categories, the latter especially for women). We also uncover negative effects on general health that reflect both physical and mental health. Consistent with the anthropometric literature demonstrating that height is associated with mortality and morbidity at the population level (Steckel, 1995; Deaton, 2007), we find that our treatment positively correlates with the incidence of disease in mid-adulthood, such as diabetes, respiratory issues, and cancer. We see some effects on mortality but they are not precisely estimated.

We explore the mechanisms driving our effects, as well as their persistence. Documenting the role of economic resources, we observe that children exposed to the shock are raised in less privileged conditions, and this economic hardship passes on to the next generation. More specifically, the parents show worse employment conditions after the shock (e.g. unemployment or low-skilled jobs); children are more likely to receive free school meals and less is spent on them by their families; and, the condition of the houses in which they grow up are comparatively worse (e.g. open coal heating and no hot water). Moreover, in adulthood, respondents accumulate less wealth. We also uncover that their own children have birth com-

[1]Regional disparities then drastically increased in the 1990s, even surpassing the levels observed at the start of the 20th century.

plications and are less healthy, further demonstrating the persistence of the effect over three generations (parents, respondents, and respondents' children).

Our dataset allows us to track migrants. Although policymakers at the time were betting on families moving to better opportunities, we document that this mitigation strategy did not materialize in general and was not effective. Mine closures generally decreased the probability of moving later in life; those who move are selected on socioeconomic background; and migration does not have a strong compensating effect on the main outcomes.

Notably, not all effects documented are negative. We observe that males exposed to the shock are more educated later in life, shedding new light on the scholarship highlighting that booms in manufacturing and mining industries increase men's opportunity cost of education (Black et al., 2005b; Esposito and Abramson, 2021; Franck and Galor, 2021). Our findings suggest that this increased education may compensate for some of the loss in economic opportunities, but it is insufficient to compensate in terms of wealth. In contrast, women experience no gains in education, as well as income and wealth losses.[2]

Related Literature — A growing body of research documents the effects of exposure to industrial decline on labor market outcomes, often using detailed modern administrative records combined with rising import competition (for a review see Autor et al., 2016). This scholarship has estimated impacts on workers' health, such as on mortality (Case and Deaton, 2020; Pierce and Schott, 2020), disability benefits (Autor et al., 2014), or health outcomes (Adda and Fawaz, 2020). A related body of reseach studies the impact of regional and individual employment shocks on infant health (Lindo, 2011; Wüst, 2015; Mörk et al., 2020; Celini et al., 2022; Charris et al., 2024). We contribute to this literature by taking a historical perspective, using data that span throughout people's lives and over multiple generations, and that also follow migrants.[3] In doing so, we provide evidence of the persistence of the effect throughout life and across generations and space. To the best of our knowledge, we are the first to document this fact, which speakes to contemporary policy debates on the long-term social costs of industrial decline.

The focus on the coal industry relates our findings to the extensive research on the effect of natural resources on economic development. A growing consensus has emerged from it that natural resources may boost or harm development depending on initial conditions. In countries with stronger and more inclusive institutions, an abundance of natural resources tends to be a blessing for economic development. In contrast, in those with weaker institutions, more corruption, and worse property rights, resource abundance can become a "curse" trapping countries into inequality, conflict, and political instability (for an extensive review of the literature on the resource curse, see van der Ploeg, 2011; on institutions and the resource

[2]Aragón et al. (2018) suggest that industrial decline leads to women losing their job to men.

[3]Our data cover fewer individuals than modern administrative records. However, the data's strength is their longitudinal coverage (from birth to adulthood, and including information on the generation before and after). This longitudinal dimension is what enables us to to document persistence.

curse, see Mehlum et al., 2006a and 2006b). Norway and Australia are commonly used examples of the "resource blessing" today. Looking into the nineteenth century, van der Ploeg (2011) also cites the case of coal in the UK and Germany.

Economic historians have frequently emphasized the "blessing" of coal endowments for industrialization. Illustrative of the attention given to this resource in the historiography of early modern European growth is Braudel's statement that "Civilizations before the eighteenth century were civilisations of wood and charcoal, as those of the nineteenth century were civilisations of coal" (Braudel, 1981, p. 362). Coal abundance is seen as a necessary condition for growth, "what made the industrial revolution possible"(Allen, 2009, p.80), because it liberated production from the energy constraints of the "organic economy" that relied on wood and charcoal (Wrigley, 2010, p.193-196).

Our paper contributes to this literature by investigating what happens once a natural resource is no longer valuable. Can agglomeration around natural endowments turn into a curse once the technology has evolved past it? Research suggests that incentives to invest in human capital were lower in mining areas, especially for men (Black et al., 2005a), and that this may have even translated into persistently low education in the long-term (Esposito and Abramson, 2021).[4] We augment the existing evidence on the reversal of the resource blessing in two ways. First, from a methodological standpoint, our estimation strategy uses variation in the timing of mine closures. This allows us to move away from strategies purely based on the geographical distribution of coal resources, and compare people who were all born in mining counties.[5] Second, we are the first to document persistent effects throughout life, and across generations and space.

Finally, this paper relates to the vast economic history literature on the measurement of standards of living with anthropometric data (see preface in Komlos, ed, 1994; Steckel, 1995). While there has been extensive literature documenting the link between development and anthropometric indicators throughout the Industrial Revolution and the early twentieth century, there is markedly less research on the health consequences of industrial decline. Our paper fills that gap.

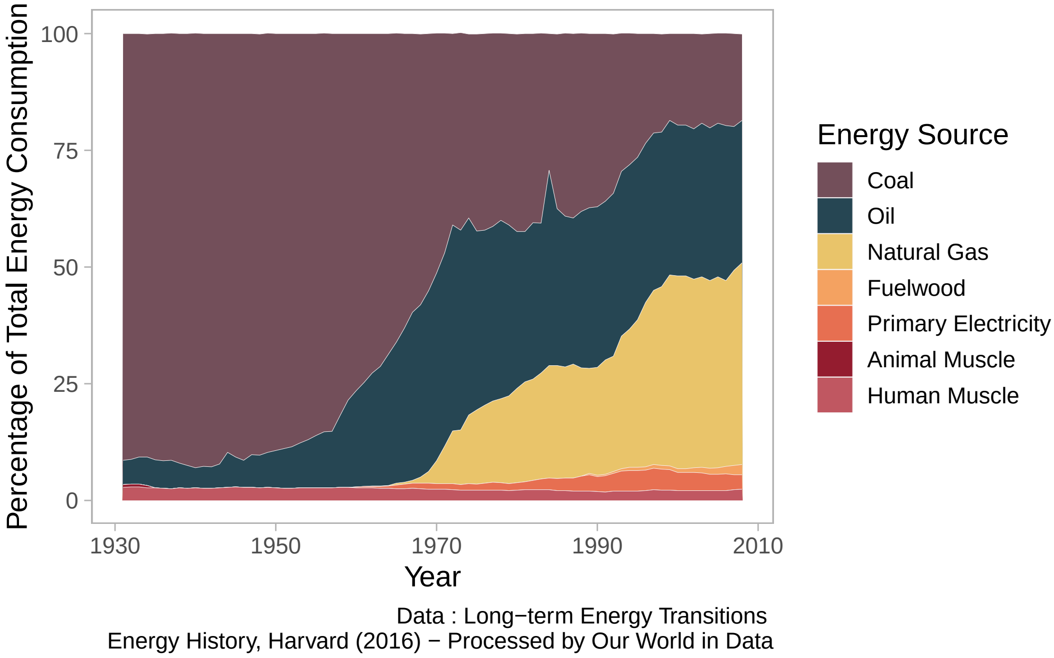
The remainder of the paper is organized as follows. Section 2 discusses the context. We then turn to describing the data and the empirical strategy in Section 3. Section 4 presents the results and main robustness checks, and section 5 discusses mechanisms. Section 6 concludes.

[4]More broadly, Franck and Galor (2021) shows that this curse can also stem from early regional specialization in unskilled-intensive technology. Brey (2021), on the contrary, finds positive effects for early electrification in Switzerland, suggesting that some regions manage to escape the trap.

[5]In its empirical strategy, our paper is closer in spirit to Aragón et al. (2018) andRud et al. (2024), who use the timing of mine closures from 1976 onward as a source of variation to study gender displacement in the labor market.

Figure 1: Coal in the UK over Time

A) Energy Consumption by Source



B) Coal Production and Imports

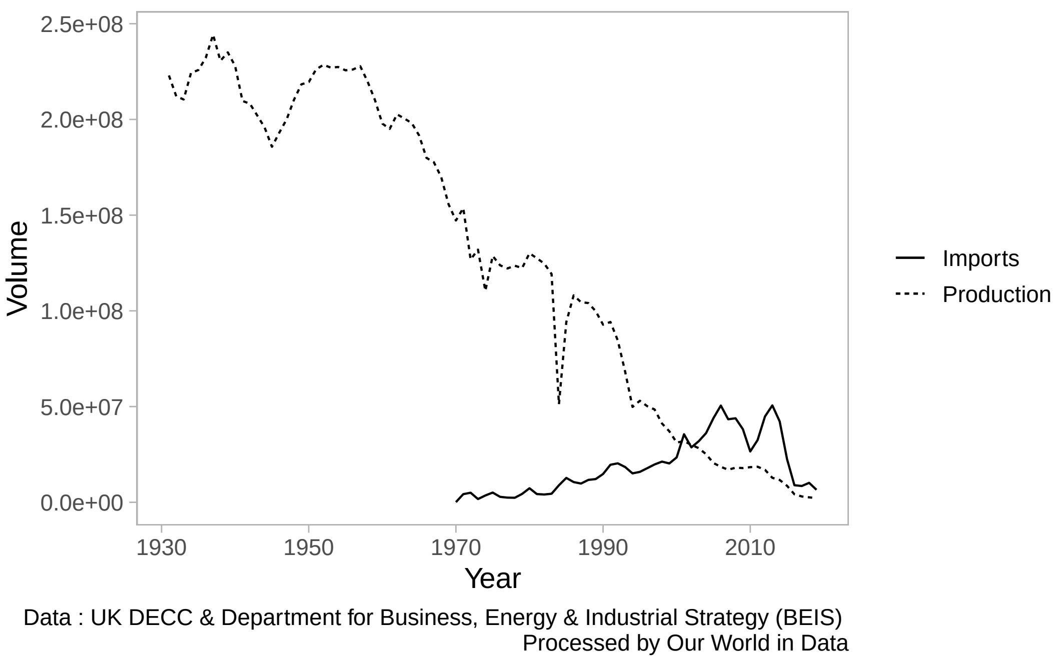
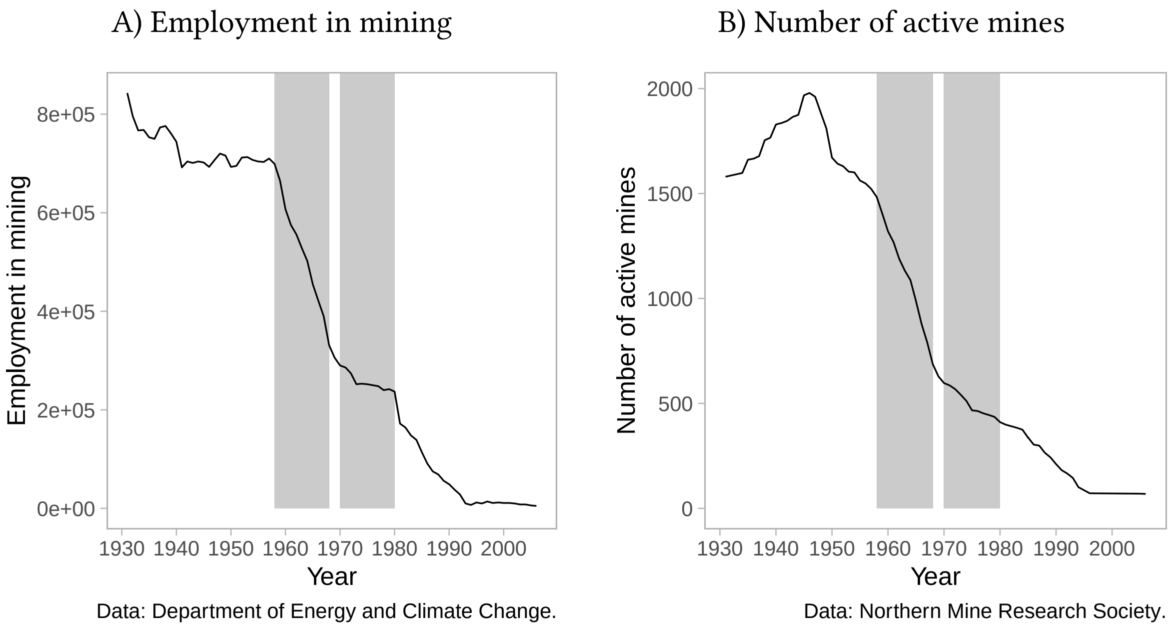


Figure 2: Evolution of the coal mining industry



Notes: The greyed areas depict the periods at which the treatment (exposure to pit closures in childhood) is constructed for the NCDS and BCS cohorts.

2 Context

2.1 Mining Industry

We study the effect of pit closures during childhood for two cohorts, born in 1958 or in 1970. Mine closures were frequent during that period, as reflected in Figure 2. This section is concerned with understanding the causes of the contraction and how they relate to determinants of health and living conditions in the long run.

Coal mining was a nationalized industry run by the National Coal Board (NCB) from 1947 to 1987. Despite miners' hopes that nationalization would durably secure jobs, large waves of closures started just a decade later. The first wave started in 1959 when 36 pits were closed down. Then, in 1961, the NCB decided to close more than 400 pits, leading to 315,000 job losses and a 27.5% cut in production (see Figure 2; for more details on the historical context refer to Powell 1993, p. 178, and Waddington et al. 2001). This trend continued until the 1980s, when Thatcher's government administered the final blow to the industry.

In the 1960s and 1970s, the main driver of pit closures was the abrupt decline of the global demand for coal, and increased foreign competition. Coal consumption fell as a result of a drop in oil and gas prices and the expansion of the nuclear sector, two trends that were largely unexpected even just a decade before (Allen,1981, p. 44; Ashworth, 1986, p. 236). Simultaneously, public attitudes were shifting. The health hazards of burning coal became better known in the aftermath of the Great Fog of London, leading to the Clean Air Act in 1956 (Powell, 1993, p. 176). On the supply side, there was emerging foreign competition from countries such as Australia, China, and the USSR. Faced with these market pressures, the NCB tried to increase productivity by pushing improvements in mining technology, encouraging mechanization, and ultimately closing the least productive pits.

Since the industry was nationalized, the government, in theory, could have taken into account political pressures and local development to allocate closures. This would matter to our identification strategy, as it would imply that development and political trends, which correlate with health, also determined mine closures.

However, historical accounts do not support this hypothesis. The government's view was that the NCB was a business undertaking and had to be treated as such. Less productive and less competitive pits were closed despite reminders from some executive members of the NCB, that closures affected workers' morale and created "difficult problem of public relations" (meaning risks of strike action, Ashworth, 1986, p.238). These concerns were shared by the National Union of Mineworkers (NUM), but did not change the government strategy. Closures were dictated by geological conditions—such as the thickness and accessibility of seams, access to water, and the friability of the coal—as they determined the feasibility of increasing productivity with new machines, economies of scale, or new organization techniques (Allen, 1981; MMC, 1983; Burns et al., 1985, p. 53).[6]

The negative social consequences of these closures were well known. At the very least, it was expected that miners would pay the price of exile. The government and the NCB anticipated that most job losses would be absorbed through outmigration, with men leaving affected regions to find jobs in other industries (Hudson and Beynon, 2021). This option was mostly favored by younger miners (House and Knight, 1967). For those who refused to change industries, a redeployment scheme was put in place that aimed at encouraging miners to settle in other mining towns. These schemes were picked up reluctantly and did not fully help to recover workers' morale. One reason was strong community ties in mining towns that increased the cost of mobility (Powell, 1993, p. 179; Bulmer, 2015, p. 251). The vast majority of miners relocated to neighboring pits, sometimes commuting long distances, while mobility across coalfields remained limited (Bulmer, 2015). Our data allows tracking outmigrants. We can confirm that outmigration was not widespread, and exhibits selection. We also observe that those who move experience very limited catching-up throughout life in our outcomes of interest.

Mine closures were thus determined by factors external to pre-existing and expected socio-economic conditions. Moreover, migration was not a widespread mitigating strategy. Still, public investment could have also targeted the hardest-hit regions *ex-post*. Furthermore, in the 1960s, it was feasible to encourage the relocation of miners to other nationalized industries in the short run. In fact, such measures were requested by members of the opposition. In 1962, the Scottish Labour MP Margaret Herbison addressed Richard Frederick Wood, the Minister of Power, in the House of Commons asking whether the government would "give an assistance that the areas which (had) already been badly hit, and the same areas which (were) going to be very seriously hit by further pit closures, (to) have (...) industrial sites and advance factories built on them" (HC Deb 23 July 1962, vol 661, col 937). The government made clear that no plans specifically directed to hardest hit areas were made: the only proposed adjustment margin for workers was geographic or industrial mobility.[7] Empirically, had such targeted public investment happened, we would expect it to attenuate our estimates since they would compensate for some of the effects to the most exposed individuals.

The NCB and the NUM hoped that the 1970s oil crisis would revive the industry. However, many forces prevented this. First, a decade of insufficient investment prevented a rapid adjustment in production and competition with cheaper imports. Second, natural gas took over as a new competing energy source. Further, planning approval to open new mines, especially deep ones, was particularly challenging to secure. Simultaneously, a major strike in 1972 led to the readjustment of wages, which had not kept pace with increasing prices. Increasing labor costs,

[6] Using data from the 1980s, Glynn and Machin (1997) demonstrate that closures affected less performing pits.
[7] Records available on the Hansard Parliamentary records online. See also the debate in 1961, led by the same MP (HC Deb 30 Nov 1961), with records also available on the Hansard Parliamentary records online.

in turn, put more mines at risk of closure. As a result of all these forces, despite more favorable conditions, the coal industry continued shrinking in the 1970s (Ashworth 1986, chapter 7).

Qualitatively, the toll of mine closures on living standards was sufficiently recognized to become, decades later, a rallying feature of the 1984 miners' strike. Gildea (2023) cites one noticeable leaflet distributed by women's groups during the strike, which stated: "What future will there be for our children when they grow up? They will be forced to leave the area in their droves to find work, leaving behind an ageing population with no-one to take care of them. As the population falls job prospects dwindle, schools will close, there will be a surplus of empty houses with the consequent reduction in value. There will be an upsurge of bankruptcies, particularly among small businesses and local shopkeepers, and so the inevitable decline will continue in a sickening and depressing spiral..." Our paper empirically examines these qualitative predictions, showing that while outmigration was not as widespread as miners feared, the "sickening and depressing " consequences on well-being were still significant.

2.2 Health and Living Standards

A seminal literature in economic history has relied on anthropometric outcomes to proxy for living standards and well-being (see preface in Komlos, ed, 1994; Steckel, 1995). The majority of this literature focuses on the Industrial Revolution, so are these anthropometric outcomes a relevant proxy for living standards in the post-war period? Crafts et al. (2007, Chapter 1) documents the close association between anthropometric data and real wages in the post-war period. More recently, these indicators have received renewed attention, with mounting concerns that children from the regions hardest hit by austerity after the Great Recession have lower heights, more extreme BMIs, and worse morbidity.[8]

A second significant concern is that regional health disparities may have been widening prior to the onset of pit closures between hardest hit areas and the rest. This scenario could have occurred if, for example, all regions began from a low baseline, with more affluent regions subsequently experiencing faster improvements in health outcomes. However, historical evidence does not substantiate this hypothesis. On the contrary, it indicates that health inequalities between regions and social classes were diminishing until the early 1980s, after which they began to widen (see, for instance, Dorling and Thomas, 2019; Smith et al., 2003). These trends have been prominent enough in Britain to prompt numerous governmental inquiries (Black et al., 1980; Acheson, 1998; Marmot, 2010). In our empirical approach, we find that at birth, anthropometric and health indicators are indistinguishable for individuals who later become more exposed to mine closures compared to those who are not.

[8]See, for instance the article from epidemiologist Michael Marmot on the Guardian issue of the 23rd of June 2023, commenting on Britain's decline in height indicators. See also the editorial from the Lancet "Britain is Broken: Poor Child Health Proves It" (of the Lancet, 2019).

3 Data and Empirical Strategy

3.1 Data

The main data sources are two UK longitudinal studies, the National Child Development Study (NCDS, 1958) and the British Cohort Survey (BCS, 1970). These data follow all individuals born 3-9 March 1958 and 5-11 April 1970, respectively, over their entire life. Power and Elliott (2006) and Elliott and Shepherd (2006) provide detailed information on these studies, along with comprehensive descriptive statistics.

From the NCDS (1958) and BCS (1970) we construct a panel that covers 8 life-stages for each cohort. More specifically, life-stage 0 measures individual characteristics at birth for both cohorts. Life-stage 1 measures early childhood (age 7 in NCDS and 5 in BCS), life-stage 2 measures mid-childhood (age 11 in NCDS and 10 in BCS), life-stage 3 measures adolescence (age 16 for both cohorts), life-stage 4 early adulthood (age 23 in NCDS and 26 in BCS), life-stage 5 is young adulthood (age 33 in NCDS and 34 in BCS), life-stage 6 is middle adulthood (age 42 for both cohorts), life-stage 7 covers the late 40s (age 50 in NCDS and 46 in BCS).[9]

For each of these life-stages we obtain height and weight measures.[10] We also construct a proxy for bad health. When respondents are 23 years of age or older (life-stages 4 or above), this measure is self-reported. For younger years, when the survey is still mainly answered by parents, we construct an index based on responses to questions about child health. These questions flag the presence of concerns specific to each age, such as breathing problems, migraines, or school absenteeism due to health concerns.[11] We complement these outcomes, available throughout life, with additional health measures and socio-economic characteristics of the individual and their parents available at different life stages.

We match the longitudinal data with a dataset documenting the occurrence of coal mine closures, based on the geo-localized history of mines in Great Britain from Northern Mine Research Society (2023). The linking is done at the county level (1981 boundary), which was the main administrative unit in the UK.[12] The data covers 112 counties in Great Britain (England, Scotland, and Wales, using 1981 county boundaries). The final dataset with geographically matched observations and non-misisng data in our main outcomes and controls contains 11,105 observations in the NCDS and 11,634 in the BCS. On average, each county samples 99

[9]In NCDS, we do not use age 46–which focuses on household structure–and older, as these stages did not yet have a correspondent survey in BCS. For the same reason, we do not use ages 30 and 38 in the BCS.

[10]Outcomes related to weight are not available for life-stage 1 because they are not collected in the BCS at that age.

[11]In childhood, "bad health" equals one if one of the health concerns is raised. In adulthood, we flag as "bad health" any answer strictly worse than "good" to the question: "How do you describe your general health generally?". See also Appendix section C

[12]The main variables from NCDS (1958); BCS (1970) are public access data, while the county-level information is secure access data. Access to the latter data can only be obtained via registration and access agreement on `https://ukdataservice.ac.uk/`, last access February 10, 2023.

valid observations in the NCDS and 104 in the BCS.[13] Figure 3 maps the differential exposure to coal mine closures across counties for these two cohorts. County-level information is provided from age 16 onwards for the NCDS and age 10 onwards for the BCS.[14] We acknowledge the important caveat that our geographical attribution is based on a variable that is not asked at birth. In the analysis, we address this important limitation in two main ways. First, we leverage questions in the first sweep that ask whether individuals have changed addresses. We verify that our results are robust by focusing on respondents that remained at the same address. Similarly, we confirm that the results are robust to focusing on individuals who never change regions (a broader administrative unit, which is reported in all sweeps).

Finally, we obtain geo-localized powerplants for England, Scotland and Wales over time from (Wikipedia, 2023a,b,c). Appendix Figure B.1 provides a map of all fossil fuel powerplants in this dataset by closure date since 1906.

Table 1 presents summary statistics for our main variables of interest. The anthropometric outcomes are the $z-$scores of height and weight for each age category, which present the deviation of each outcome compared to the population mean. The standardization is based on the British 1990 Growth Reference Chart, the typical reference for the UK. We also employ measures of body mass index (BMI, which is the weight divided by the square of height) and categorical measures of over- and underweight based on the BMI. Panel A provides summary statistics for individuals across all life stages. It shows that they are slightly shorter than the 1990 population (11% of a standard deviation), which is expected given that they were born decades earlier. They are also heavier (30% of a standard deviation), but on average they remain within the healthy BMI range (average 20.78 and the health range is 18.5-24.9). To uncover unhealthy weights at the extreme we use BMI categorical variables recording overweight (category 1) and obesity (category 2) as well as three categories of underweight, respectively.[15] Unhealthy weight levels are mostly due to overweight or even obesity (out of a total 99,326 observations for individuals age 10 and above, individuals are in 21,251 cases categorized as overweight and in 9,401 as obese). Individuals being in the categories of underweight is considerably less frequent. Appendix Figures B.2, B.3 and B.4 show corresponding maps of height, weight and bad health across UK counties at ages 0 and 16 separately for the NCDS and BCS cohorts.

Panel B in Table 1 provides the summary statistics of the family characteristics at birth, which are used as controls throughout the paper. 3% of children are born from mining fathers. Parents are in their late 20s, and mothers are typically around 2 years younger than the fathers. Most mothers are married (95%) and most fathers are present in the household (4%

[13] The average county population is approximately 457,000 according to the 1961 census and 482,000 according to the 1971 census.

[14] This issue affects approximately 15% of individuals in the NCDS and 11% in the BCS based on other geographic identifiers that are available at birth and the point in time county-identifiers become available.

[15] Note overweight (underweight) categories are not defined at birth, so these variables are only used in lifestage 1 (early childhood) onward.

have left). 29% of mothers are educated, measured with a binary variable flagging whether they stayed in school beyond the minimum required age (15 years old). Finally, 17% of fathers have a white-collar occupation.[16] Panel C lists summary statistics for characteristics used in additional analysis.

Appendix C provides detailed descriptions of all the variables used, and Appendix Table C.1 lists all the outcomes used throughout the paper, citing the original variables in the survey.

Our treatment of interest is the number of coal mine closures per capita in the county that occurred during the individual's childhood (aged 0-10). Table 1 Panels B and C shows that there is on average one mine closure per 100,000 individuals. Throughout the paper, we standardize the treatment. We provide reassurance on its validity by checking the plausibility of the identifying assumption and verifying relevance. Since we control for county and cohort fixed effects, our identifying assumption is that coal mine closures in childhood are uncorrelated with unobserved county-cohort-specific determinants of health throughout life. In addition to the historical evidence provided in section 2, we also assess the plausibility of this assumption by verifying that the treatment is not systematically correlated with observable socio-economic characteristics and outcomes at birth. Panel B, columns (3) to (7) provide reassurance on the absence of systematic correlation between the treatment and health outcomes of the individual at birth. In other words, outcomes prior to treatment are not statistically different in levels. The same holds for socio-economic characteristics of the family, with the exception that fathers of children more exposed to coal mine closures are significantly more likely to be miners. We will disentangle the effect of mine closures from that of being born in a miner's family in the empirical analysis. Also reassuringly, Panel C shows that neither for non-miners nor miners, the treatment is systematically correlated with occupational quality.

We verify the relevance of the shock by checking its correlation with employment data from the census. This exercise can only be done for the NCDS-period, since sectoral employment data with harmonized boundaries, which comes from the Great Britain Historical Database (1971), are only provided in 1951 and 1971.[17] Appendix Table A.1 presents the results. Results confirm that coal mine closures are associated with substantial declines in employment. One standard deviation higher exposure to coal mine closures is associated with a 7% decline in overall employment, reflected in mining, manufacturing, and services. The effect is particularly concentrated in coal mining, where employment declines by 29%, and manufacturing industries that use coal as an input, where the loss is 57%. Notably, employment losses are high for both men and women, albeit stronger for men. Reassuringly, we do not observe any negative effect on agricultural employment from coal mine closures, a sector that was nationally and internationally integrated (Sharp and Weisdorf, 2013). Studying the

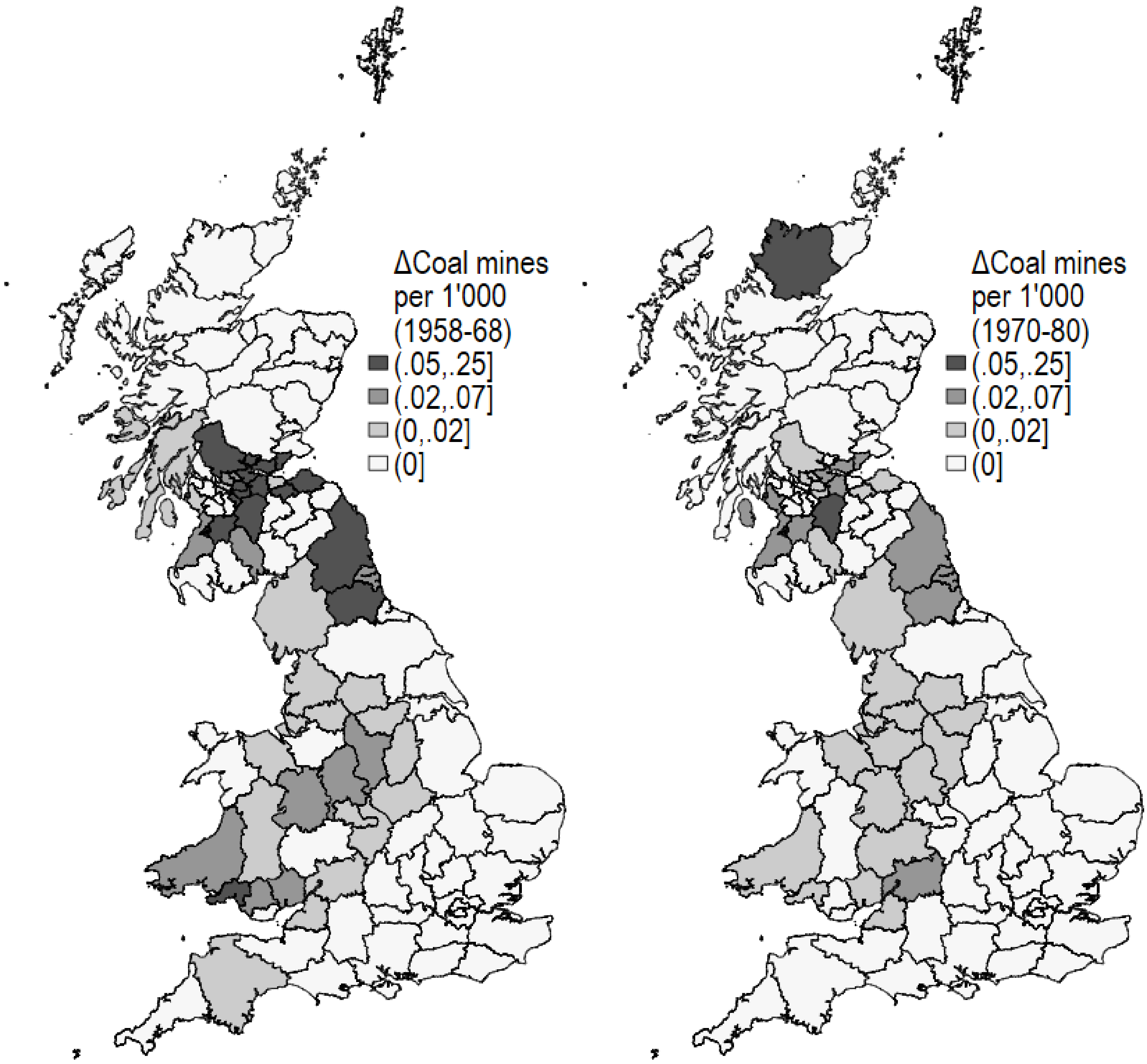
[16] SC-I refers to "professional" occupations and SC-II flags "managerial and technical" occupations.

[17] The definition of counties differed between 1951 and 1971. We aggregated geographic units so that they are consistent over time, this harmonized sample includes 45 counties in England and Wales.

1984 pit closures, Aragón et al. (2018) and Rud et al. (2024) also document long-lasting effects on earnings and employment.[18]

Figure 3: Exposure coal mine closures during childhood

A) NCDS cohort (1958-68) B) BCS cohort (1970-80)



Notes: Coal mine closure per 1,000 people across British counties during childhood for the NCDS(1958-68) and BCS cohort (1970-80). Source: Northern Mine Research Society Records

[18]They document in particular job displacement for women.

Table 1: Summary statistics

	Summary stats		Balance checks				
	Mean (1)	Std. dev. (2)	Coeff. (3)	Std. error (4)	p-value (5)	RW p (6)	Valid obs. (7)
Panel A. Main outcomes (changing over time)							
z-score height	-0.11	1.11					134,805
z-score weight	0.30	1.26					125,146
Body mass index (BMI)	20.78	6.19					120,496
BMI overweight categories	0.40	0.66					99,326
BMI underweight categories	0.07	0.32					99,326
Bad health	0.23	0.42					145,564
Panel B. Exposure variable and controls (at birth)							
Childhood mine closures per 1000	0.01	0.03					22,739
z-height at birth	-0.30	1.15	-0.002	0.020	0.94	1.00	21,170
z-weight at birth	-0.37	1.13	0.009	0.019	0.63	1.00	22,340
BMI categories at birth	13.41	0.61	0.000	0.010	0.96	1.00	21,170
Bad health at birth	0.13	0.34	-0.006	0.005	0.19	0.91	22,738
Mother age	26.76	5.62	0.081	0.075	0.28	0.94	22,716
Mother educated	0.29	0.46	0.009	0.006	0.14	0.86	22,739
Mother height	1.61	0.06	0.001	0.001	0.30	0.91	22,192
Mother smoker	0.49	0.50	0.000	0.005	0.97	1.00	22,739
Mother married	0.95	0.21	0.002	0.002	0.37	1.00	22,739
Father age	29.02	8.08	0.075	0.116	0.52	1.00	20,942
Father SC I & II	0.17	0.37	-0.002	0.003	0.45	1.00	21,756
Father miner	0.03	0.17	0.022	0.005	0.00	0.01	21,756
Father absent	0.04	0.20	-0.002	0.002	0.44	1.00	22,738
Panel C. Other available characteristics at birth							
First in birth order	0.33	0.47	-0.002	0.003	0.55	1.00	22,739
Second in birth order	0.29	0.46	-0.008	0.006	0.15	0.94	22,739
Third or above in birth order	0.38	0.48	0.010	0.007	0.14	0.82	22,739
Father unemployed	0.01	0.12	-0.002	0.002	0.22	0.94	21,755
Father SC III (non-miner)	0.60	0.49	0.005	0.006	0.40	1.00	21,145
Father SC IV & V (non-miner)	0.21	0.41	-0.007	0.005	0.15	0.94	21,145
Father SC III (miner)	0.71	0.45	0.023	0.022	0.30	0.94	611
Father SC IV & V (miner)	0.27	0.44	-0.024	0.021	0.26	0.94	611

Notes: The table presents summary statistics and balance checks. Panel A presents the main outcomes of interests across life-stages. Panel B presents the explanatory variable, individual and household characteristics at life-stage 0 (birth) and Panel C additional available characteristics at life-stage 0 (birth). To check that the treatment (childhood mine closures per head) is balanced, columns (3)-(7) present the results of a bi-variate regression of the treatment on the respective variable, controlling for county- and survey-fixed effects. Standard errors and p-values clustered at the county level. Romano-Wolf (RW) stepdown p-values for multiple hypothesis testing reported based on 1000 bootstrap replications. BMI over- and underweight categories are not defined at birth, so are left out of Panel B.

3.2 Empirical strategy

We study the relationship of coal mine closures with anthropometric, health, and socioeconomic outcomes throughout life. We estimate the following regression using OLS:

$$y_{is\ell c} = \sum_{\ell} \beta_{\ell} \text{Mine closures 0-10}_{sc} + \sum_{\ell} \gamma'_{\ell} (\lambda_s + X_i + \eta_c) + \varepsilon_{is\ell c}. \tag{1}$$

We use different outcomes $y_{is\ell c}$ that are either anthropometric, health, or socioeconomic indicators for individual i in survey s at life-stage ℓ born in county c. Survey s is either the NCDS or BCS cohort study. Mine closures 0-10$_{sc}$ is our variable of interest, measured at the county-survey level. It measures the number of coal mine closures relative to the population, experienced during childhood (age 0-10). β_{ℓ} varies over life-stages, allowing for heterogenous effects throughout life. The vector of controls X_i includes gender and the characteristics of the parents at the time the individual is born (listed in Panel B of Table 1). Standard errors are clustered at the treatment level, namely the county-survey level.

When estimating the impact of coal closure, a first challenge is that closures of coal mines might be related to other nation-wide developments. For example, governmental fiscal restrictions that could correlate with the closing of mines and other welfare cuts. To deal with this concern, λ_s accounts for geographically invariant shocks affecting survey s, interacted with life-stage fixed effects γ_{ℓ}. The interaction captures that the outcomes' trajectory may differ between individuals born in 1958 and 1970, as opposed to just the levels differing.

A second challenge is that individuals from the coalfields exhibit systematically different characteristics over life compared to others. We deal with this issue by including the county fixed-effect η_c that captures survey-invariant factors determining outcomes for those from county c. As before, this term is interacted with life-stage fixed effects.

Since our specification accounts for survey and county fixed effects (λ_s and η_c), our coefficients of interest β_{ℓ} capture the average impact within county of the difference in coal mine closures across cohorts on the difference in outcomes. A third challenge is that, as shown by a large body of literature, OLS estimates of this type of specifications can yield biased estimates of average treatment effects outside the canonical two-period setting for binary treatments (among others see, de Chaisemartin and D'Haultfœuille, 2020; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Borusyak et al., 2024), and including in two-period settings for continuous treatments (Callaway et al., 2024). In section 4.4, we show the robustness of our results to addressing the key concerns raised by this literature.

A fourth element to consider is that shocks correlated with mine closures varying at the survey and county levels may have determined household characteristics before birth. For instance, best-informed parents may have anticipated that local economies were going to contract, prompting a decision to outmigrate, thus changing the composition of households in counties differentially between the two surveys. We first verify that the treatment has no effect at life-stage 0 and that it does not systematically correlate with parental characteristics, as shown in Table 1 and discussed in section 3. In addition, we also control for household characteristics X_i, which are also interacted with life-stage fixed effects.

A fifth challenge is, that mines targeted by closures were expected to have specific socio-economic developments in the future, hence biasing our estimates. In section 2 that the historical evidence does not align with this hypothesis. We still go one step further to address this problem, by proposing a leave-one-out shift-share instrumental variable. The instrument is based on the age of the pits and the timing of mine expiration in the remainder of Britain. The results are consistent with those from the main specification (see discussion in section 4.4).

Finally, as is the case for any longitudinal study, there is attrition due to death, migration out of the UK, or individuals dropping out of the study permanently. In section 4.4, we establish selective attrition is not a concern in our study.

4 Main results

This section analyzes the effect of pit closures during childhood on anthropometric and health outcomes.

4.1 Effect on anthropometric outcomes

We begin by studying the effects on height and weight. Figure 4 plots the effect of coal mine closures during childhood on z-score height of individuals over life. In equation 1, this corresponds to the estimates $\hat{\beta}_\ell$. The full dots depict the baseline estimates, which include the entire battery of controls described in Section 3.2. To show that the results are stable to the addition of controls, we also present results for alternative specifications that only control for either life-stage-survey fixed effects or one that also adds county-life-stage fixed effects.

All specifications suggest that coal mine closures during childhood led to persistently lower height. The effect is most pronounced in early childhood (life-stage 1), when coal mine closures are associated with a decrease in height of approximately 6% of a z-score. The effect stabilizes later in life to around 5% of a z-score, showing evidence of some catch-up growth consistent with the literature in medicine (Boersma and Wit, 1997). In terms of magnitude, we observe a decrease in height of approximately 0.3 cm in adulthood (see Appendix Figure B.6). This magnitude can be compared to the historical literature on anthropometrics and deprivation. Blum et al. (2020) find that the very severe deprivation caused by the Irish famine decreased height by 0.3-2.5 cm in Dublin.[19] In other words, our effects are comparable in absolute terms to the lowest bound of these estimates. According to Baten and Komlos (1998), in the 1950s, a 1 cm decrease in stature is associated with a decrease in life expectancy of 1.2 years. Extrapolating from these findings, our results would correspond to a 4-month decrease in life expectancy.

Next, we turn to the effect on body weight, shown in Figure 5. Note that weight is not recorded for life-stage 1 (early childhood) in the BCS survey. The outcome is the body mass

[19] Dublin was less severely exposed to the famine than other areas in Ireland, which is important for the comparison. Areas that are the most severely hit exhibit *weak* effects on height because of selection due to mortality (see literature on scarring and selection effects, in particular, Deaton (2007)).

index (BMI), which is the weight divided by the square of height. This normalization is important, given that we document effects on height and shorter individuals are, everything else equal, lighter. In Figure 5, we observe that closures are associated with higher BMI from adolescence to life-stage 5 (mid-30s).

A higher weight on average does not in itself necessarily reflect poor health. First there is non-monotonicity, both under-weight and over-weight categories are negative health indicators. Second, the severity of each of these indicators matters. We analyze this heterogeneity in Figure 6, presenting results in Panel A (respectively Panel B) when the outcome is a categorical variable that equals BMI categories for overweight (underweight) and is 0 otherwise. We observe that individuals exposed to mine closures during childhood are more severely overweight from adolescence into their mid-30s. We also observe effects on underweight in later life stages.

4.2 Effect on health

Anthropometric indicators such as weight and height are well-measured proxies for health. In this section, we unpack these results and study which dimensions of health are affected. In particular, we focus on perceived overall health and a variety of specific mental and physical health outcomes.

4.2.1 General health

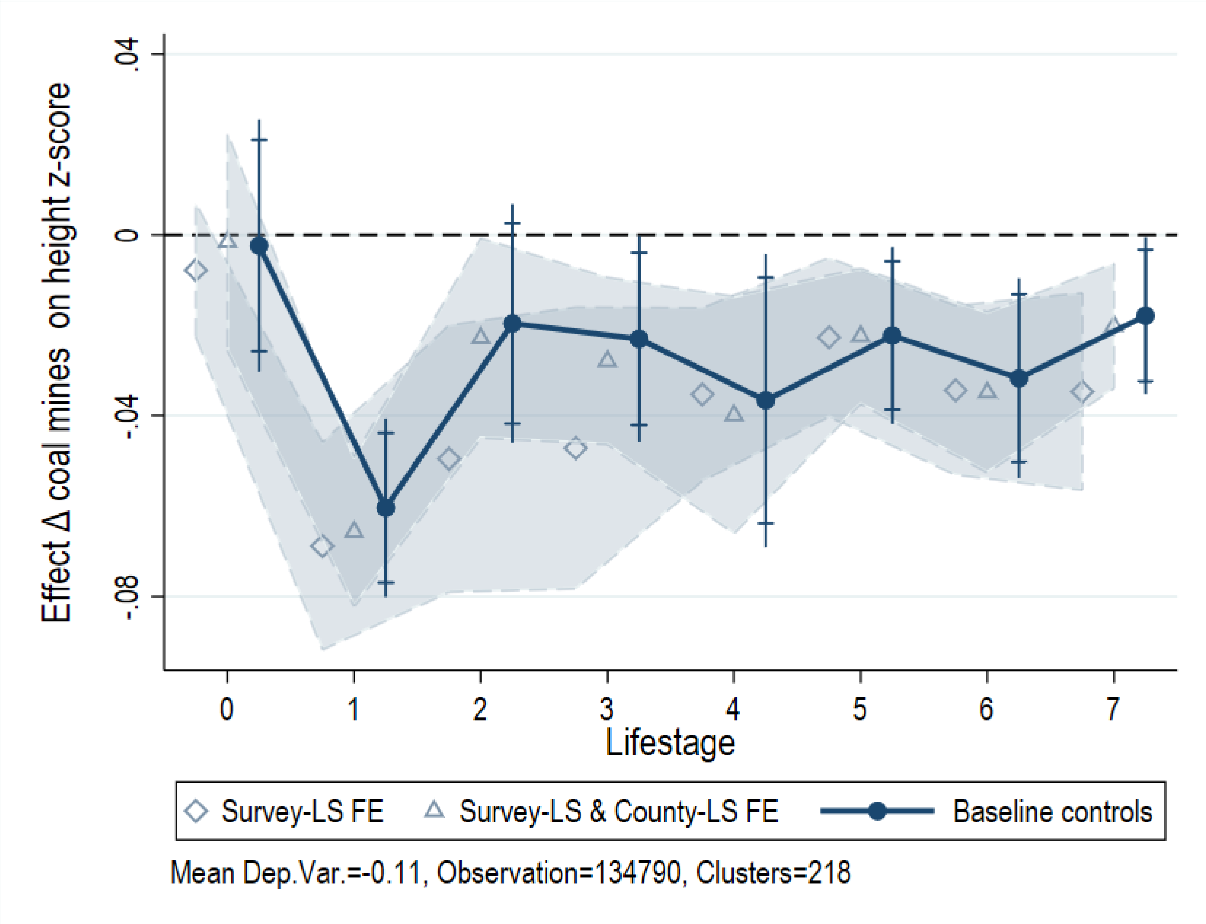
We start by looking at an overall measure of bad health. The outcome variable is a binary variable flagging occurrences of poor childhood health and externally assessed characteristics up to adolescence (e.g. missing school due to illness). In adulthood, the outcome is a binary measure of a negative self-assessment of general health. Appendix C provides more details on the construction of this outcome.

Figure 7 presents the effects. During childhood, those exposed to more mine closures exhibit increased morbidity. From adolescence onwards, the effects remain positive but decline in magnitude and are mostly statistically insignificant. One reason for this decline may be that these outcomes are self-reported and people get accustomed to their worse health conditions, or potential attrition linked to mortality. To explore these possibilities, we exploit the richness of the studies and study a variety of mental and physical health outcomes.

4.2.2 Mental health

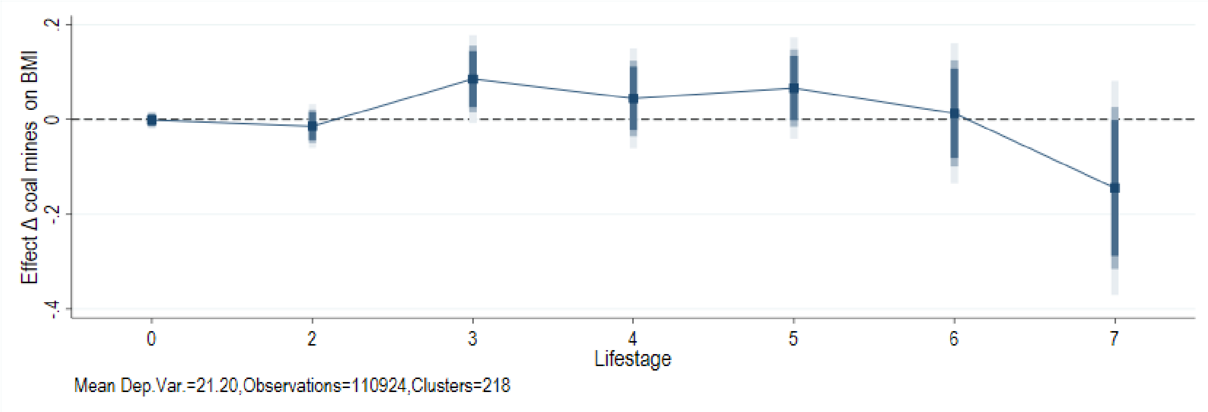
Figure 8 presents the effects on overall mental health, measured with a binary variable flagging the occurrence of states of depression (see Appendix section C for details). There is little effect on mental health during childhood, but as soon as individuals enter adulthood, those impacted by mine closures face significantly higher rates of depression. This effect is remarkably persistent over the remainder of their lives. The difference between childhood and adulthood

Figure 4: Effect coal mine closures on z-Score height



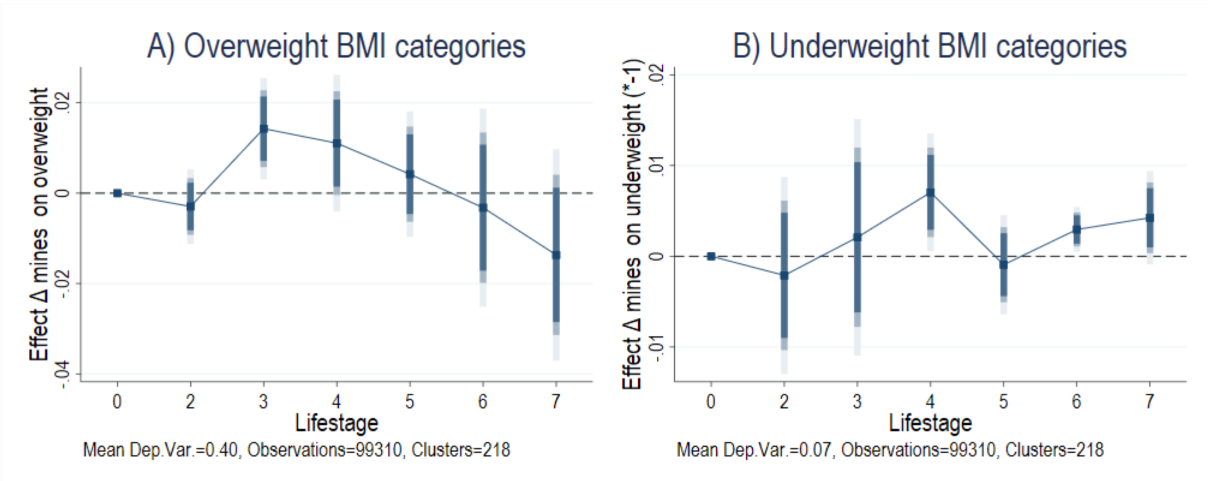
Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on height z-Score over life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Dark blue dots depict our baseline estimates including controls for survey-life-stage, county-life-stage and controls for initial household characteristics interacted with life-stage fixed effects. Initial characteristics are mother height, educated, smoker, and married as well as father household member, coal miner and social class. 90% & 95% confidence intervals depicted. Diamonds depict estimates including solely survey-life-stage fixed effects. Triangles depict estimates including solely survey-life-stage and county-life-stage fixed effects. The shaded areas depict the respective 90% confidence intervals. Standard errors clustered at county-survey level.

Figure 5: Effect coal mine closures on individual weight



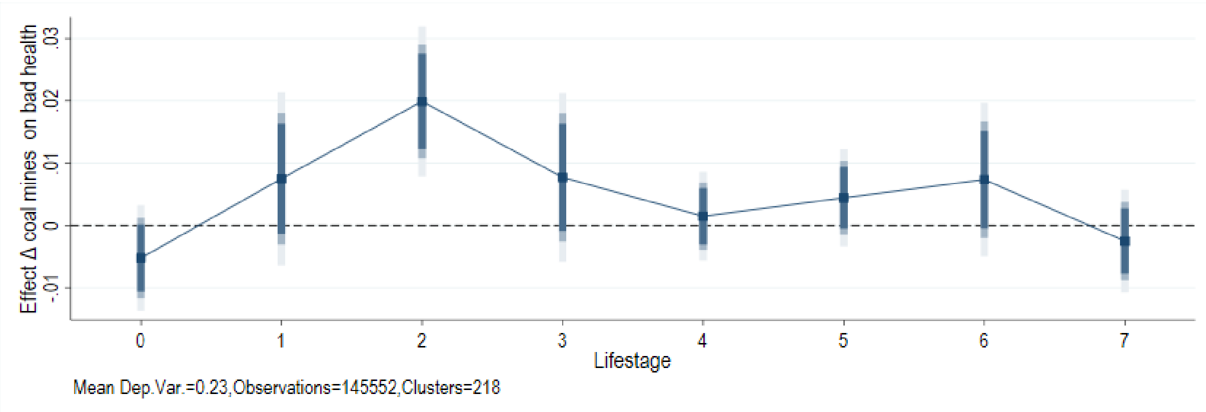
Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on BMI (Body mass index) over life-stages. BMI standardizes weight by height. Life-stages on $x-$axis are: 0 birth; 1 early- (missing due to no data in BCS); 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level.

Figure 6: BMI (height-related) over- & underweight categories



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on BMI over- (panel A) and underweight (panel B) categories. No individual falls into any over- or underweight categories at age 0. Life-stages on $x-$axis are: 0 birth; 1 early- (missing due to no data in BCS); 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

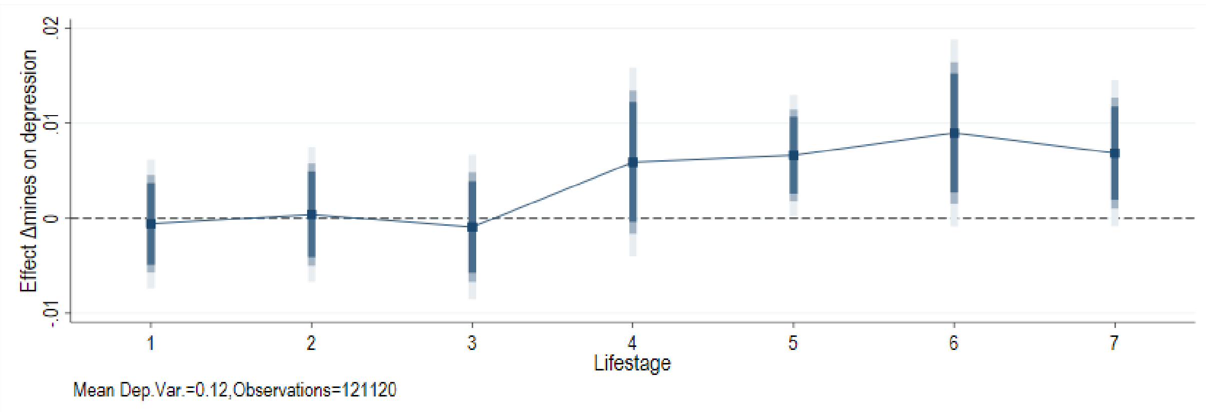
Figure 7: Effect coal mine closures on bad health



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Measures of bad health up to life-stage 3 (age 16) based on assessed health outcomes including breathing problems, migraines, pregnancy complications of mother, missing school. In adulthood, the health outcome self-reported. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

could be due to the prevalence of depression increasing with age (de la Torre et al., 2021), or due to improved measurement once depression is self-assessed.

Figure 8: Effect coal mine closures on mental health



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on bad mental health over an individual's life-stages. Life-stages on $x-$axis are: 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

We also explore the effect of our treatment on behavioral indicators of negative mental health that are reported in adulthood and across surveys. In particular, we focus our attention on the incidence of drinking and eating disorders. Considering alcohol consumption is important because it is a component of the "death of despair" epidemic highlighted by Case and Deaton (2020). However, measuring consumption is difficult due to selection in under-reporting, and, in our case, inconsistencies in how questions are asked across surveys and, within surveys, across life-stages. As a result, the results need to be interpreted with caution. Regular drinking is defined as a binary variable equal to one for individuals reporting drinking more than 2-3 times a week in adulthood, or more than 8 units per week at age 16.[20] The variable on eating disorders is a binary variable equal to one for individuals who report "ever having an eating problem."

Figure 9 presents the results. Panel A shows that coal mine closures are associated with a significantly higher incidence of drinking in early adulthood (mid-20s), a period when alcohol consumption may have long-term consequences on brain development, potentially affecting neurocognitive performance (Squeglia et al., 2014, 2015). This increase in drinking aligns with the behaviors linked to "deaths of despair" in the American Rust Belt (Case and Deaton, 2020).[21] Drinking patterns revert to the mean later in life, or insignificantly below, which could be due to the limitations in our measure highlighted above, people quitting drinking as a consequence of earlier over-consumption, or habituation leading to under-reporting. Further research is needed to address this point. Panel B shows that our treatment of interest significantly increases the probability of eating disorders, especially later in life.[22] These results also suggest that the worsened mental health reported in Figure 8 has different behavioral manifestations throughout lifestages.

4.2.3 Physical health

Lastly, we examine the effects on indicators of physical health. We first consider the impact of pit closures on mortality. To do so, we obtained access to the confidential records of respondent mortality from the NCDS and the BCS. These data provide the exact age of death from official records or the respondents' relatives.

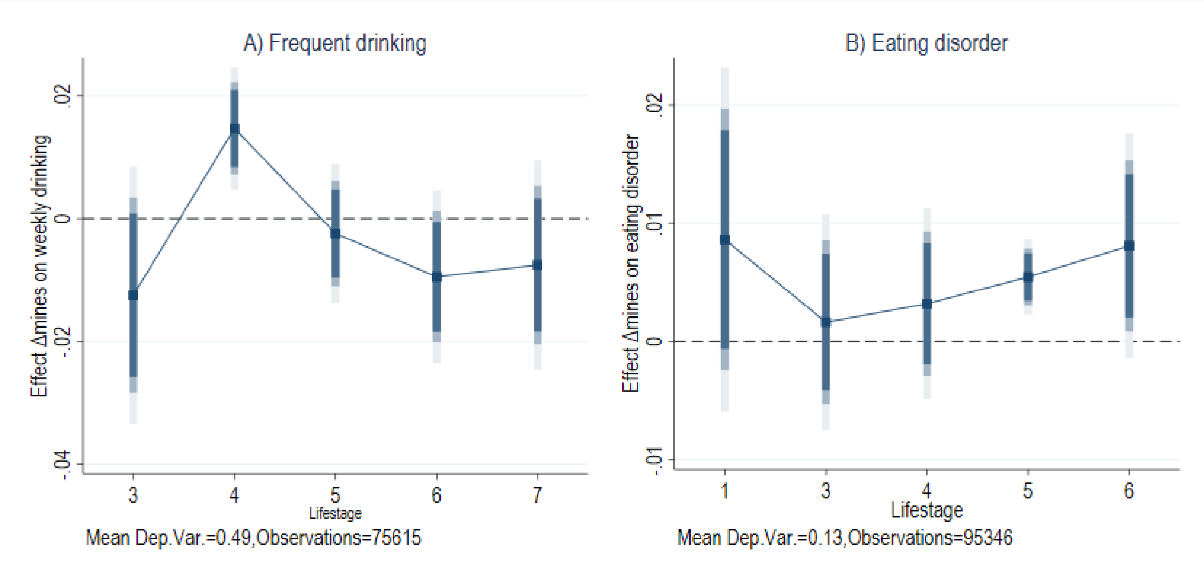
Analysis of the timing of death is typically done through a model of duration that accounts for censoring. To provide a first raw comparison, we rely on the commonly used Kaplan-Meier estimator of the survival function. This estimator has the advantage of being simple to compute and interpret. However, it is not suitable for the analysis of the effect of a continuous treatment, nor to account for controls. Figure 10 shows the Kaplan-Meier failure estimate of the timing of death for individuals from areas with mine closures during childhood and those from ones without them. We restrict this analysis to ages above 16 years old and up to 46 years.

[20] This represents 50% of the population. We acknowledge the limitations of this measure, first because the question is inconsistently asked across life-stages. Second, even in adulthood, when the question is consistently asked, it does not account for the amounts that individuals drink (questions on amounts are too inconsistent across waves to rely on them). We expect that county-lifestage fixed effects will absorb cultural norms around drinking, so that at the population levels, our results will effectively capture increased alcohol consumption compared to the norm.

[21] In contrast to Case and Deaton (2020), drug abuse is relatively rare during our study period (only 0.4% (1.1%) of individuals at age 20 (30)). Accordingly, while this is plausibly not a major contributor to death in our context, Appendix Table A.2 documents a higher likelihood of individuals struggling with drug abuse at age 20 due to pit closures (column 1). The effect turns insignificant for the population as a whole by age 30 (column 4).

[22] Interestingly the results are more precisely estimated for women, attaining significance across all life stages. Results are not reported to remain concise, but they are available upon demand.

Figure 9: Effect coal mine closures on drinking and eating disorders



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on excessive drinking (panel A) and eating disorders (panel B) over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Missing periods no data available. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

Up to the early 20s, death rates are similar between the two groups. However, the lines start diverging in the mid-20s.[23] Furthermore, to assess more precisely this relation, in particular to account for controls and fixed effects, we estimate a Cox hazard model. The results, presented in Table 2 confirm that exposure to coal mine closures is associated with an increased probability of early death (2.7-19% increase depending on the specification). However, these results are not statistically significant across all specifications. Note that the lack of significance is due to an increase in the standard errors and not to a decrease in the magnitude of the estimate. The noise in the estimates may be due to the rarity of the event—less than 4% of individuals die by the end of the study, and the majority of deaths occur at the end of the survey. Overall, our results on mortality suggest that coal mine closures are associated with increases in mortality, but noisily so and the baseline death rate is generally low. Returning to the seminal discussion on scarring and selection by Deaton (2007), the findings suggest that the collapse of the mining industry in Britain left a "scar" on the population's health rather than striking a killing blow.

We further explore other physical health indicators that may be at the root of observed differences in bad health and mortality. Unfortunately, there are very few indicators of physical health that are consistently reported across all waves and for both surveys, except for the

[23]Note that the large jump in both groups at ages 23 and 33, moments at which respondents are surveyed, plausibly reflects attrition erroneously counted as mortality or death occuring between life-stages but with uncertain timing. These are special nodes in the survey as it is when people are likely to leave the parental house.

incidence of migraines and breathing difficulties.[24] We thus take a different approach. More specifically, we run a repeated cross-section regression using the health outcomes reported in adulthood (life-stage 5 and 6, mid-30s and 40s). Table 3 presents the estimates of the treatment on whether an individual reports to have ever had diabetes (column 1), back pain (2), migraines (3), and breathing problems (4) in their mid-30s, and cancer in their mid-40s (5). We also construct an outcome indicating whether an individual had cancer and forever disappeared from the data, proxying for death or leaving the sample due to sustained illness (6).[25] The results suggest that mine closures in childhood are associated with increased probability of diabetes, breathing problems, and cancer later in life. These results permit discussing a common conjecture on the possible positive effects of the collapse of the mining industry on respiratory conditions. Coal mining is a polluting industry exposing workers to respiratory hazards. As a result, the collapse of the industry may have positively impacted health through the environment and occupational choice. Our results suggest that overall, mine closures may have increased rather than decreased breathing problems. In the next section, we discuss how living conditions and the geography of coal power plants help us rationalize this effect.[26]

Table 2: Effect childhood mine closures on death

	(1)	(2)	(3)	(4)	(5)
Mine closure	1.058**	1.059***	1.196	1.027	1.101
	(0.025)	(0.023)	(0.148)	(0.029)	(0.240)
Death at 50	0.038	0.038	0.038	0.058	0.015
Controls	No	Yes	Yes	Yes	Yes
County FE	No	No	Yes	No	No
Survey	Both	Both	Both	NCDS	BCS
N	21228	20699	20699	11185	9514

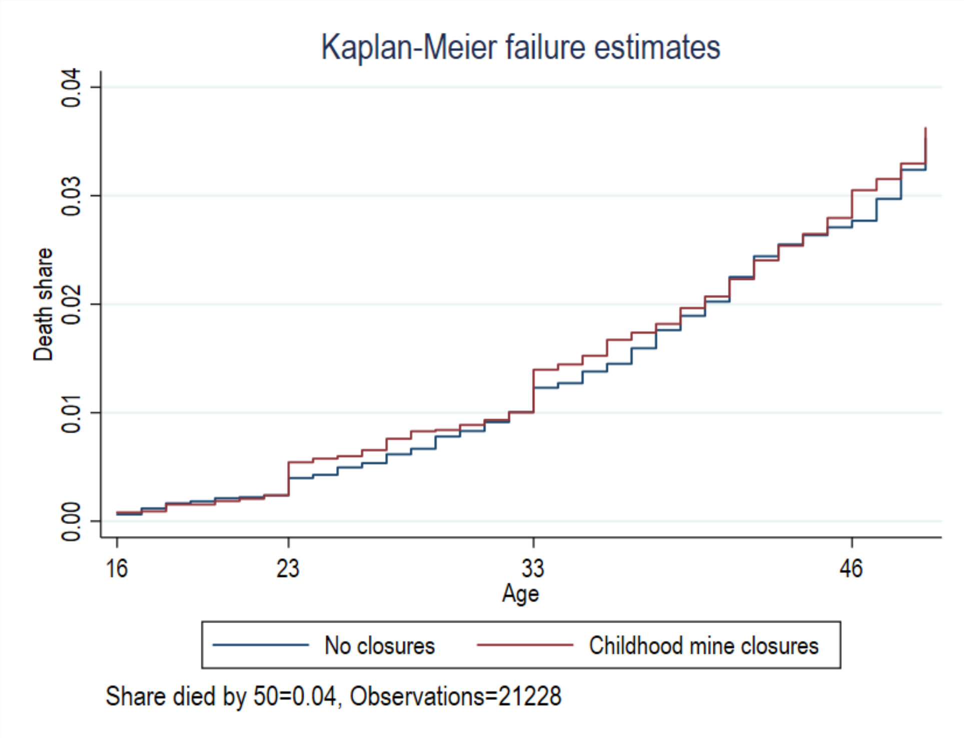
Notes: The table reports coefficient estimates reflecting the effect of a one standard deviation higher exposure to pit closures during childhood on the likelihood of death. Coefficients (1-hazard ratios) estimated using a Cox proportional hazards model. Standard errors clustered on county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[24]We report the results for the regressions using these health outcomes in Appendix Figure B.7, which do not show consistent patterns. This lack of effect may be because these health concerns can be minor and widespread in the population.

[25]In the death data, few individuals are reported dead after having had cancer in their 30s (16 individuals), which is why we don't directly code individuals as death from those data and instead use this more general indicator.

[26]In the 1980s, even the remnants of the British coal mining industry disappeared. Therefore, even those whose first job was in mining were exposed to the hazards for shorter periods than in the past. Correspondingly, only 7 individuals in the surveys report working in mining in their 30s.

Figure 10: Correlation between mine closures and deaths



Notes: The figure plots the Kaplan-Meier failure estimates on likelihood of death for individuals from areas with pit closures during childhood and those from ones without closures.

Table 3: Mine closures and physical health

	Dia-betes (1)	Back pain (2)	Migr-aine (3)	Brea-thing (4)	Cancer Ever (5)	Cancer to Attrition (6)
Mine closure	0.001**	-0.002	-0.004	0.010**	0.002**	0.001***
	(0.001)	(0.004)	(0.003)	(0.004)	(0.001)	(0.000)
Outcome mean	0.012	0.317	0.209	0.226	0.016	0.003
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes
N	17137	15674	17151	17137	17742	15734
R^2	0.007	0.138	0.040	0.119	0.010	0.008

Notes: The table reports cross-section estimates for the effect of pit closures during childhood on an individual ever having had the respective health problem at life-stage 5. Outcomes are diabetes (column 1), back pain (2), migraines (3), and breathing problems (4) in their mid-30s, and cancer in their mid-40s (5). We also construct an outcome indicating whether the person had cancer and forever disappeared from the data, proxying for death or leaving the sample due to sustained illness (6). Standard errors clustered on county-survey. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3 Heterogeneity by gender

We now turn to assess heterogeneities in the effect by gender of the respondent. With this exercise, we can assess whether girls or boys were hit differentially, which could happen if there is a preferential allocation of resources towards sons or daughters. Even in the absence of such preferential treatment, our analysis permits gauging whether the treatment hits the same dimensions of health for men and women.

The results, presented in Figure 11 suggest that both genders are affected by the shock, although not always at the same time or in the same magnitude. First, girls see a starker hit to their height in early childhood (age 5) but they recover, resulting in similar effects to boys in the long run. The patterns for overweight are also similar across genders. In contrast, the results for underweight are gendered. While exposure to pit closures does not significantly impact underweight for men, the effect is positive for women throughout life (except in their early 30s, when results are most likely to be contaminated by weight gained from pregnancies). Similarly, while both boys and girls are more likely to have worse general health in childhood (age 10), only women are likely to report worse health later in life. Finally, we explore the heterogeneities by gender for the additional results on physical and mental health discussed in sections 4.2.2 and 4.2.3. While most effects are qualitatively similar, we observe that women experience a higher increase in the probability of early death (see Appendix Table A.3) and a higher incidence of breathing problems (see Appendix Table A.4).[27] Overall, pit closures have adverse consequences for both genders, but some effects are more pronounced for women. In section 5.3, we document that women also experience worse economic consequences, which may explain some of the differences documented here.

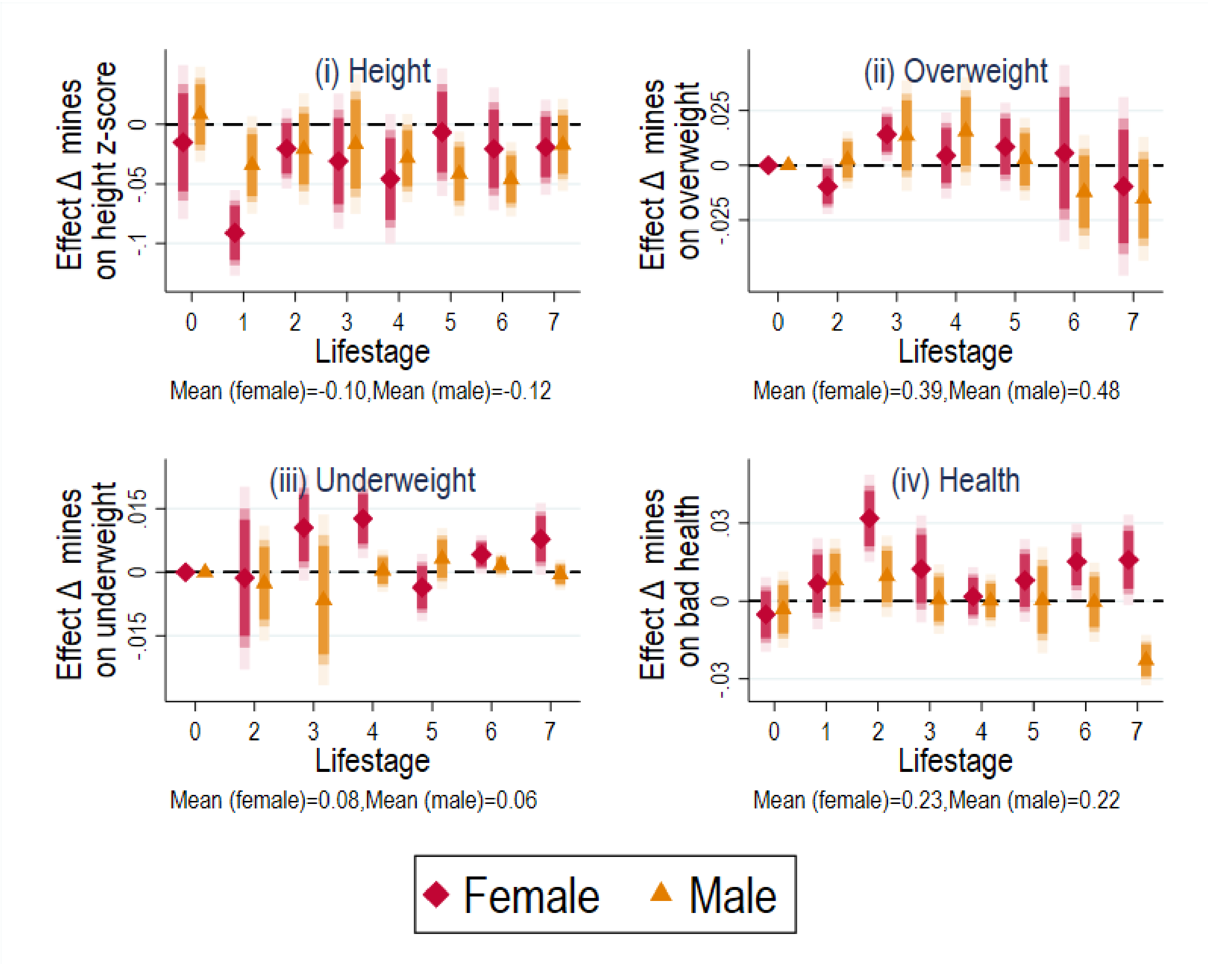
4.4 Robustness

We next turn to evaluate the robustness of the effects. We propose an additional strategy to address concerns regarding the exogeneity of mine closure decisions. Additionally, we rule out that the baseline results are driven by attrition, data limitations on birth location, differential trends in coal mining regions, or by mine closures preceding and following childhood.

Exogeneity of mine closures – The identifying assumption of the baseline results is that *ceteris paribus* pre-existing trends in living standards did not determine exposure to mine closures. In addition to the historical evidence supporting this assumption, we have provided reassuring evidence that the shock, which is constructed for the childhood years following birth, does not correlate with health outcomes and parental characteristics measured at birth. In this section, we take one step further to address endogeneity concerns and propose an instrument for the shock.

[27] Similarly, Appendix Table A.2 documents that issues with drug abuse are more severe and more persistent for women (columns 3 & 6) than for men (columns 2 & 5).

Figure 11: Effect coal mine closures by gender



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on (i) height z-Score, (ii) overweight, (iii) underweight, (iv) health by gender. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Red diamonds represent estiamtes for women and orange triangles represent estimates for men. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

Since pit productivity was the main determinant of closure, we leverage information on the date of opening of mines to predict counties' exposure to closures. Older pits were more likely to close because they were closer to expiration and less likely to be suited for new machines, independently of the socio-economic characteristics of their location.[28,29] The instrument ΔMine expiration 0-10$_{sc}$ is a shift-share variable that allocates the national-level mine closures, for each vintage of mines, to each county according to the county's proportion of mines in each respective vintage. The variable is defined in equation (2).

[28]The average year of mine opening was 1903 for closures between 1958 and 1968 and 1917 for closures between 1970 and 1980 highlighting that in both closure waves mines had on average been exploited for slightly more than half a century

[29]Appendix Figure B.5 maps the opening dates of the mines in our sample, and shows that there are no significant geographic clusters of older versus newer mines.

$$\Delta\text{Mine expiration 0-10}_{sc} = \sum_{d} \frac{\text{Mines}_{dc}}{\text{Mines}_{d}} \Delta\text{Mine closures 0-10}_{-cds} \qquad (2)$$

The sample used contains the mines operational in 1958, the beginning of our period. Mines_{dc} is the number of mines operating in county c that initially opened in decade d ("vintage d"), and Mines_{d} is the total number of vintage-d mines at the national level. The variable $\Delta\text{Mine closures 0-10}_{-cds}$ is the number of vintage-d mines that closed in the 10 years following the start of survey s (1958 for NCDS, 1970 for BCS), at the national level—excepting county c. This measure is normalized by county population (as is the case for our main treatment).

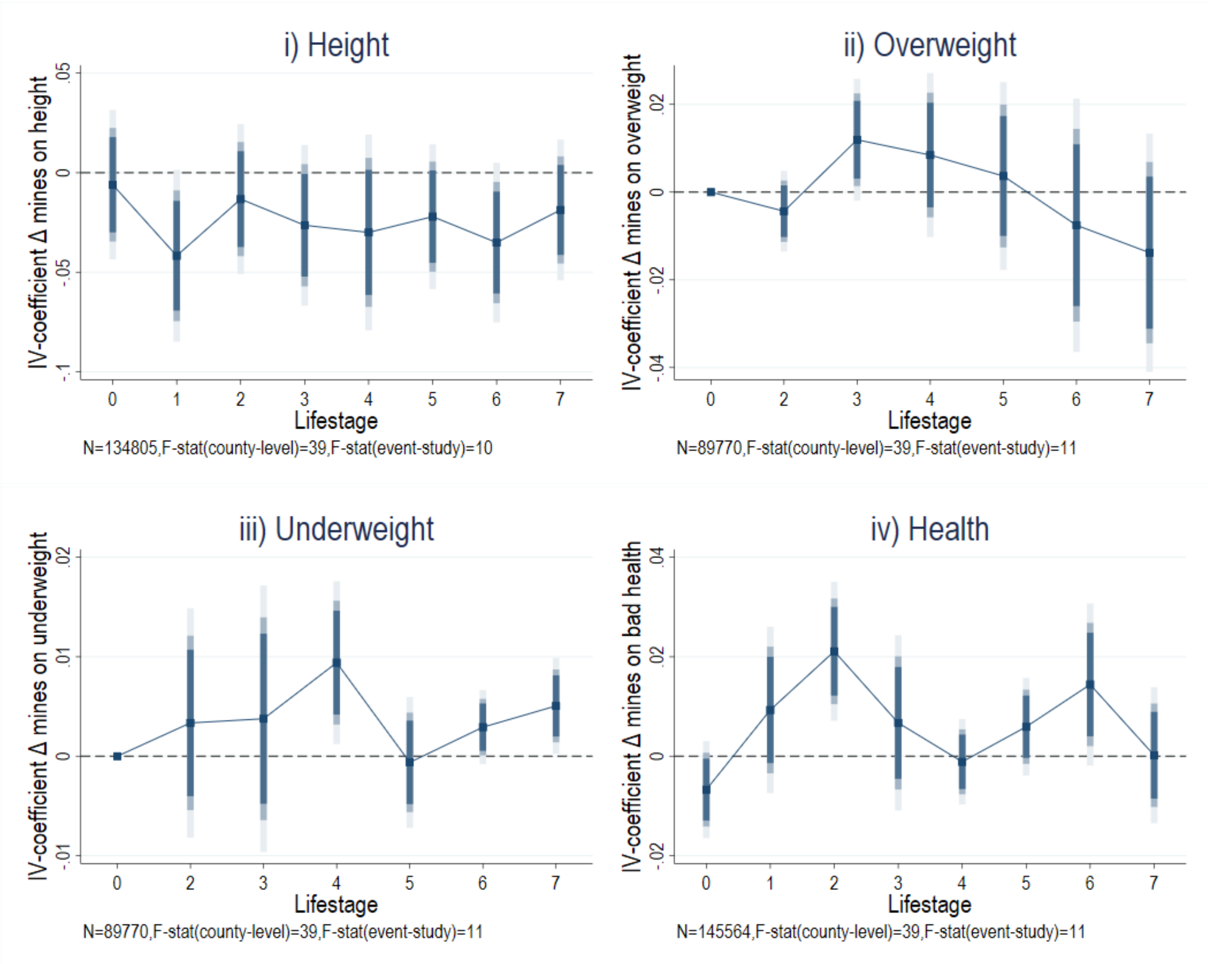
The results from the first-stage regression are presented in Appendix Figure B.8. They show the strong and significant correlation between the instrument and the treatment, providing reassurance on the instruments' validity. Figure 12 presents the second-stage results, which are reassuringly similar to the baseline OLS estimates for height (Panel.I), overweight (Panel.II), and underweight (Panel.III). The IV coefficients are at times less precisely estimated than the OLS. Finally, for bad health (Panel.IV) we find similar effects of similar magnitude to the baseline until mid-life, but they are more pronounced for later life-stages. Taken together, our IV-estimates confirm our main findings and rule out that our baseline estimate can be completely explained away by pre-existing unobservable county characteristics.

Specification– A substantial body of literature demonstrates that OLS estimates of average treatment effects from two-way fixed effects models can be biased outside the canonical two-period setting with binary treatments (among others see, de Chaisemartin and D'Haultfœuille, 2020; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Borusyak et al., 2024), and even in two-period settings for continuous treatments (Callaway et al., 2024). Two key issues raised in this literature are relevant to our paper: (i) undesirable comparisons biasing the effects (units shifting from treatment to control); (ii) biased estimates of average treatment effects for continuous treatments.

The rationale for considering issue (i) is that in our setting, some units experience a reduction in treatment intensity between 1958 and 1970, others experience an increase, and others do not see any change ("pure controls"). To address this potential concern, we run the analysis restricting the sample to pure control counties and counties with the same direction of treatment. The results, presented in Appendix Figure B.9 remain virtually identical (except a slightly stronger effect for bad health).[30] Issue (ii) highlights the potential bias in OLS estimates of average treatment effects in staggered differences-in-differences with continuous treatments (Callaway et al., 2024). OLS provide a weighted average of treatment effects across treatment intensities, and the weighting may not have desirable properties. To check for bias, we follow Callaway et al. (2024) and compare our estimates to the effect of a binary treatment

[30]New estimation procedures proposed for "staggered" differences-in-differences are designed for binary treatments, therefore cannot be applied to this setting.

Figure 12: IV-strategy: Exploiting differential mine expiration



Notes: First-stage regression at county-survey level with county and survey fixed effects: Coeff=.79(.13)***, R^2=0.92. Instrument: Shift-share variable interacting share of mines by opening data in a county with closure-wave specific expiration timing of mines in the remainder of Britain.

variable on the first-differences of the outcome. This specification has to be carried out at the county level rather than at the individual, so the estimates are noisier.[31] The results are larger in magnitude, suggesting our baseline estimates are conservative (see figure B.10).

Attrition – Attrition occurs in our data, as expected from any longitudinal study, especially one that traces individuals for such a long time. Importantly, attrition is low: among those who stay alive, 73% do not leave the study, and 45% of those who leave permanently do so in life-stage 5 (mid 30s), thus leaving unaffected most of our results, which appear earlier in life.

One common cause of attrition is early death, which we discussed in section 4.2.3. Attrition due to reasons other than death may be problematic if it systematically correlates with the treatment and determinants of height, weight, and health, even after conditioning on controls

[31]The proposed specification focuses on the first differences of the outcome. Since individuals are only observed in one out of the two longitudinal studies (a structure similar to a repeated cross section), we have to rely on the geographical unit to compute the first difference.

and fixed effects. In particular, migration could bias the estimates because local economic decline is a shock to the determinants of migration, since incentives to leave increase but people may have fewer resources to do so. One first answer to this point is that both the NCDS and the BCS devote significant attention to tracing people across sweeps, contacting them via different means including reaching out to relatives (see section "Making Contact" in NCDS, 1958; BCS, 1970). We also discuss the implications of migration for our findings in section 5.4, and confirm that it is unlikely that they are driving our results.

Attrition may also affect our estimates if those who are facing severe health concerns are less likely to respond, thus introducing sample selection bias. However, since we expect this issue to be more pronounced for severe health issues, it would mean that the unobserved individuals would be the illest ones. Therefore, the bias is most likely to attenuate our estimates. We further verify the correlation between mine closures in childhood and attrition later in life. The results, presented in Appendix Figure B.11, provide reassurance that the treatment of interest does not correlate systematically with the probability of leaving the study.

Finally, to rule out that the effects could be driven by the composition change induced by individuals leaving the survey after the treatment period. We do so by running the analysis focusing on individuals who never miss a single sweep. Appendix Figure B.12 presents the results, which remain unchanged (or become even more pronounced for overweight and bad health later in life).

Birth location – Next, we verify the sensitivity of our estimates to the construction of the birth location of the individual. County-level geographical information is provided at lifestage 2 (age 10) for the BCS and at lifestage 3 for the NCDS (age 16). We use this location to create the treatment measure. Therefore, our treatment may contain measurement error for those who change county of residence beforehand (≈15% in the NCDS and ≈11% in the BCS, see footnote 14). This measurement error may only bias our estimates if migration in childhood correlates with coal mine closures and height after conditioning on controls and fixed effects. Note that previous research has concluded that internal mobility during childhood is limited in the UK (Stillwell, 1994; Bernard et al., 2016). Our data contain the region of birth, so we can confirm that interregional mobility in childhood is low (around 2% of respondents).[32]

We leverage the richness of the data to further address this concern. In addition to the region of residence, which is asked in all sweeps, lifestage 1 sweep (age 7 in NCDS and 5 in BCS) also reports whether respondents have lived at the same address since birth. In Appendix Figure B.13, we present the results restricting the sample to those who were born in the same region as the one to which the recorded county belongs to (Panel A) and those who remained in the same address (Panel B). Overall, the results are unchanged. If anything, especially in Panel B, the patterns are larger and more precisely estimated. This change in magnitude is in line with classical measurement error attenuating the baseline effects.

[32]The region is a broader unit than the county. It corresponds to the European NUTS-1 division.

Coal mining regions – Pit closures can only occur in coal mining regions. It is thus natural to inquire whether our results are driven by characteristics in coal mining areas that could determine anthropometric and health outcomes throughout life. Our baseline estimation accounts for this issue by including county-fixed effects that vary over lifestages. However, this approach may be insufficient if coal-mining counties heterogeneously affect unobserved determinants of our outcomes of interests for each cohort differently. In Appendix Figure B.14, we present the results of specifications where instead of relying on county FEs we disentangle the effect of mines that were closed during childhood from the effect of mines that remained open at least till 1980. As visible in Panel A, the baseline effect of coal mine closures remains similar.[33,34] Furthermore, we also focus on the intensive margin variation. More specifically, Appendix Figure B.15 plots the estimates computed for the sample of individuals born in coal mining counties. The results remain consistent.

Timing of mine closures – We turn to evaluate the impact of the timing of mine closures on health throughout life. Examining the impact of mine closures at different timings permits extending the analysis in two main ways. First, it allows us to construct a placebo treatment that measures exposure to coal mine closures later in life. At older ages, we do not expect effects on height, and we do not expect to see any effects on the other outcomes (e.g. weight) before this late exposure. Second, we can also check the impact of coal mine closures experienced in-utero and before conception. Existing research suggests that in-utero shocks impact health in the long term, and our setting permits adding evidence to this literature (see e.g. Cunha and Heckman (2007); Almond and Currie (2011)).

In our placebo exercise, we study the effect of coal mine closures experienced after early childhood. The rationale for these analyses is to verify that our results are not driven by pre-existing trends in locations that end up experiencing a decline in the mining industry. We are particularly interested in the effects on height, as this outcome is particularly determined around the time of birth, and later in puberty (Van den Berg et al., 2014; Depauw and Oxley, 2019). In Appendix Figure B.16, we present our baseline estimates when also adding measures of coal mine closures experienced at ages 10-20 and 20-40. First, the effects of our preferred treatment remain robust to this addition. Children exposed to mine closures in childhood have lower height, a higher probability of being overweight in early life or underweight in adulthood, and of declaring worse general health. Second, mine closures in later life do not affect height throughout and there are no effects prior to exposure for the other outcomes.

Moreover, we can analyze the impact of coal mine closures experienced before and during the mother's pregnancy. We conduct a similar exercise as the one presented just above, where

[33] Especially when compared to results without county-lifestage fixed effects

[34] Panel B shows coal mines that remained open do not correlate with worsened height or health. However, they do correlate with less underweight in childhood and more overweight in adulthood. This pattern is consistent with wages in the mining industry having been higher than for many other blue-collar jobs after WW2 (and saw especially strong wage growth during the 1970s), and the plausibly less healthy lifestyle of those who would become miners later on, around regions where mines still operated in the 1980s.

we add to our preferred specification two additional treatments: a measure of exposure to pit closures before conception (1-5 years before) and in-utero.[35] The results are presented in Appendix Figure B.17. The impact of our preferred treatment remains robust to the addition of these two treatments (Column A). Pre-birth closures do not appear to have stable effects on height, weight, or bad health (Column C). Although this shock arguably affected household socioeconomic conditions, we may not be observing any impact because families may have had time to adjust, fertility decisions may have also reacted, and our set of controls at birth could also be absorbing part of the effect. In contrast, considering in-utero exposure permits refining our understanding of the results (Column B). In-utero exposure also durably decreases height and worsens health (especially early in life) but the magnitudes are slightly smaller than for exposure in childhood. One meaningful difference is the effect on weight. While in-utero exposure does not affect the probability of being underweight it appears to significantly and meaningfully increase the probability of being overweight in adulthood.

5 Mechanisms and Additional Results

In this section, we study the mechanisms underpinning our effects. We first rule out that the effects are only driven by miners' families. Secondly, we explore the role of socioeconomic conditions and present intergenerational effects. We then discuss the role of migration in mediating the impact of pit closures. Finally, we study the role of pollution from coal power plants as a potential positive externality.

5.1 Are mine closures only affecting miners' families?

In this section, we aim at understanding the composition of the effect. In particular, we assess whether the effects are only driven by miners' families or by the general local economic shock generated by pit closures. Firstly, Table A.1 discussed in section 3 shows that mine closures are negatively correlated with employment across all sectors, and not only mining. This first result suggests that the treatment affects individuals across a broad range of employment categories.

We take one step further in answering this question, by analyzing the employment situation of mining and non-miners' families affected by the shock.[36] In Figure 13, we present the results of regressions in which the outcome is a binary variable indicating whether the father is unemployed (panel I) or in low-skill occupations (panel II). We check that our treatment affects these employment outcomes for all families and not just for those where the father was employed in coal mining. We do so by adding an interaction term between our treatment and

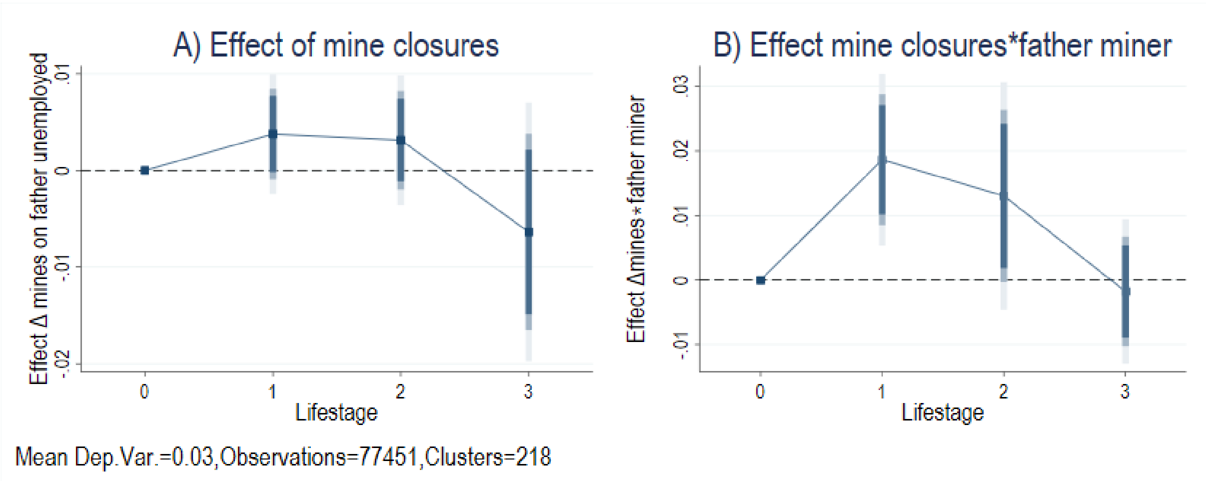
[35]In-utero is defined using coal mine closures the year before birth, since the exact month of closures is not specified in the database.

[36]In these specification, we can include individual fixed effects treating the period at birth as the untreated reference period. Further, we do not include household characteristics as they are either our outcomes of interest or might be bad controls in these specifications.

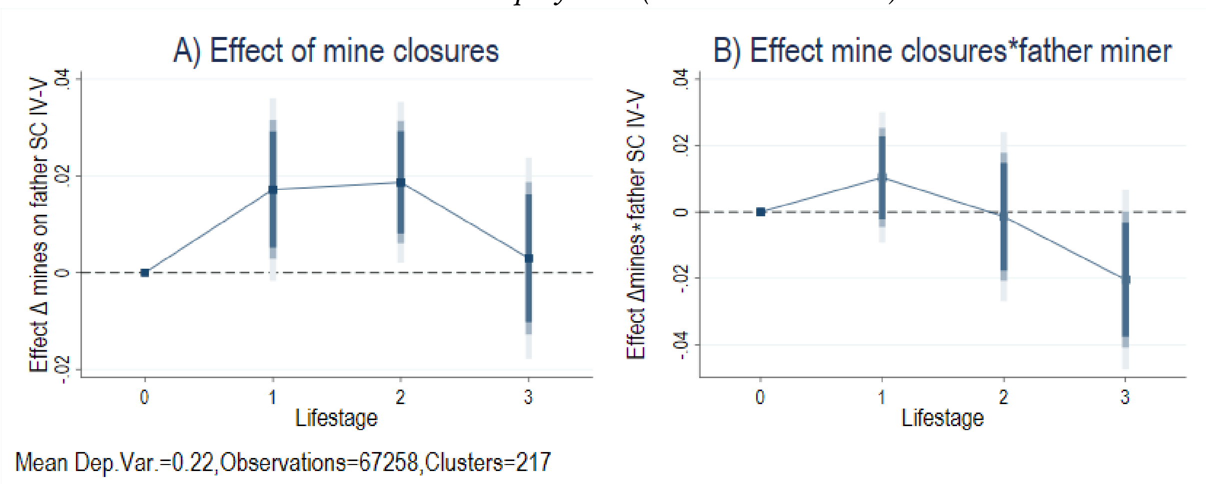
the control variable that flags whether the father is employed in mining. Figures I.A and II.A in the graphs confirm that coal mine closures are associated with an increased probability of unemployment and low-skill occupation for the father throughout childhood for all individuals, independently of whether the father is a miner. The effect on unemployment is even stronger when the father is a miner (panel B.I) but that is not the case for the one on low-skill occupations (panel B.II).

Figure 13: Effect coal mine closures on father unemployment by miner

I. Unemployment



II. Low-Skill Employment (Social class IV or V)

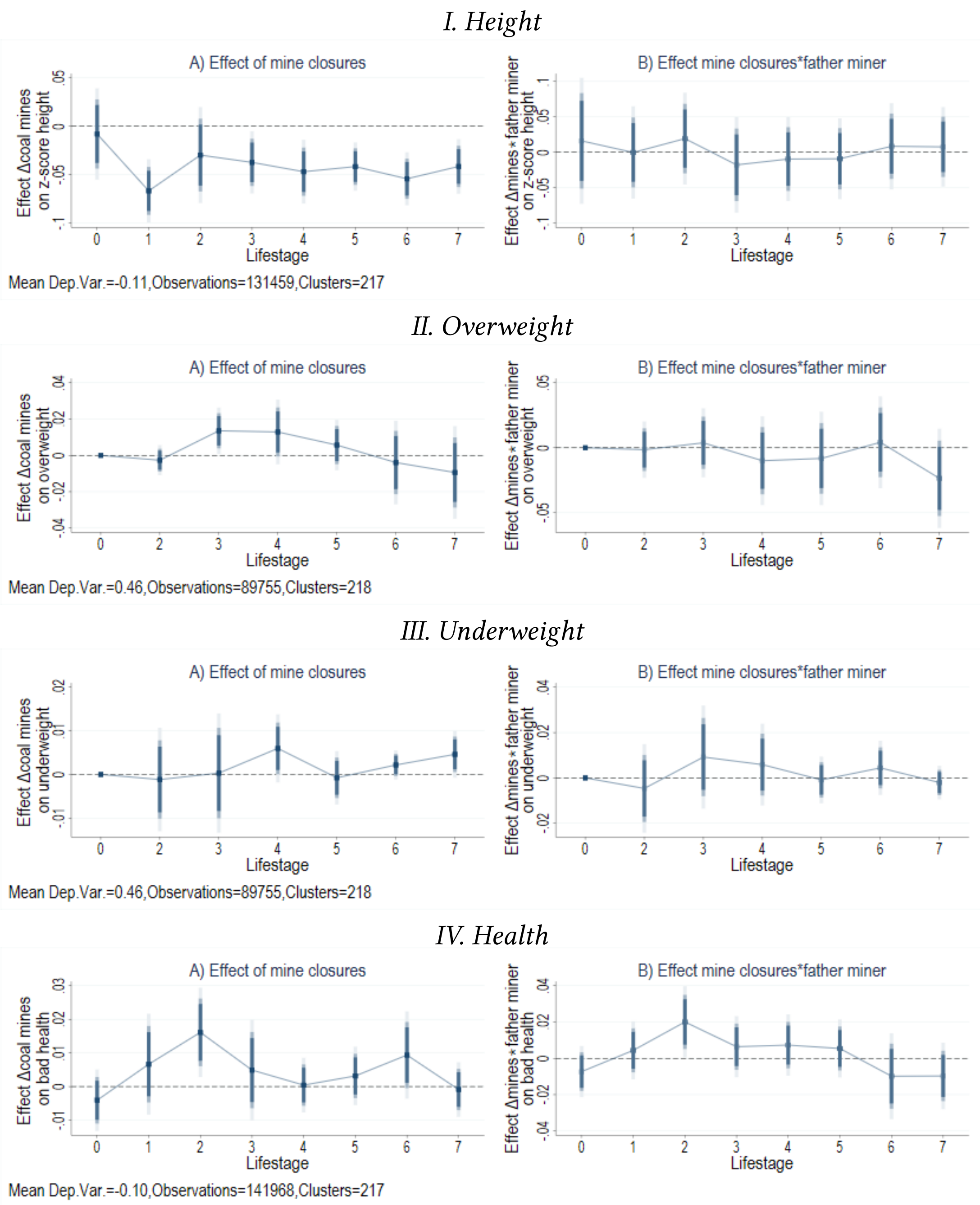


Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants on fathers' unemployment and job status. Job status being a dummy for whether fathers' occupation is social class IV or V, i.e. low-skilled employment. Controls are individual, county-life-stage and survey-life-stage fixed effects with period 0 before closures occurred being the reference period. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

Figure 14 presents the interaction effect between the treatment and families in which the father is employed in mining in our baseline regressions. In panel B, we see that the interaction term does not have a robust association throughout life with our baseline outcomes, except for the reporting of bad health, which appears to be significantly worsened in childhood and early life for miners' families even more than for the general population.

Taken together, the results presented in this section suggest that mine closures affect the broader community and not only miners' families.

Figure 14: Effect coal mine closures on anthropometrics by father coal miner



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood (panel A) and the variables interaction with father miner (panel B) on (i) z-score height, (ii) over- and (iii) underweight, and (iv) bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey.

5.2 Do mine closures affect children's living environment?

In this section, we assess the impact of coal mine closures on the living conditions of children, which could be at the root of the long-lasting results on health documented above. Table 4 presents the results of the cross-section regression between our treatment and indicators of family situation and living conditions of children at age 10. Panel A, focuses on parental employment, echoing the discussion in section 5.1. In addition to worsened employment (Columns (1)-(3)), coal mine closures are associated with an increased probability that the parents are ill, as proxied by reported weeks taken off for illness (Column (4)). Closures also appear to increase the likelihood that households report receiving retirement or disability benefits (Column (5)), however, the coefficient is borderline insignificant and it is unknown who within the household receives these benefits.

Panel B examines the available variables capturing expenses on the child. Overall, coal mine closures are linked to lower expenditures on children, as proxied by receiving free school meals, parental expenditure on activities (pool and cinema) or housing arrangements (children are more likely to be sharing a bedroom). Panel C looks more carefully into the quality of the housing environment. Children who were exposed to more coal mine closures grow up in substantially worse sanitary conditions. In particular, they are more likely to be exposed to open coal heating, which is a known lung health hazard, less likely to have had access to hot water in the house, more likely to share a bathroom with other families, and not have access to a toilet indoors. All these variables measure housing conditions that were improving throughout our period, so our results suggest that children exposed to coal mine closures grew up in families lagging behind national trends.

Additionally, we run our baseline specification interacting the birth order of the respondent to our treatment. The results, presented in Appendix Figure B.18, show that respondents born after more siblings see a more pronounced effect on height and health, but no significant pattern on weight. Since we would expect resource constraint to hit large families more *ceteris paribus*, the patterns observed are consistent with the treatment putting pressure on resources available for children. Further, mine closures could have also affected family size *ex post*. This could have restricted or increased the resources available per child depending on whether mine closures increased or reduced fertility and family size. We study this in Appendix Table A.5. We find no evidence supporting this channel, as we do not observe any impact of closures on future pregnancies of mothers (column 1), the number of later born siblings (column 2), or the size of the household the individual lives in (columns 3 to 5).

Taken together, the results in this section are in line with the view that the lasting imprint of local economic shocks on people's health can be at least in part driven by the limited resources that parents can put into their children's environment. We find no evidence that this effect is mediated by fertility choices.

Table 4: Mine closures and children's environment growing up

Panel A. Parental situation	Unem-ployed (1)	Low skilled (2)	High skilled (3)	Weeks off illness (4)	Retirement & disability (5)
Mine closure	0.004**	0.005**	-0.009*	0.431***	0.007
	(0.002)	(0.002)	(0.005)	(0.131)	(0.005)
Outcome mean	0.030	0.149	0.538	2.157	0.191
N	21473	19220	19220	17591	18495
R^2	0.023	0.044	0.107	0.034	0.039
Panel B. Expenditure on child	School meals	Taken child to: Pool	Cinema	Library	Shared bedroom
Mine closure	0.010**	-0.012**	-0.010***	-0.004	0.015**
	(0.004)	(0.005)	(0.004)	(0.004)	(0.006)
Outcome mean	0.125	0.702	0.340	0.617	0.552
N	20865	20741	20718	20651	20153
R^2	0.052	0.251	0.320	0.144	0.046
Panel C. Sanitation quality	Open coal heating	Access hot water	Family non-shared bathroom	Indoor toilet	Damp issue
Mine closure	0.082***	-0.007***	-0.008***	-0.011***	-0.002
	(0.031)	(0.002)	(0.003)	(0.004)	(0.011)
Outcome mean	0.185	0.977	0.968	0.898	0.823
N	10926	19436	20865	9847	10921
R^2	0.014	0.023	0.049	0.018	0.018
Controls	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes

Notes: The table reports cross-section estimates for the effect of pit closures during childhood on family situation at life-stage 2. Father weeks of illness, shared bedroom and access to hot water measured at life-stage 1 due to no data available for life-stage 2 in the BCS. Question asked on open coal heating and damp problem only in BCS and question on indoor toilet only in NCDS (for these three regressions county fixed effects can not be included). Controls include mother education, mother smoker, mother married, father social class, father absent and gender of individual at birth. Standard errors clustered on survey-county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.3 Intergenerational Transmission

In section 5.1 and 5.2 we showed that the shock worsened the socio-economic conditions of the parents of the individual in the sample. In this section, we leverage the unique questions asked in specific sweeps of the data to show the persistence of the effect. First, we assess the impact of the pit closures on the economic situation of respondents in adulthood. Second, we study the health status of respondents' children. We find that the shock is transmitted over generations through less wealth accumulation and worse health.

Table 5 presents the cross-sectional estimate of pit closures' effect on the economic situation of respondents in their 30s. We are interested in the effect on education, earnings, benefits, and wealth. First, we observe that the treatment *positively* impacts education for men, but not for women (columns (1) and (2)). This result is in line with previous findings that emphasize that manufacturing and mining industries increase the opportunity cost of education, especially for men who were more likely to enter manual jobs in those industries (Black et al., 2005b; Esposito and Abramson, 2021; Franck and Galor, 2021). As a consequence, contractions in these industries can have a positive impact on education. Turning to the effects on earnings, we observe that despite their increased education, these men do not earn more than their counterparts (columns (3) and (4)). Women—who are not more educated—earn significantly less. One interpretation of this finding is that, in the absence of the education effect, men would have earned less—as is the case for women. Similarly, we observe that both men and women are more likely be in a household that receives state benefits (e.g. for housing, health, income support, or children, see columns (5) and (6)), reflecting that both men and women are in poorer households or those that receive benefits due to worse health. Consistently, they are also less likely to accumulate wealth as reflected by their lower probability of being homeowners (columns (7) and (8)).

To study the transmission of the shock to the third generation, Table 6 gives the estimated impact of the treatment on the characteristics of the firstborn of the individuals in the sample, as asked when individuals are in their 30s. Around 50% of respondents already have children at that age. Children of respondents exposed to treatment are significantly more likely to have younger mothers, especially mothers under the age of 21. These children are also more likely to be born late, and more likely to have been born with a disorder.[37]

Taken together our results highlight that despite some positive impact of the treatment on education for men, the overall shock is negative and persistent over generations.

5.4 Does migration mediate the impact of mine closures?

Worsening economic conditions increase the incentives to outmigrate but also reduce the resources available for people to do so. In section 4.4 we already ruled out that migration during childhood significantly contaminates our estimates. In this section, we investigate the question of whether internal migration was an effective strategy to mediate the impact of the economic contraction *for those who left.* This question bears important policy relevance. The government and the NCB's rationale for dismissing place-based policies in response to pit closures was that in a country as well integrated as the UK, individuals could easily migrate to thriving locations (Hudson and Beynon, 2021, p.59-62). The debate over the necessity of place-based policies is still salient today (All-Party Parliamentary Group on Coalfield Communities, 2023).

[37]The disorder variable is a binary variable equal to one if the respondent agrees to the question "Was there something wrong with this baby at birth?"

Table 5: Mine closures and economic outcomes for individuals in adulthood

	Education		Log Pay		Benefits		Home owner	
Gender	M	F	M	F	M	F	M	F
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mine closure	0.014**	0.006	0.009	-0.024*	0.021***	0.013**	-0.024***	-0.030***
	(0.006)	(0.006)	(0.009)	(0.013)	(0.004)	(0.006)	(0.009)	(0.005)
Outcome mean	0.411	0.472	9.065	8.504	0.768	0.864	0.742	0.751
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	7418	8053	5742	5972	6068	7059	7453	8151
R^2	0.175	0.160	0.232	0.236	0.158	0.117	0.037	0.041

Notes: The table reports cross-section estimates for the effect of pit closures during childhood on respondents' economic situation at life-stage 5 depending on their gender. Outcomes are a binary variable equal to 1 if the respondent has more than the mandatory years of education (columns 1–2), log pay (3–4), a binary variable equal to 1 on whether their household receives government benefits (5–6), and a binary variable equal to 1 for being a homeowner (7–8). Question on years of schooling completed asked at age 42 in NCDS and 34 in BCS. Benefits measure at age 38 in BCS as question not asked at age 34. Standard errors clustered on county-survey. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Since the British cohort studies track people over time, we can distinguish between stayers and leavers. We can follow those who outmigrate to a different county or a different region after childhood. In particular, we construct a binary variable flagging individuals living in a different county to the one where they are recorded at age 16. This variable permit answering three questions: Did coal closures trigger mobility later in life? Did mobility help mitigate the negative health effects of closures? Was mobility a mitigation strategy equally accessible to all? Our findings show that mobility was limited, unequally distributed in the population, and did not fully compensate for the negative health effects.

Did coal closures trigger mobility later in life? Appendix Figure B.19 shows the impact of pit closures in childhood on the probability of migrating later in life. The figures suggest that, if anything, the probability of such migration decreases with closures. This negative effect kicks in in early adulthood, when migration is the most likely. In other words, migration probability at the lifestage when it is most likely is relatively lower for those exposed to the shock.[38]

Was mobility a mitigation strategy equally accessible to all? We further investigate the initial family characteristics of the individuals who migrate later in life. Appendix Table A.6 shows that those who would later migrate are significantly different from the rest of the population: Migration decisions are not randomly distributed in the population. Changes in the cost of moving and potential gains from migration play an important role. Individuals born in families with more educated mothers and fathers of higher social class, who arguably had more job

[38]While we cannot rule out effects on within-county migration, the results in this section establish that migration to the largest cities in the country, arguably the best locations in terms of durable employment prospects and which required inter-county migration for most respondents, was not increased by the shock.

Table 6: Mine closures and outcomes of first-born child

	Mother			Birth		Newborn	
	Age	Under 21	Miscarriage	Early	Late	Weight	Disorder
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mine closure	-0.110*	0.006*	-0.002	-0.003	0.027***	0.004	0.008**
	(0.066)	(0.003)	(0.005)	(0.008)	(0.008)	(0.009)	(0.004)
Outcome mean	26.468	0.178	0.087	0.306	0.395	3.327	0.110
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8650	8650	8477	7757	7757	7536	7767
R^2	0.453	0.122	0.018	0.018	0.016	0.036	0.017

Notes: The table reports cross-section estimates for the effect of pit closures during an respondents' childhood on outcomes related to their first pregnancy later in life and the health of their first-born child. The outcomes are the age of the mother (column 1); binary variables equal to one if the person had a miscarriage (2), an early (3) or late birth (4); the weight of the baby at birth (5) and a a binary variable equal to 1 if individuals declare that "there was something wrong with the baby at birth" (6). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

opportunities and resources, are more likely to move throughout life (columns (5) and (10)). Similarly, those born in families with fewer local ties, who may experience lower moving costs, such as those with younger parents or single-mother households, were also more likely to move (columns (4), (8), (9), (11)).

Did mobility help mitigate the negative health effects of closures? We show that our baseline results also hold for those who migrate later in life. In other words, migration did not fully mitigate the health impact of the shock. Appendix Figure B.20 presents the results for the estimates of our baseline regressions to which we add a binary variable flagging whether the individual migrates later in life, interacted with our preferred treatment. We interpret our findings with caution, since we uncovered above that there is selection into migration. The results show that pit closures had the same negative impact on height for movers and stayers, which is expected since this outcome is determined early in life. Regarding weight, movers exposed to the treatment have a lower chance of being overweight than non-movers but the overall effect is not fully compensated until age 30 (the effect starts materialize already at age 16 reflecting the positive selection). In contrast, they exhibit an even higher probability of being underweight throughout life. Finally, the effect on bad health appears to be partially compensated up to late adolescence (when the outcome is constructed from medical reports), but movers exposed to treatment report worse self-reported health in adulthood.

5.5 Do mine closures improve health through positive environmental impact?

Coal mining is a polluting industry with documented health hazards for its employees (see Liu and Liu 2020 for a review) and for those exposed to coal combustion (see Hendryx et al. 2020 for a review). Since those exposed to our treatment are children, effects observed before adulthood cannot be attributed to occupational hazards. Consequently, our primary concern lies in evaluating the positive environmental repercussions resulting from mine closures. Note first that coal remains an important source of energy throughout the period (the first source in the energy mix until the 1990s, see figure 1). Therefore, many power plants remain in operation, and continued to expose individuals to toxic particles despite the reduction in domestic coal mining employment.

We address this question empirically using crowd-sourced data on all the coal power plants in the UK (Wikipedia, 2023a,b,c). With these data, which are mapped in Appendix Figure B.1, we design two tests.[39] First, we check whether there is a correlation between coal mine closures and the number of power plants operating in their vicinity. Second, we check the impact of power plant closures on health outcomes.

The results from the first test are presented in Appendix Table A.7, which shows that our preferred treatment is not systematically correlated with the number of power plants closing. To measure the latter, we count the number of power plants closing within different radii from the centroid of each county during the same periods as our treatment (1958-68 and 1970-1980). This approach allows to capture that mines within a county could be serving power plants outside the county.

The results from the second test are presented in Appendix Figures B.21. In line with the literature suggesting negative health impacts of exposure to coal combustion, we observe that power plant closures decrease the probability of bad health and of being underweight (albeit only in childhood for this outcome). We do not find any robust effect on height and overweight.

Taken together, the analysis in this section permits the conclusion that although reducing coal combustion can have some positive impact on health, coal mine closures were not accompanied by a significant decrease in exposure to coal power plants within geographic proximity. Thus, they did not trigger any meaningful positive externality through respiratory health.

6 Conclusion

In this paper, we document long-lasting effects of industrial decline on health and economic outcomes focusing on the early demise of the coal industry in the UK.

[39] Our dataset comprises a total of 460 fossil fuel powerplants (327 coal power plants) with 355 of those having data on longitude and latitude available. Throughout the period 50 new coal power plants open and 130 close.

Our results show that the consequences of exposure to deindustrialisation can durably harm well-being. In particular, children who grow up in times of deindustrialisation have lower height, more extreme weight, and worse general health reflected both in physical and mental health indicators throughout their lives. We also find suggestive evidence that these outcomes also translate into higher probability of early death and lower wealth. We also show that negative effects persist over generations. Overall, these conclusions shed a new perspective on the literature on the consequences of industrial decline on wellbeing, which has predominantly focussed on worker's living standards or infant health. Taking advantage of a historical perspective, we can document how this impact persists over life, throughout generations, and across space.

These findings are important to current policy debates about increasing levels of spatial inequality and poverty within developed countries that strongly correlate with industrial decline. In the UK, demand for place-based policies has increased as a result of these trends. While we cannot prove that place-based policies would address the situation, we highlight that in the absence of any support, industrial decline has long-lasting consequences that are not resolved by access to better opportunities elsewhere. Few people move, and those who do keep a scar.

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Online Appendix

A Tables

Table A.1: Mine closures and employment growth across counties

	Total empl.	Female empl.	Mining		Manufacturing		Agri-culture	Serv-ices
			All	Coal	All	Coal		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Coalmine closures (sd.)	-0.070***	-0.064***	-0.189***	-0.290*	-0.084**	-0.569*	-0.006	-0.059***
	(0.017)	(0.019)	(0.062)	(0.151)	(0.037)	(0.300)	(0.007)	(0.019)
$N(harmonized\ counties)$	45	45	45	45	45	45	45	45

Notes: The table presents the first-differences relationship between pit closures 1958-68 per 1,000 inhabitants (in standard deviations) and employment growth based on the census 1951-71. Employment in column (6) includes manufacturing processing coal, petroleum and chemical products industries. Data from Great Britain Historical Database (1971) covers only England and Wales with counties harmonized between their 1951 and 1971 definition through aggregation. Robust standard errors reported. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Mine closures and drug abuse

	Drug abuse at age 20			Drug abuse at age 30		
	All	Male	Female	All	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
Mine closure	0.0006*	0.0007	0.0004*	0.0002	-0.0016	0.0024**
	(0.0003)	(0.0006)	(0.0002)	(0.0015)	(0.0025)	(0.0009)
Outcome mean	0.004	0.007	0.002	0.011	0.016	0.006
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes
N	16692	8030	8656	16692	8030	8656
R^2	0.009	0.017	0.013	0.012	0.018	0.011

Notes: Cross-section outcomes of childhood mine closure on drug abuse by age 20 (column 1–3), and by age 30 (4–6). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text.

Table A.3: Effect childhood mine closures on death by gender

Panel A. Male	(1)	(2)	(3)	(4)	(5)
Mine closure	1.019	1.011	1.124	0.981	1.161
	(0.049)	(0.052)	(0.142)	(0.063)	(0.222)
Death at 50	0.045	0.045	0.045	0.066	0.019
Controls	No	Yes	Yes	Yes	Yes
County FE	No	No	Yes	No	No
Survey	Both	Both	Both	NCDS	BCS
N	10498	10239	10239	5575	4664
Panel B. Female					
Mine closure	1.102***	1.104***	1.306	1.070***	0.933
	(0.028)	(0.026)	(0.258)	(0.024)	(0.490)
Death at 50	0.032	0.032	0.032	0.050	0.011
Controls	No	Yes	Yes	Yes	Yes
County FE	No	No	Yes	No	No
Survey	Both	Both	Both	NCDS	BCS
N	10730	10460	10460	5610	4850

Notes: The table reports coefficient estimates reflecting the effect of a one standard deviation higher exposure to pit closures during childhood on the likelihood of death. The sample is split by gender with panel A reporting results for males and panel B reporting results for females. Coefficients (1-hazard ratios) estimated using a Cox proportional hazards model. Standard errors clustered on county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text.

Table A.4: Mine closures and physical health by gender

Panel A. Male	Diabetes (1)	Back pain (2)	Migraine (3)	Breathing (4)	Cancer Ever (5)	Cancer to Attrition (6)
Mine closure	0.001	0.000	-0.005	0.002	0.002***	0.000
	(0.001)	(0.006)	(0.004)	(0.006)	(0.001)	(0.000)
Outcome mean	0.010	0.335	0.136	0.231	0.008	0.001
N	8301	7492	8310	8308	8617	7535
Panel B. Female						
Mine closure	0.002	-0.004	-0.003	0.019***	0.001	0.001**
	(0.001)	(0.006)	(0.006)	(0.005)	(0.002)	(0.001)
Outcome mean	0.013	0.300	0.277	0.220	0.024	0.004
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes
N	8831	8176	8836	8824	9120	8193

Notes: The table reports cross-section estimates for the effect of pit closures during childhood on an individual ever having had the respective health problem at life-stage 5. The sample is split by gender with Panel A reporting results for males and Panel B reporting results for females. Outcomes are diabetes (column 1), back pain (2), migraines (3), and breathing problems (4) in their mid-30s, and cancer in their mid-40s (5). We also construct an outcome indicating whether the person had cancer and forever disappeared from the data, proxying for death or leaving the sample due to sustained illness (6). Standard errors clustered on county-survey. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text.

Table A.5: Robustness - Mine closures and Fertility Choices

	Fertility decisions		Household formation decisions		
	Pregnant again	Number	HH members	3 or more	4 or more
	(1)	(2)	(3)	(4)	(5)
Mine closure	-0.004	-0.008	0.004	-0.002	0.001
	(0.004)	(0.012)	(0.023)	(0.002)	(0.008)
Outcome mean	0.568	0.904	4.877	0.894	0.519
N	20431	20431	20846	20846	20846
Controls	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes

Notes: The table reports cross-section estimates for the effect of pit closures during childhood on family's fertility decisions and household formation at life-stage 2. Controls include mother education, mother smoker, mother married, father social class, father absent and gender of individual at birth. Standard errors clustered on survey-county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text.

Table A.6: Robustness : Migration decision later in life and characteristics at birth

	Individual at birth			Mother characteristics					Father characteristics		
	$z-$ Height	Weight	Illness	Age	Educ.	Height	Smoker	Married	Age	SC-I&II	Absent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mover later in life	0.014	0.005	0.005	-0.195**	0.036***	0.001	0.009	-0.014***	-0.283**	0.030***	0.012***
	(0.020)	(0.010)	(0.005)	(0.096)	(0.006)	(0.001)	(0.008)	(0.004)	(0.135)	(0.005)	(0.004)
Outcome mean	-0.300	3.318	0.134	26.758	0.294	1.611	0.490	0.955	29.022	0.160	0.043
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	22340	21169	22738	22716	20941	22191	22739	22739	22739	22738	22739

Notes: The table reports estimates showing the relationship between the decision to move later in an individual's life and birth characteristics (lifestage 0). Robust standard errors clustered at the county-survey level in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text

Table A.7: Robustness: Relationship coal mine and powerplant closures

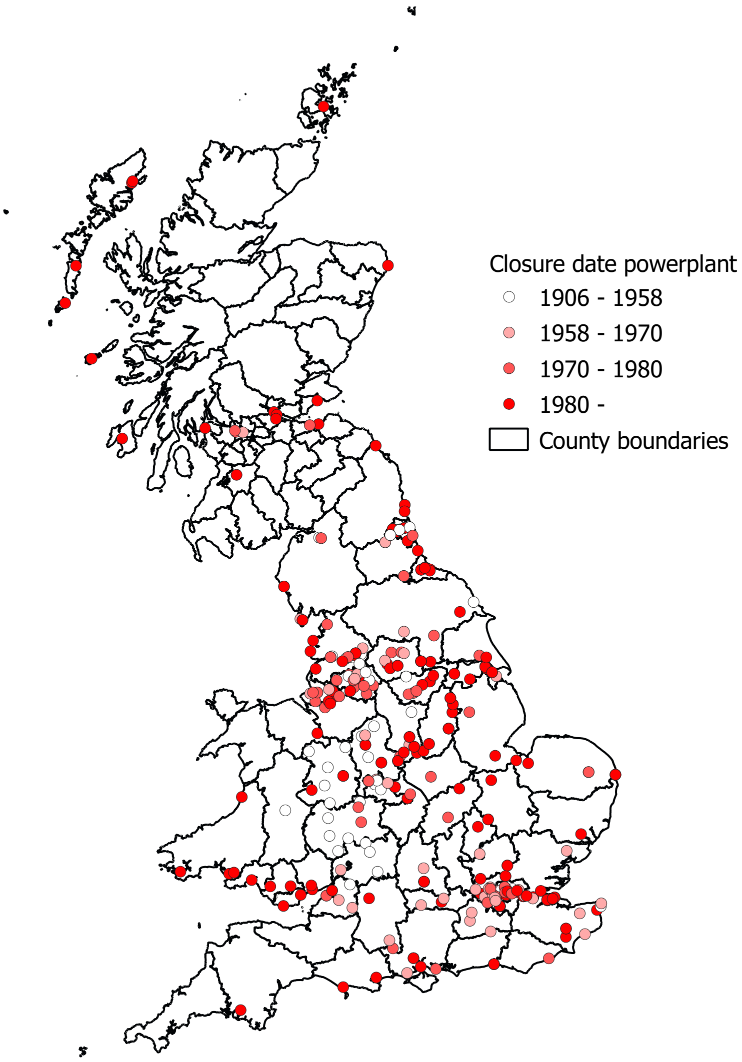
	10km (1)	20km (2)	35km (3)	50km (4)	75km (5)	100km (6)
Mine closure	-0.051	-0.009	-0.060	-0.017	-0.004	0.023
	(0.070)	(0.063)	(0.078)	(0.079)	(0.071)	(0.062)
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
$N(counties)$	218	218	218	218	218	218

Notes: The table reports estimates for the relationship between coal mine closures across counties and closures of coal power plants. Standardized coefficients reported. Both measures constructed for childhood (age 0–10) of the respective cohort. Coal power plant closures constructed based on different distances from county centroid as specified in column header. Robust standard errors clustered on county in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Return to main text

B Figures

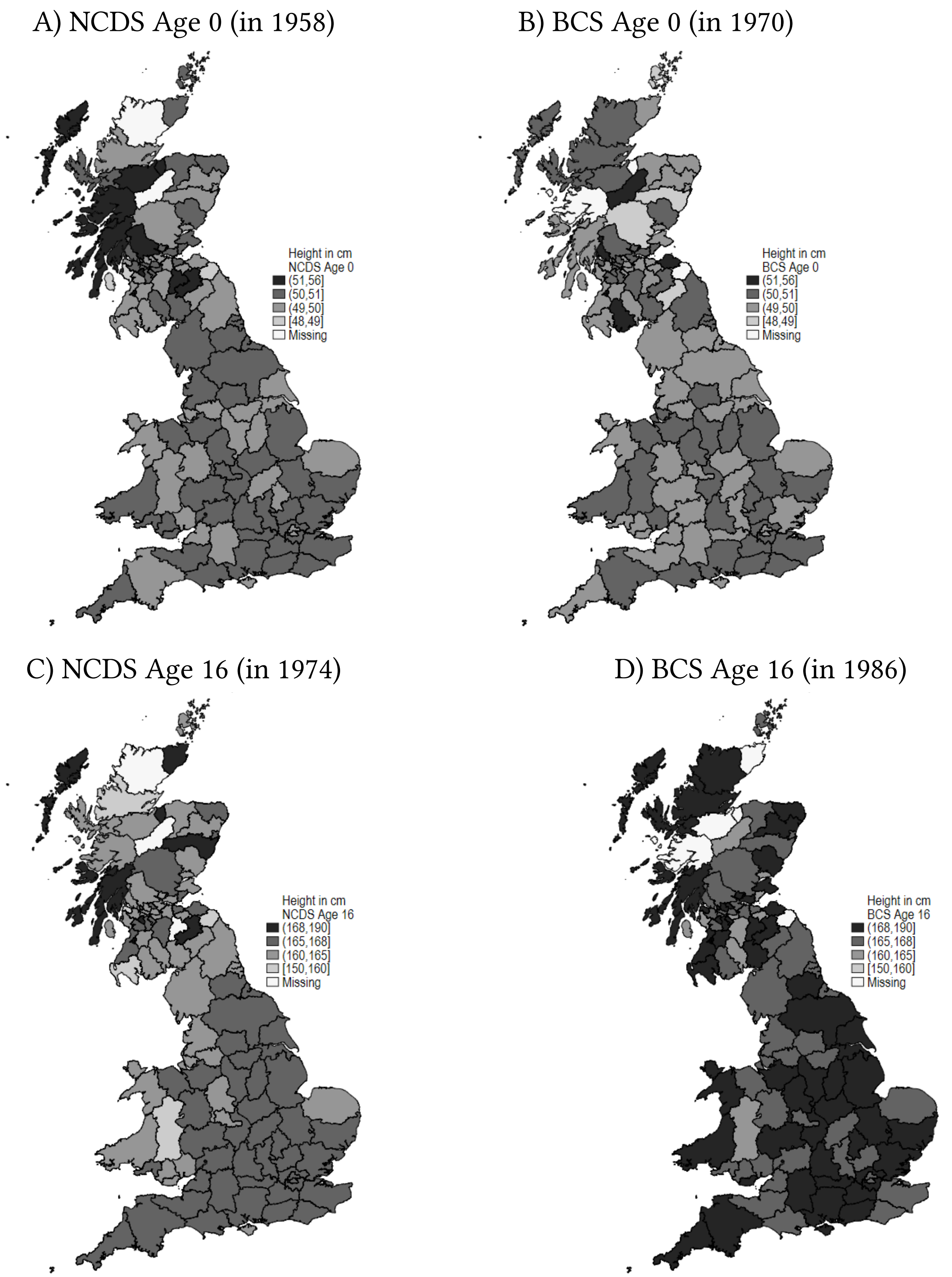
B.1 Descriptive figures

Figure B.1: Fossil fuel powerplants along with closure date



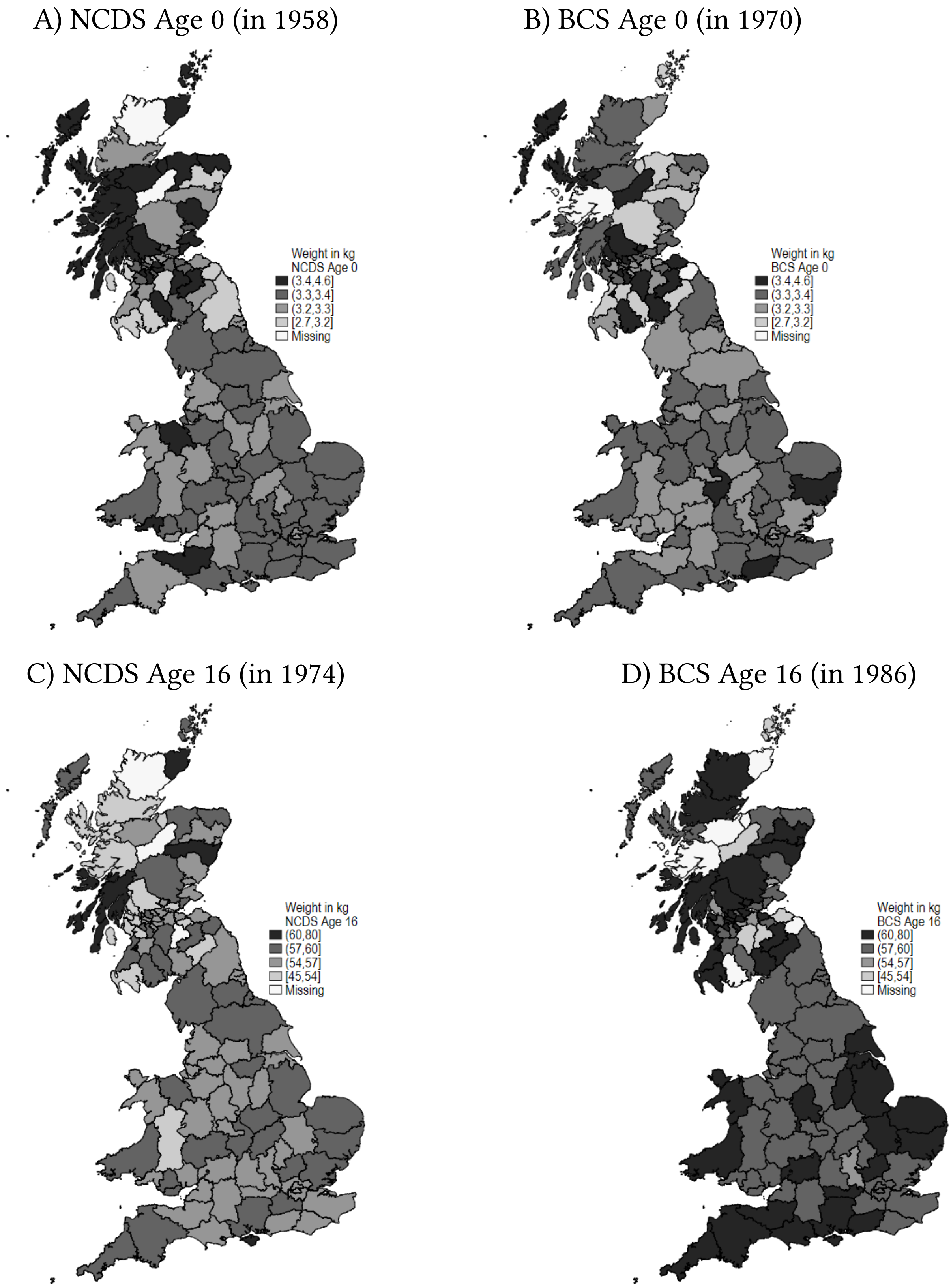
Notes: Location of fossil powerplants and their closing date. Each dot in the map represents one coal, oil or gas powerplant. Darker colors represent later closing date of powerplant. The category "1980-" includes all powerplants closed after 1980 (including those that remain in operation existing today). Return to main text.

Figure B.2: Height at age 0 and 16 in NCDS and BCS



Notes: Average height in centimeters in longitudinal surveys NCDS (born in 1958) and BCS (born in 1970) at age 0 and 16 across 1981 British counties. Return to main text.

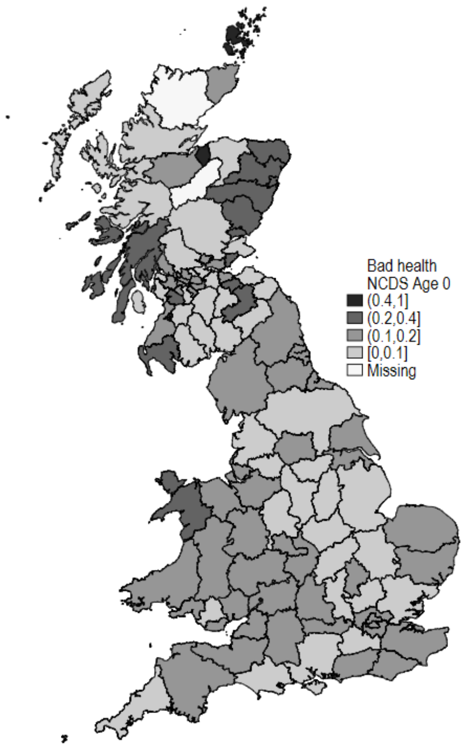
Figure B.3: Weight at age 0 and 16 in NCDS and BCS



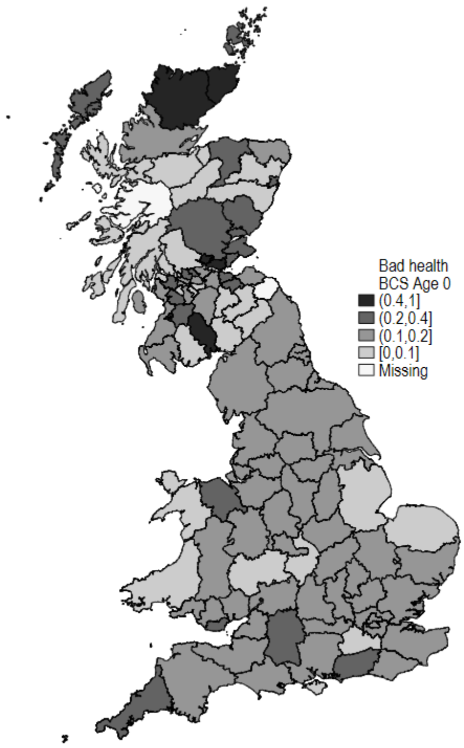
Notes: Average weight in kilogram in longitudinal surveys NCDS (born in 1958) and BCS (born in 1970) at age 0 and 16 across 1981 British counties. Return to main text.

Figure B.4: Bad health at age 0 and 16 in NCDS and BCS

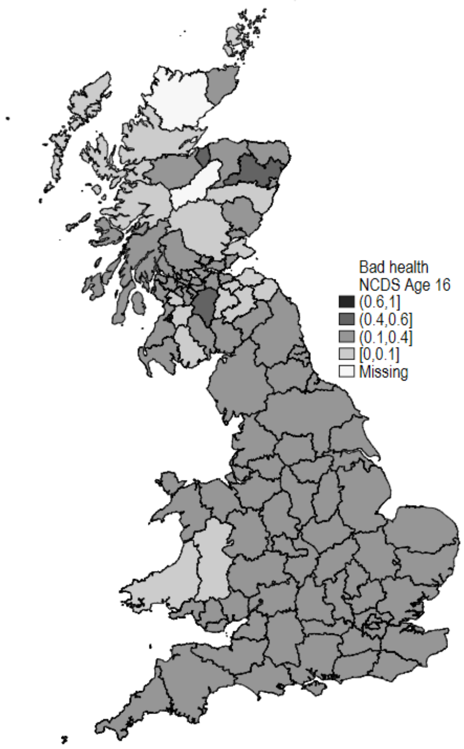
A) NCDS Age 0 (in 1958)



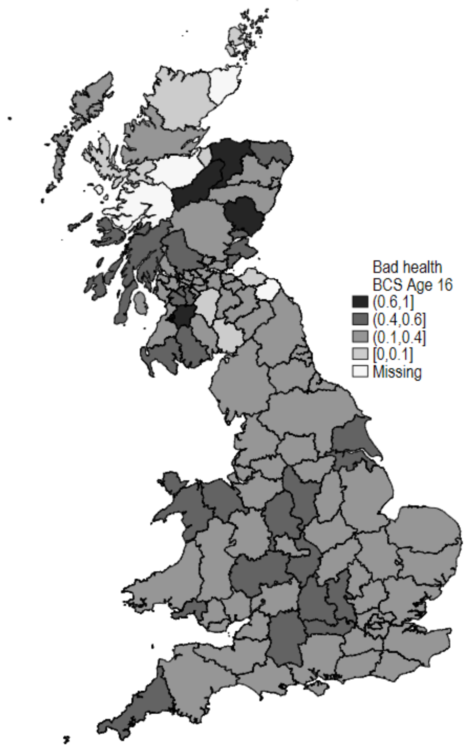
B) BCS Age 0 (in 1970)



C) NCDS Age 16 (in 1974)

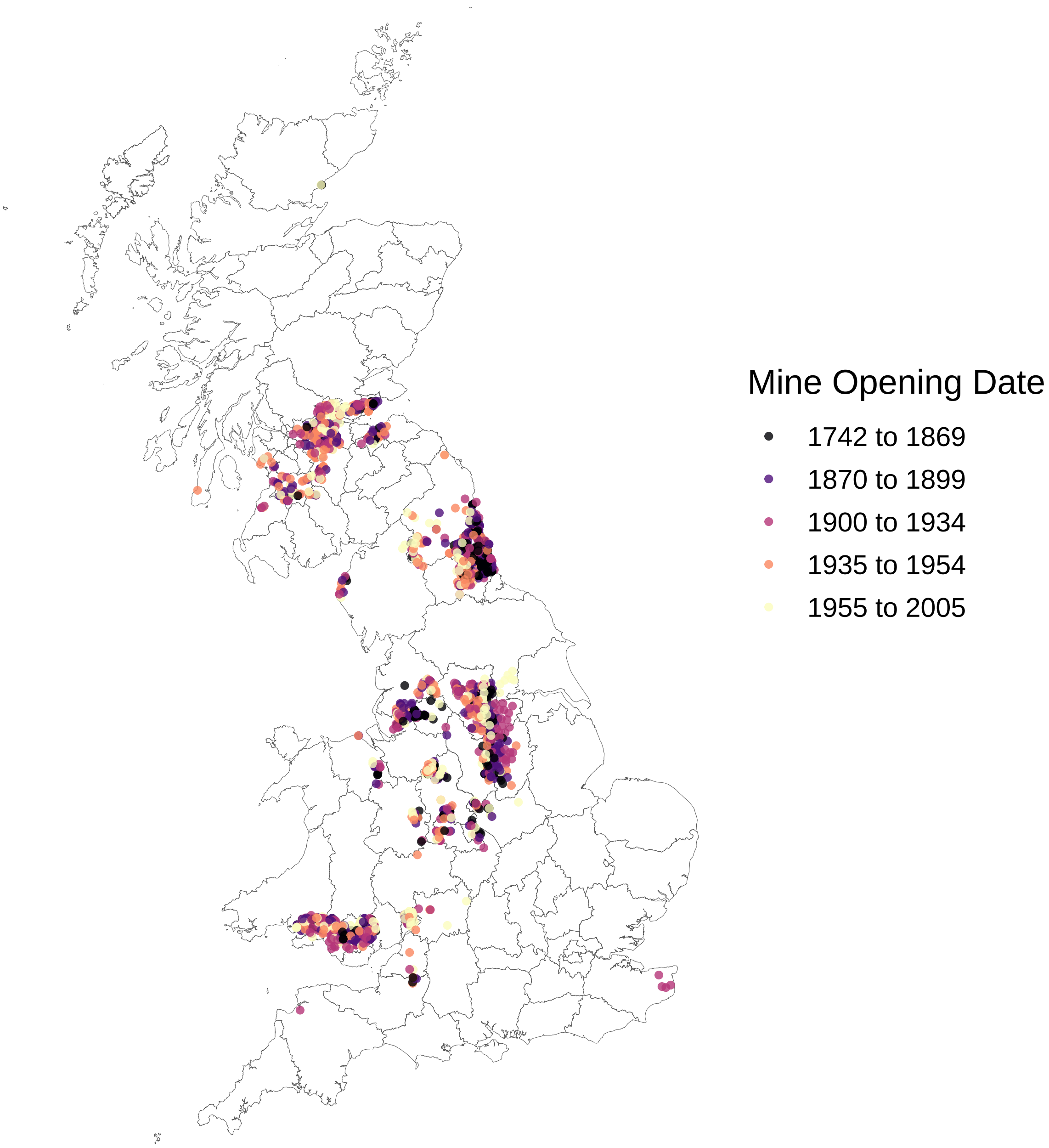


D) BCS Age 16 (in 1986)



Notes: Share of individuals with bad health in longitudinal surveys NCDS (born in 1958) and BCS (born in 1970) at age 0 and 16 across 1981 British counties. Return to main text.

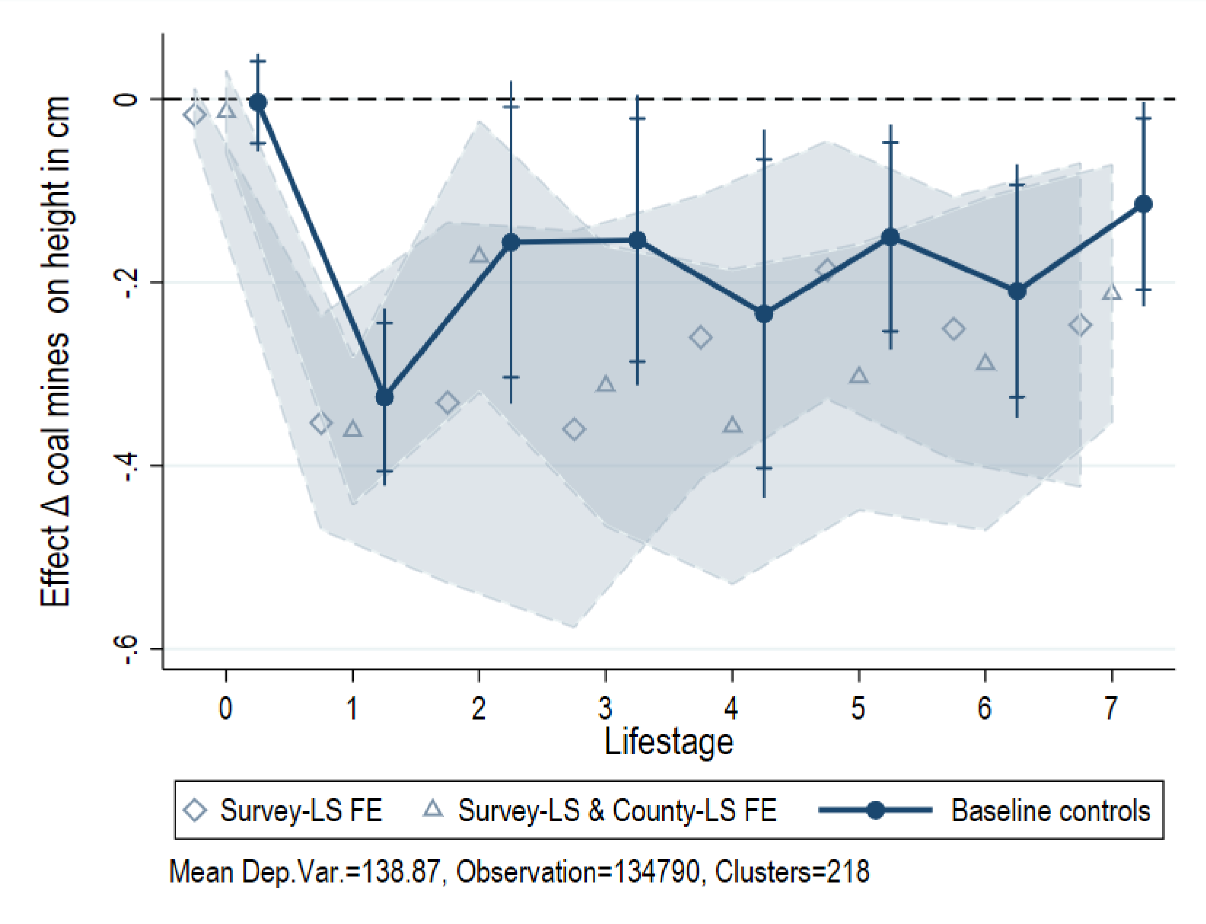
Figure B.5: Opening Dates of Mines in operation in 1957



Notes: The map shows the opening dates of mines in Great Britain. Data Source: Northern Mine Research Society.
Return to main text.

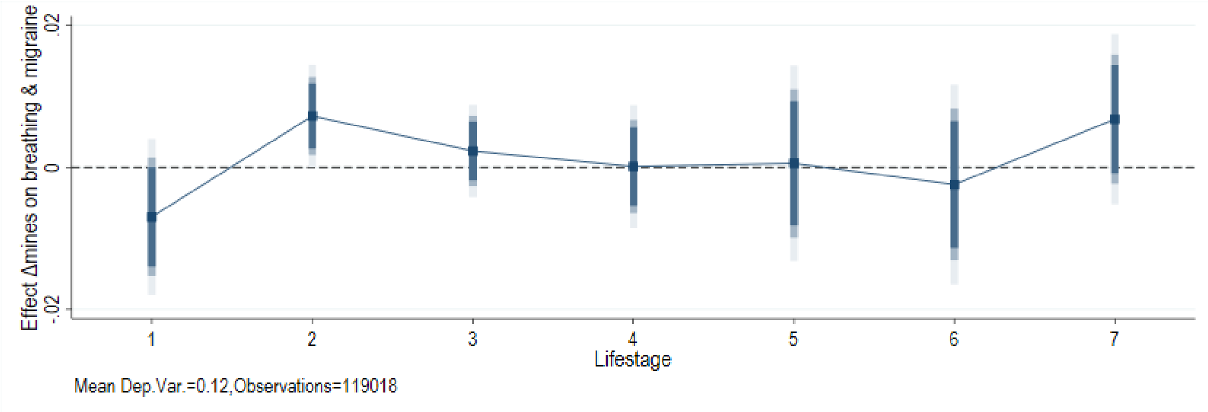
B.2 Additional results

Figure B.6: Effect coal mine closures on height in centimeters



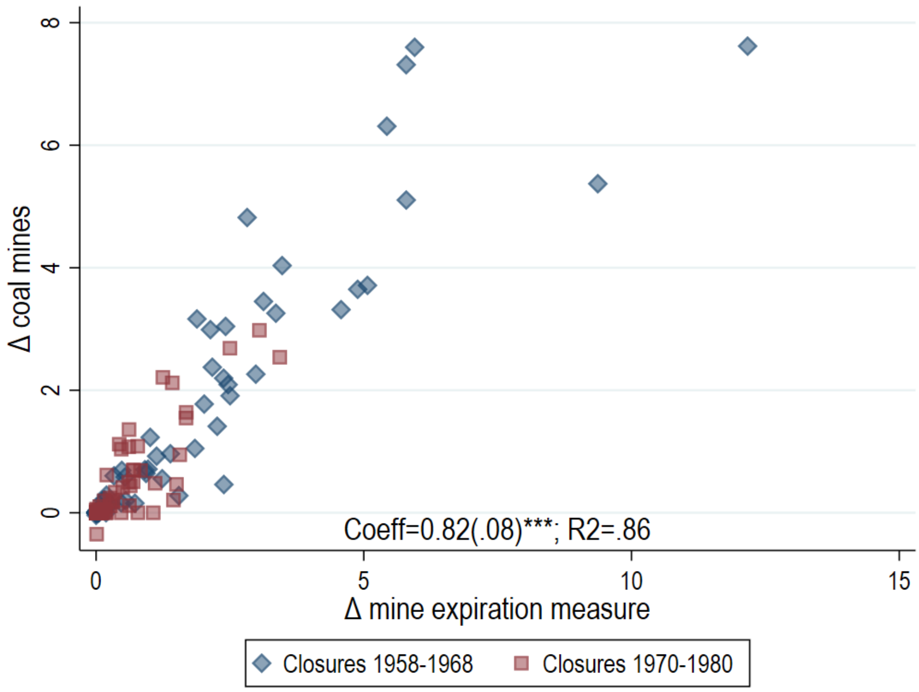
Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on height in centimeters over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Dark blue dots depict our baseline estimates including controls for survey-life-stage, county-life-stage and controls for initial household characteristics interacted with life-stage fixed effects. Initial characteristics are mother height, educated, smoker, and married as well as father household member, coal miner and social class. 90% & 95% confidence intervals depicted. Diamonds depict estimates including solely survey-life-stage fixed effects. Triangles depict estimates including solely survey-life-stage and county-life-stage fixed effects. The shaded areas depict the respective 90% confidence intervals. Standard errors clustered at county-survey level. Return to main text.

Figure B.7: Effect coal mine closures on migraines and breathing



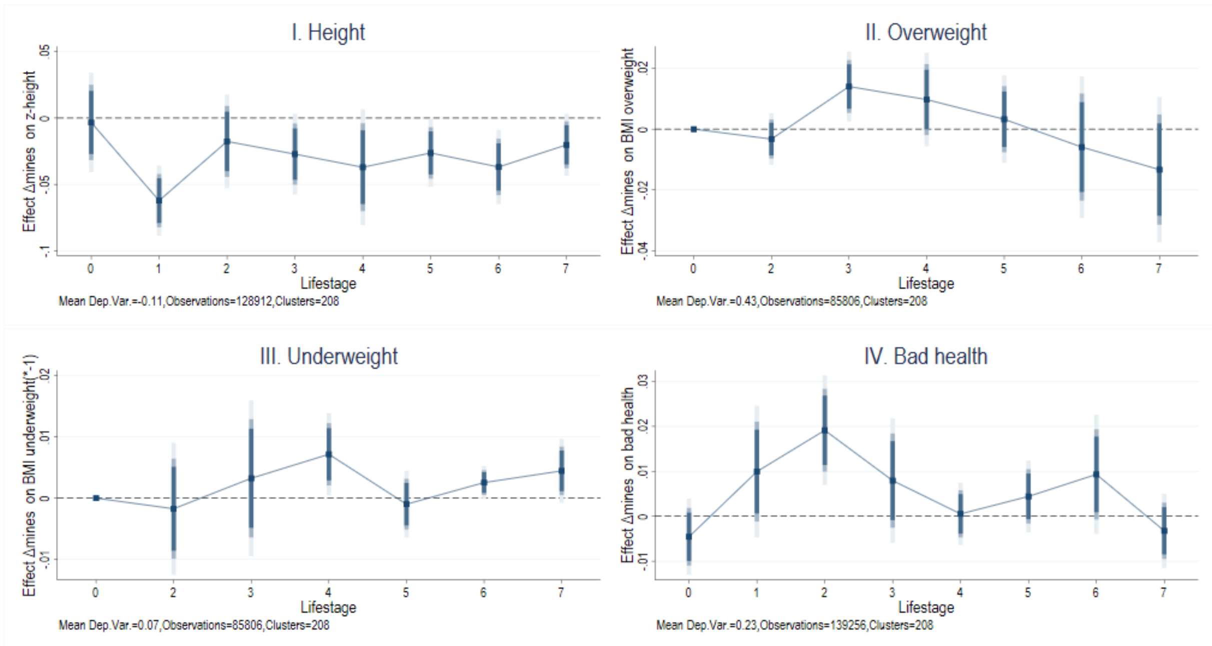
Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on migraine and breathing problems over an individual's life-stages. Life-stages on $x-$axis are: 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.8: Robustness: Instrumental Variable Strategy - First Stage



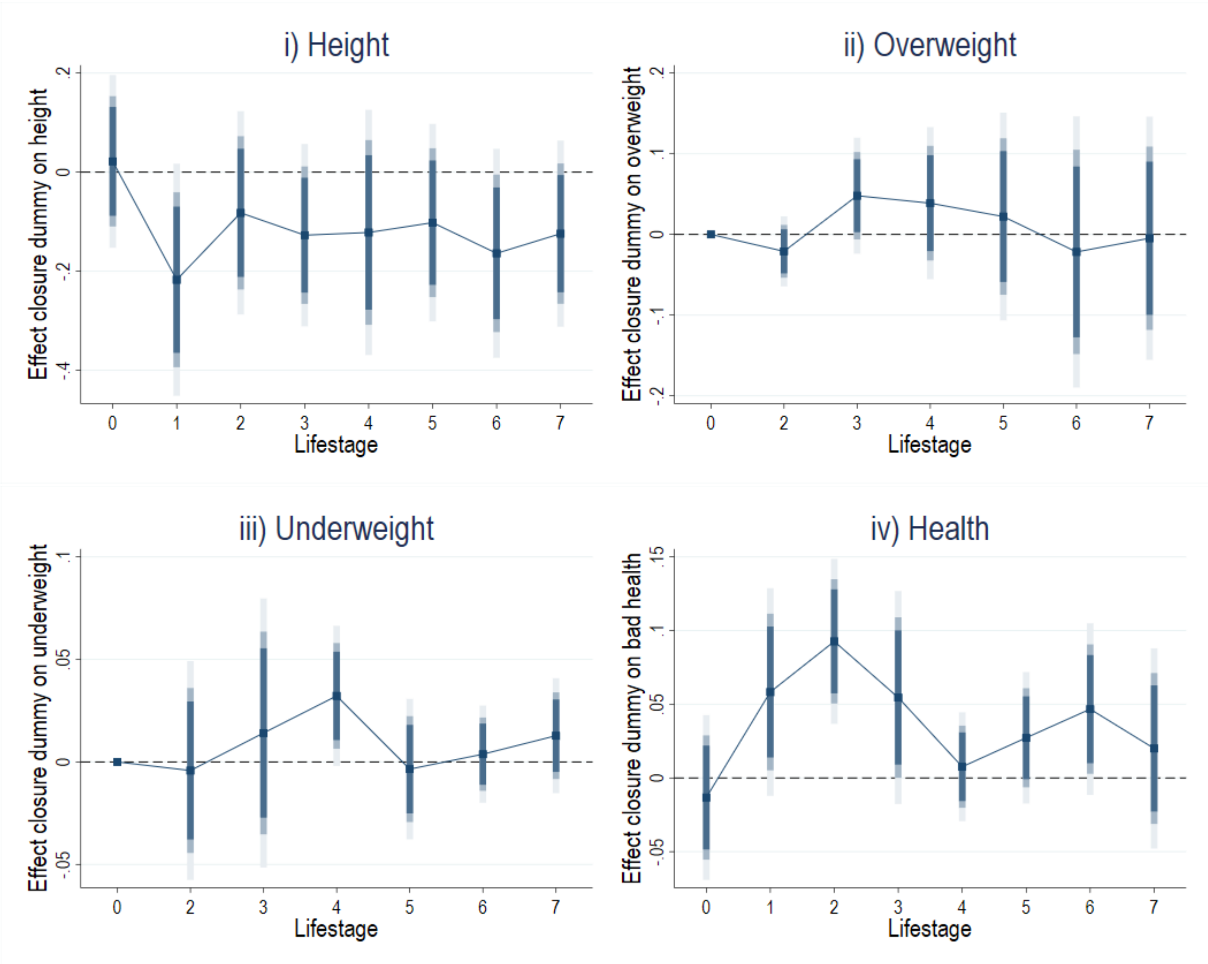
Notes: The figure visualizes the first-stage relationship between our measure of mine expiration on the x-axis and the actual childhood mine closures across counties for the NCDS (blue-diamonds) and BCS (red-squares) cohort. Return to main text.

Figure B.9: Robustness - Specification - Focus on NCDS-treatment



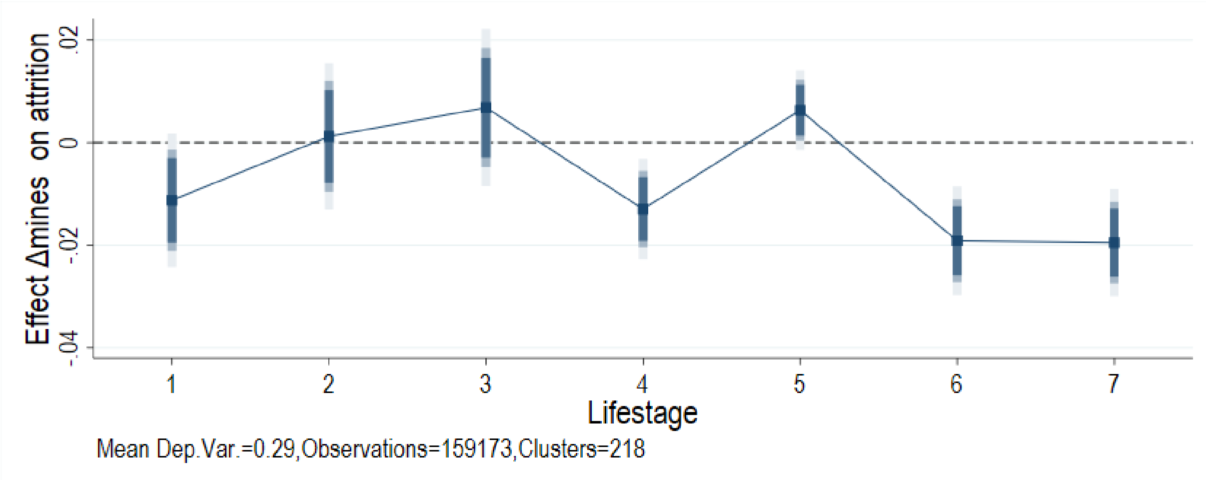
Notes: The figure reports coefficient estimates depicting the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Sample restricted to counties that are primarily treated in the period 1958-1968. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.10: Robustness - Specification - Binary treatment at county level



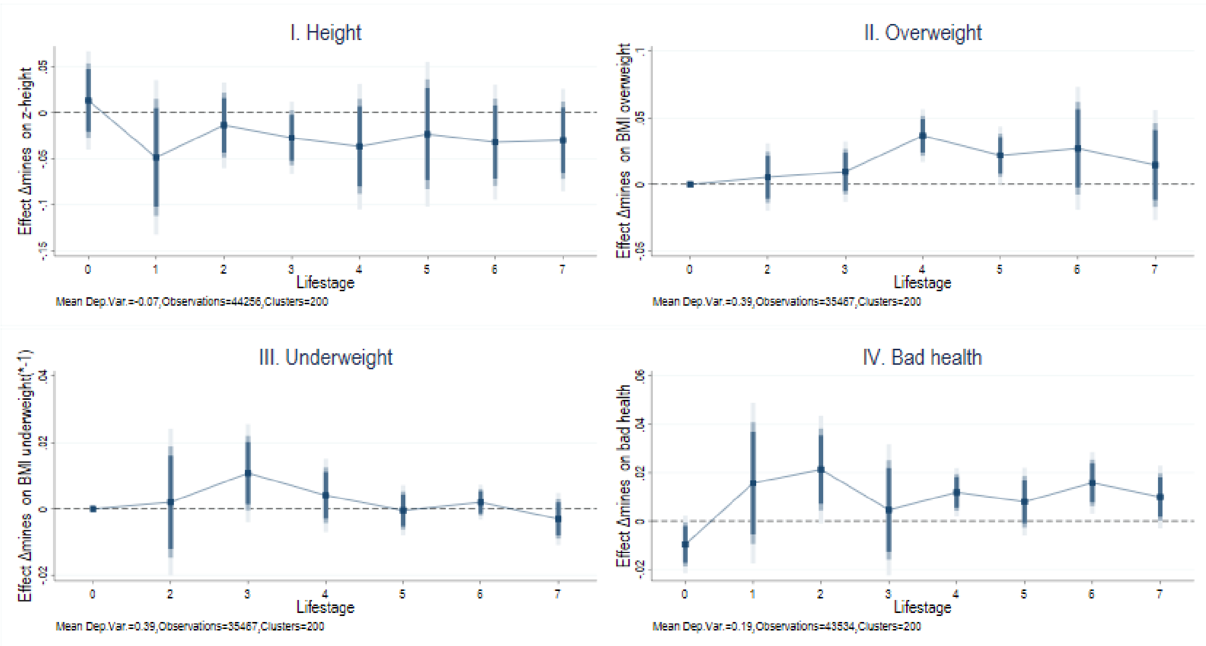
Notes: The unit of observation is the county. The figure reports coefficient estimates for first-difference regressions using a dummy variable treatment at the county level that is estimated individually for each lifestage. Areas that were more than one standard deviation exposed to coal mine closures (in period 1958-1968 minus 1970-1980) classified as treated (22 counties). Control group are areas that experienced no coal mine closures in either period (59 counties). Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Estimates weighted by 1981 county population. 90%, 95% & 99% confidence intervals depicted. Robust standard errors. Return to main text.

Figure B.11: Robustness: Treatment and sample attrition



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on missing survey response for an individual's life-stages. Life-stages on $x-$axis are: 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

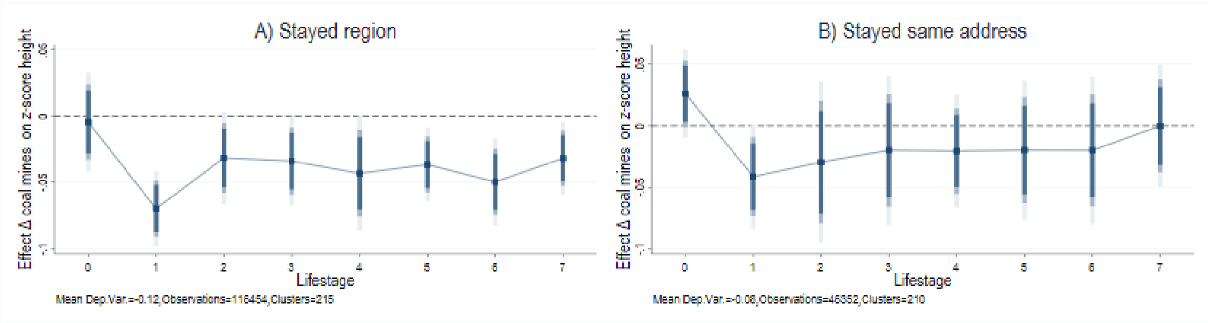
Figure B.12: Robustness: Effect in sample without attrition



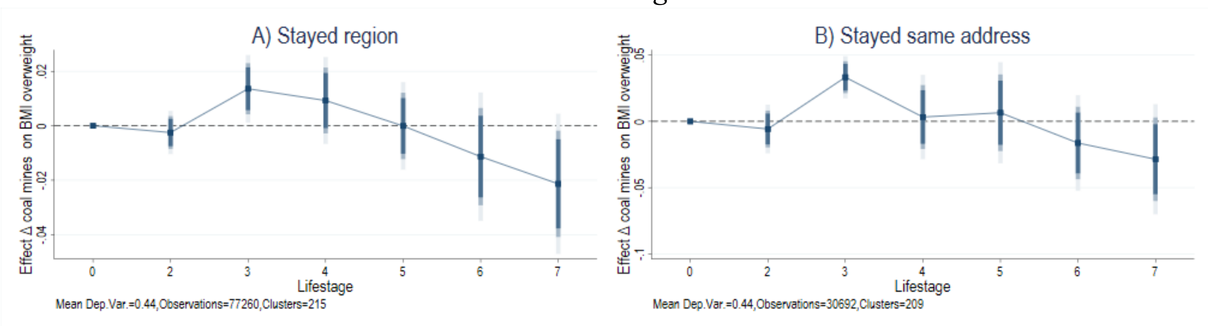
Notes: The figure replicates baseline results for the sample of individuals that are observed in all periods. Coefficient estimates depict the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.13: Robustness: Sample not moved during early childhood

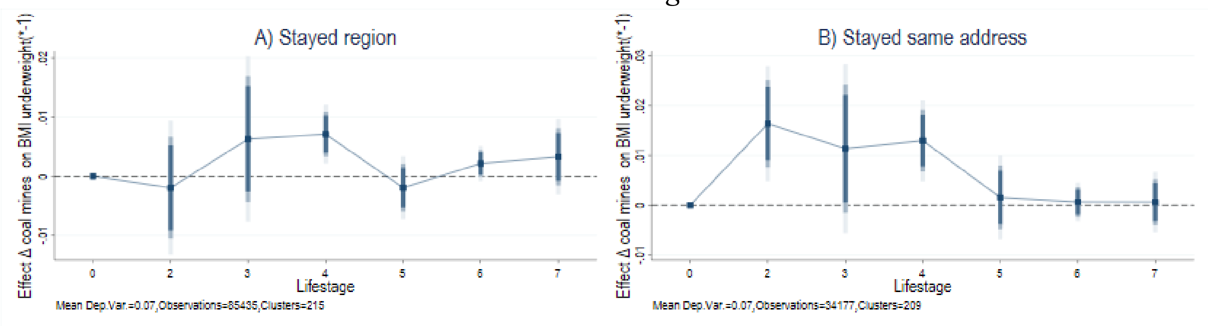
I. Height



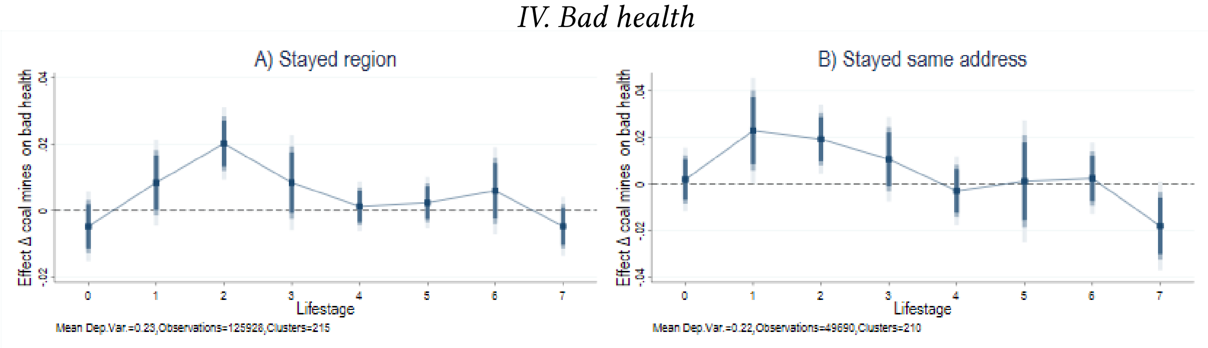
II. Overweight



III. Underweight



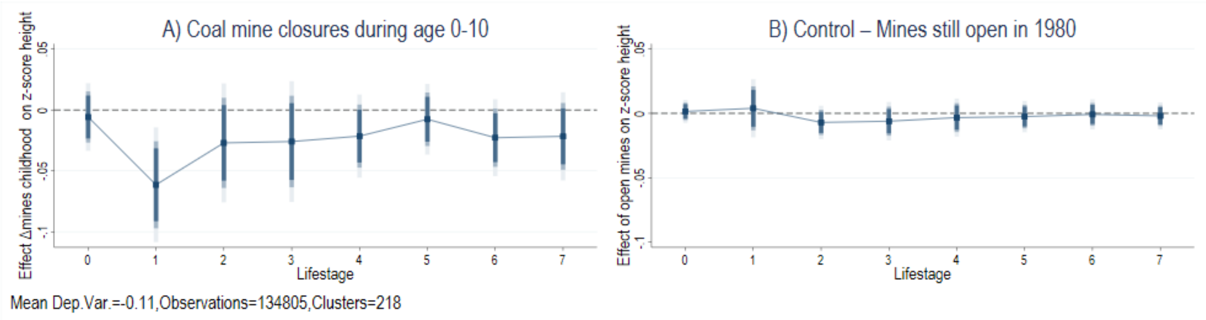
IV. Bad health



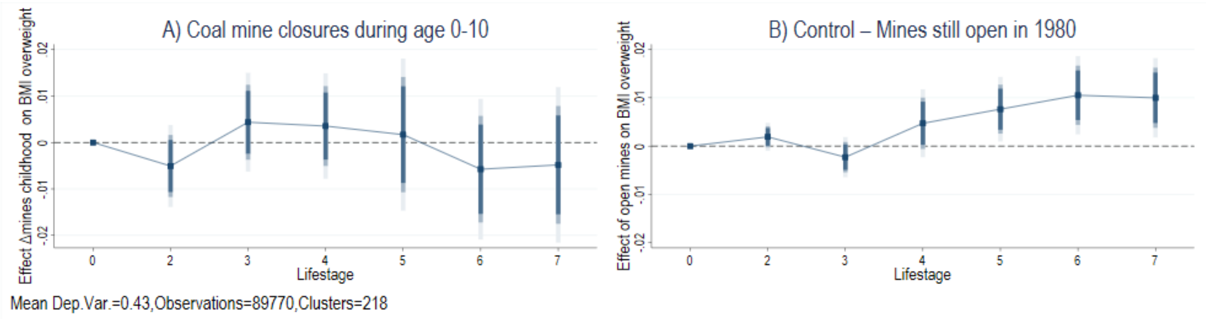
Notes: The figure replicates baseline results for the sample of individuals that did not move during childhood. Not having moved is defined as living in the same region at lifestage 2 as at birth (panel A) and as living in the identical address at lifestage 1 as at birth (B). Coefficient estimates depict the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level.Return to main text.

Figure B.14: Robustness: Effect of non-closed mines

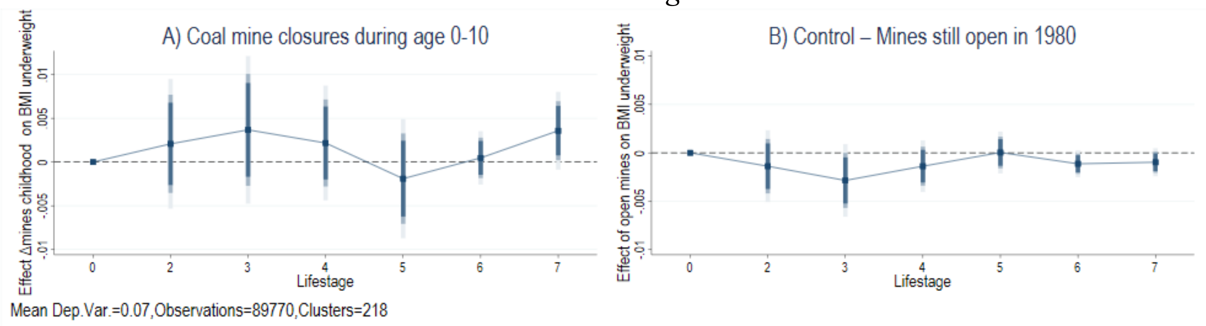
I. Height



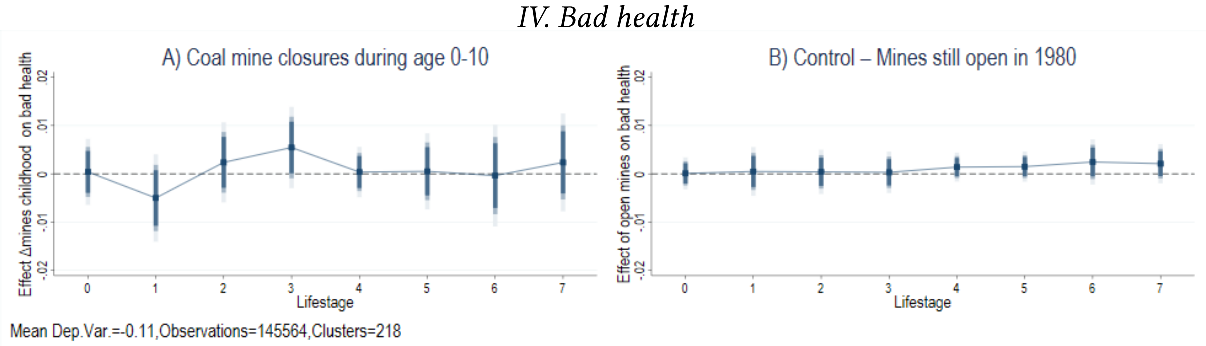
II. Overweight



III. Underweight

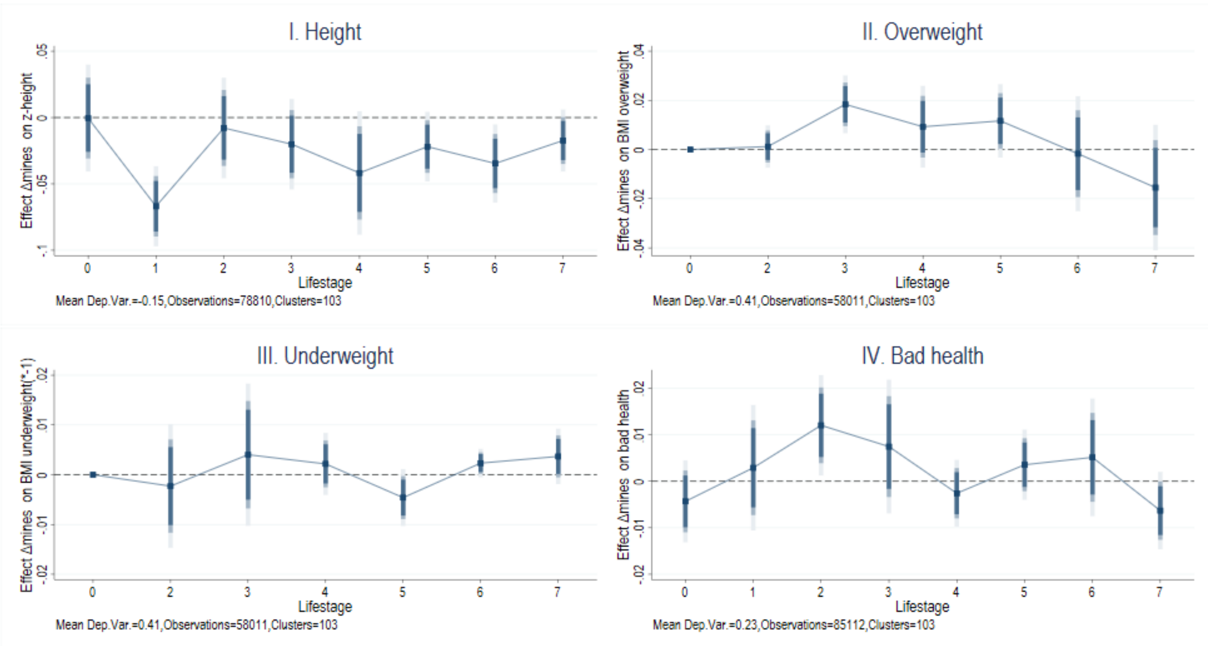


IV. Bad health



Notes: The figure reports coefficient estimates for the effect of pit closures during childhood (panel A) and mines that remained open until at least 1980 (panel B) on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. No county-lifestage fixed effects included as they perfectly absorb any variation in surviving mines. Coefficient estimates depict the effect of a one standard deviation higher exposure. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level.Return to main text.

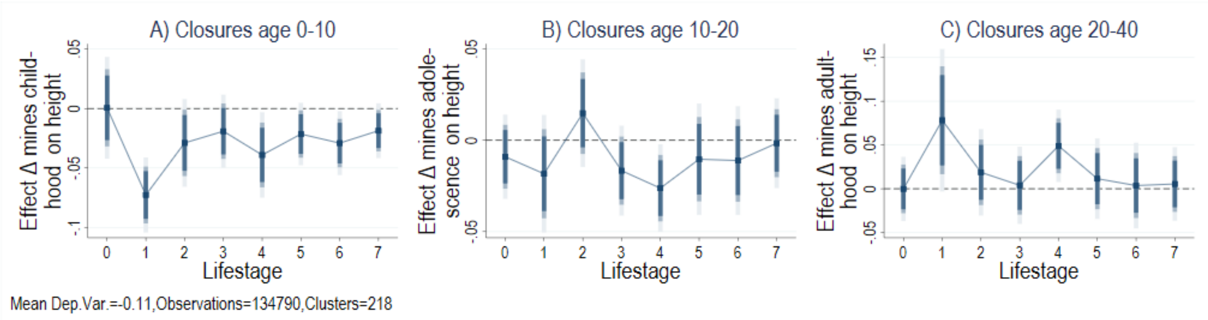
Figure B.15: Robustness: Effect in the sample restricted to only coal mining areas (NCDS & BCS)



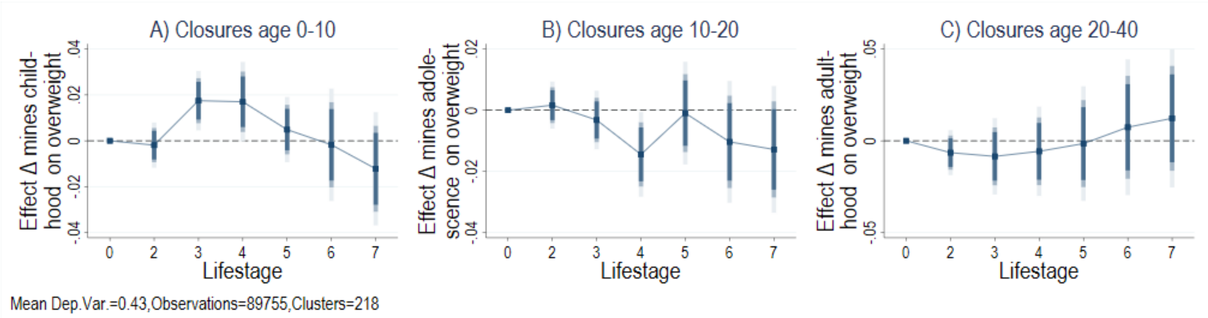
Notes: The figure reports coefficient estimates depicting the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Sample restricted to coal mining areas only (active mine by 1958). Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.16: Robustness: Effect coal mine closures in later life periods

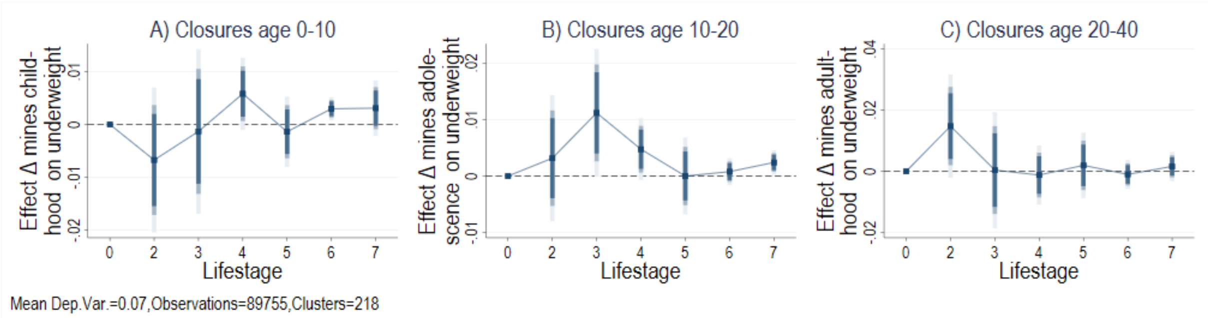
I. Height



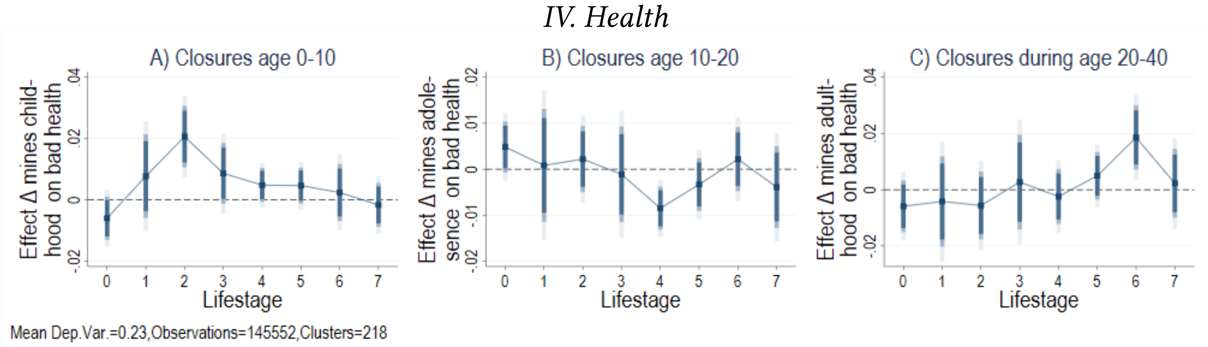
II. Overweight



III. Underweight



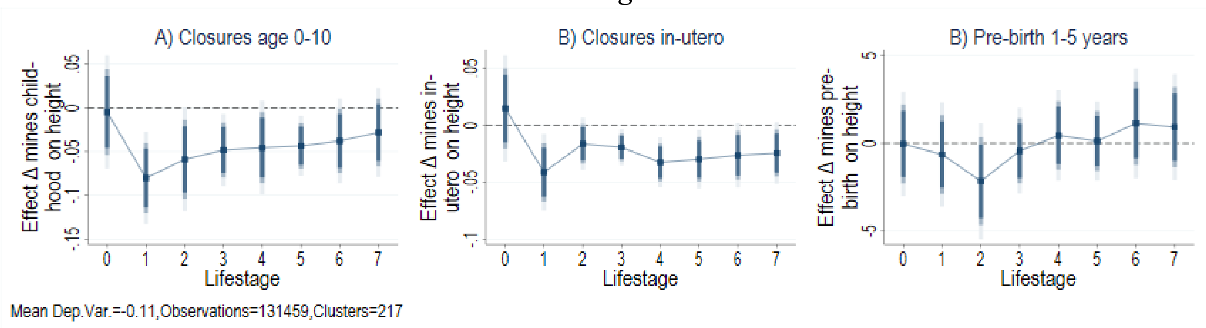
IV. Health



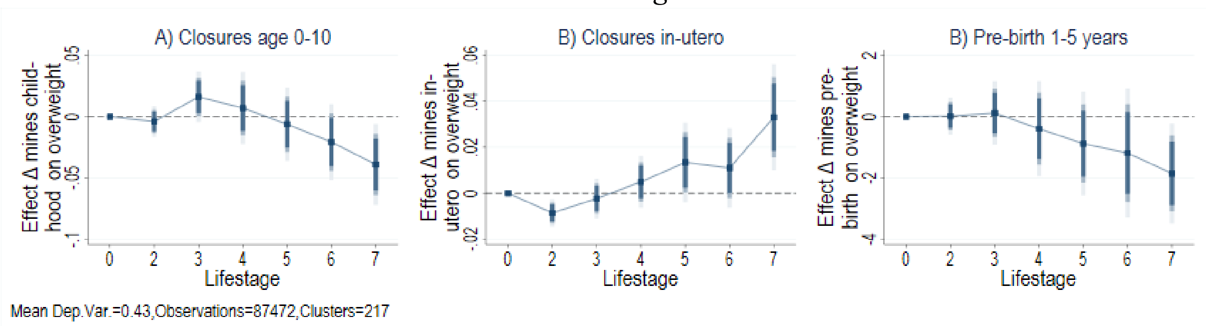
Notes: The figure reports coefficient estimates depicting the effect of a one standard deviation higher exposure (A) to pit closures per 1,000 inhabitants during childhood (B) age 10 to 20, and (C) age 20 to 40 on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.17: Robustness: Effect coal mine closures in-utero and pre-conception

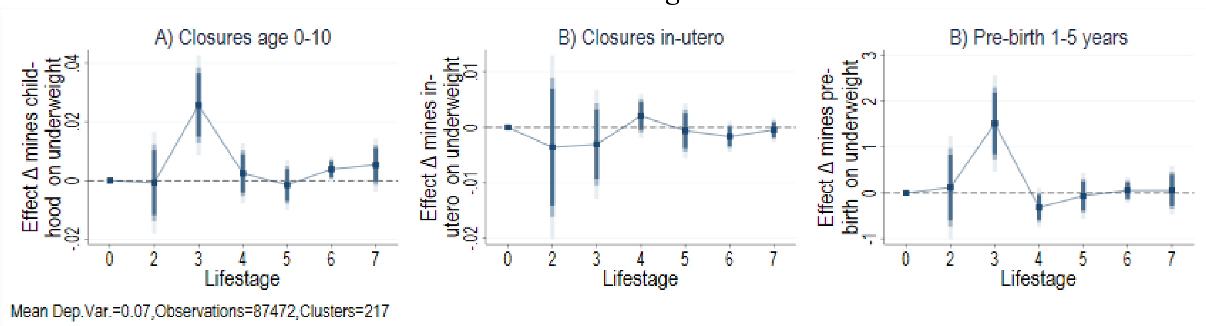
I. Height



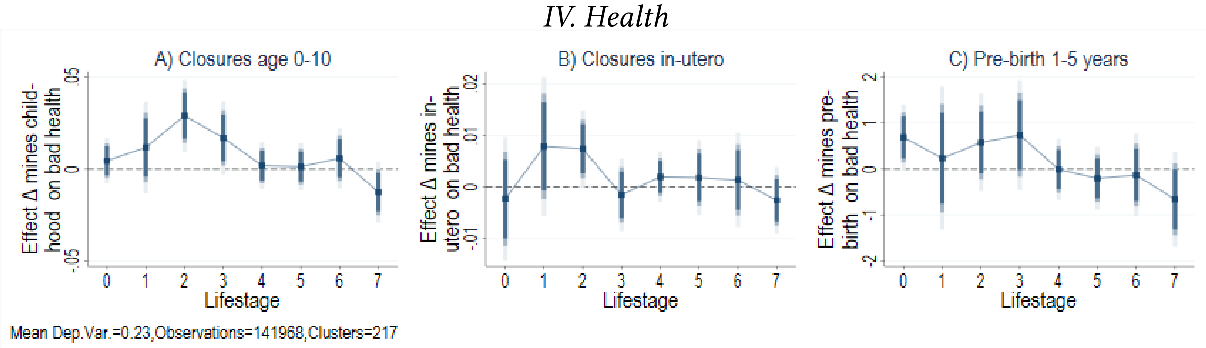
II. Overweight



III. Underweight

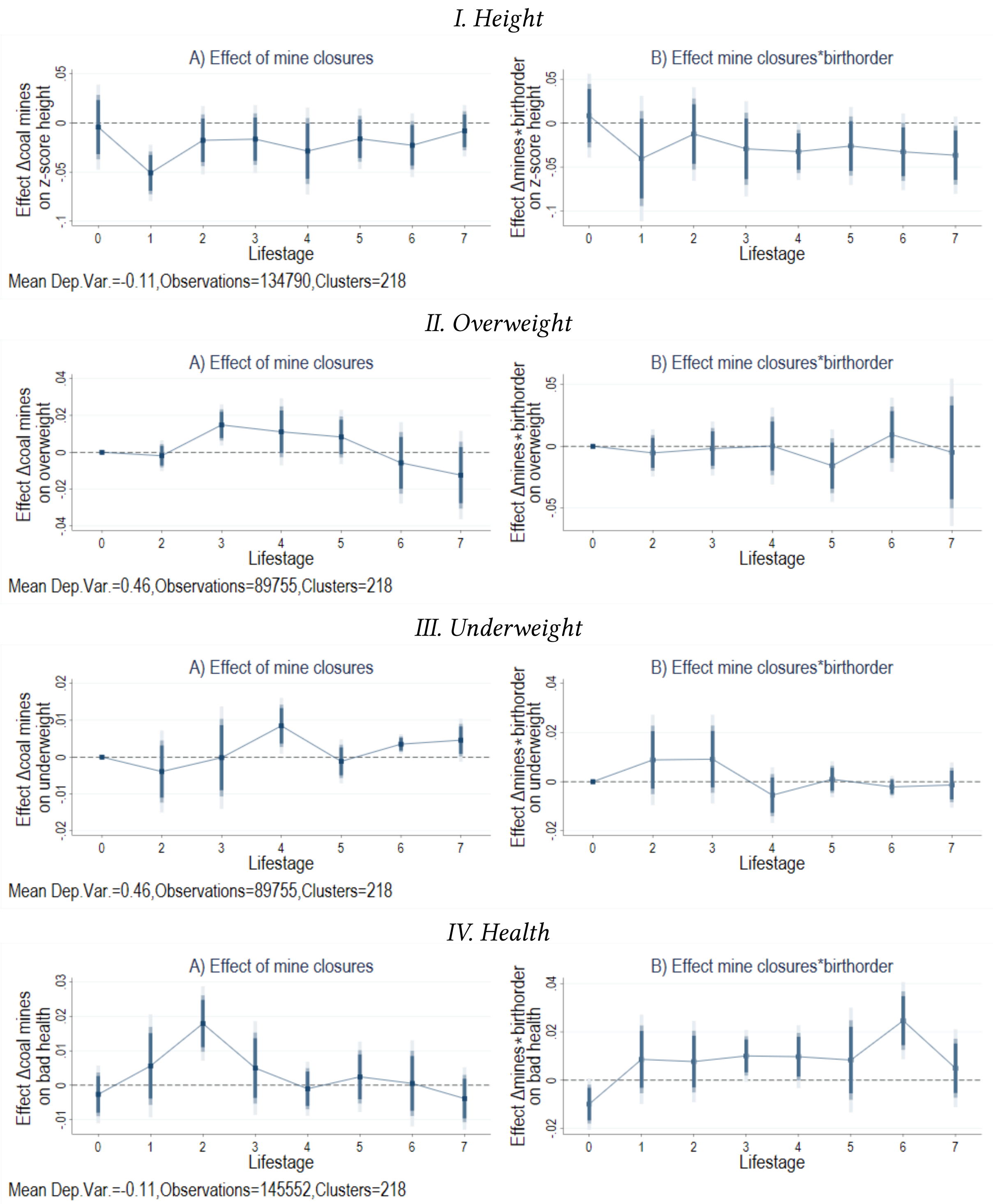


IV. Health



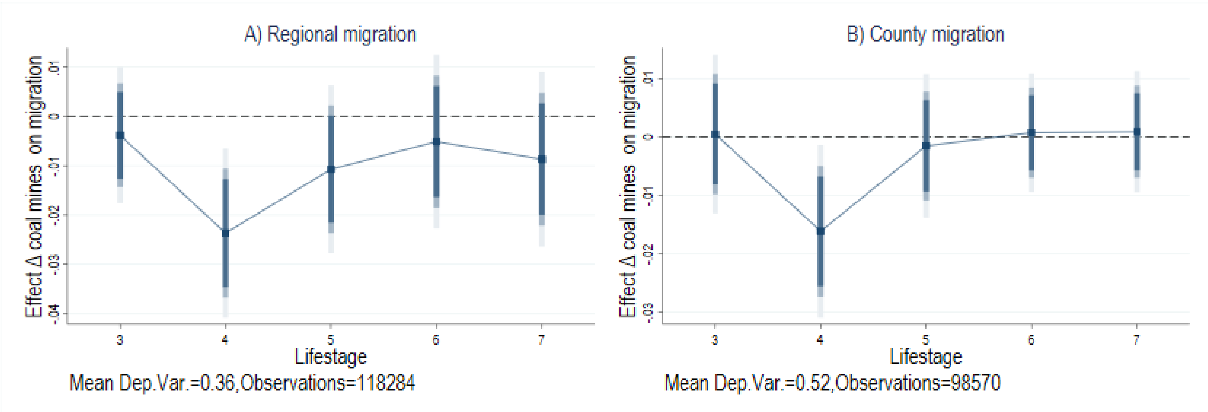
Notes: The figure reports coefficient estimates depicting the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood (panel A) during in-utero (B) , and 1 to 5 years before birth (C) on z-score height, BMI over- and underweight categories and bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.18: Mechanisms - Effect coal mine closures on anthropometrics by birthorder



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood (panel A) and the variables interaction with the individuals birth-order being higher than third (B) on (i) z-score height, (ii) over- and (iii) underweight, and (iv) bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey. Return to main text.

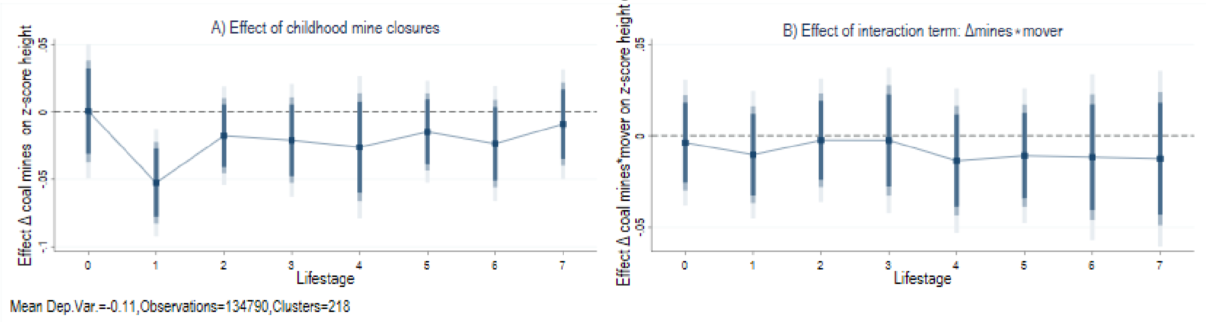
Figure B.19: Mechanisms: Effect on migration decision



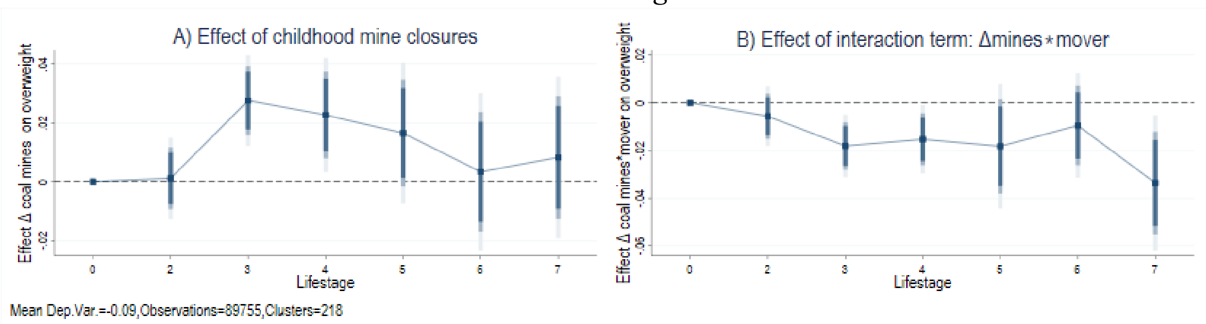
Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood on an individual moving between regions (panel A) and counties (B) after childhood. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered at county-survey level. Return to main text.

Figure B.20: Mechanisms: Effect coal mine closures on anthropometrics by migration of individual

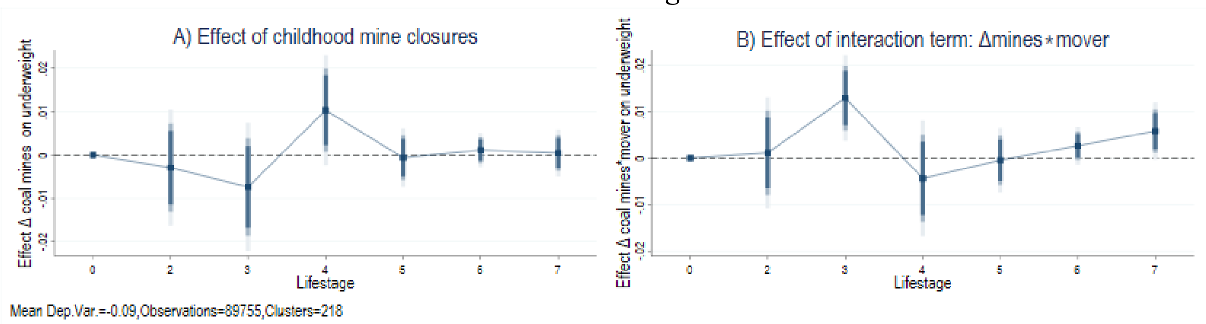
I. Height



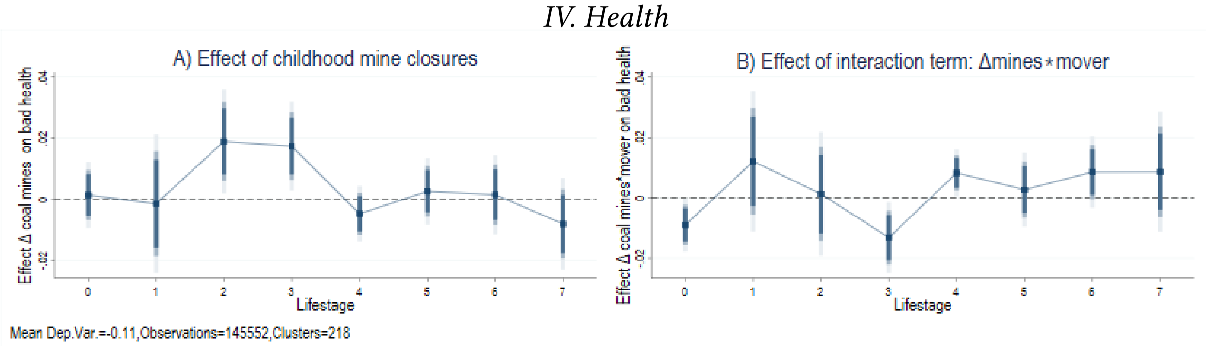
II. Overweight



III. Underweight

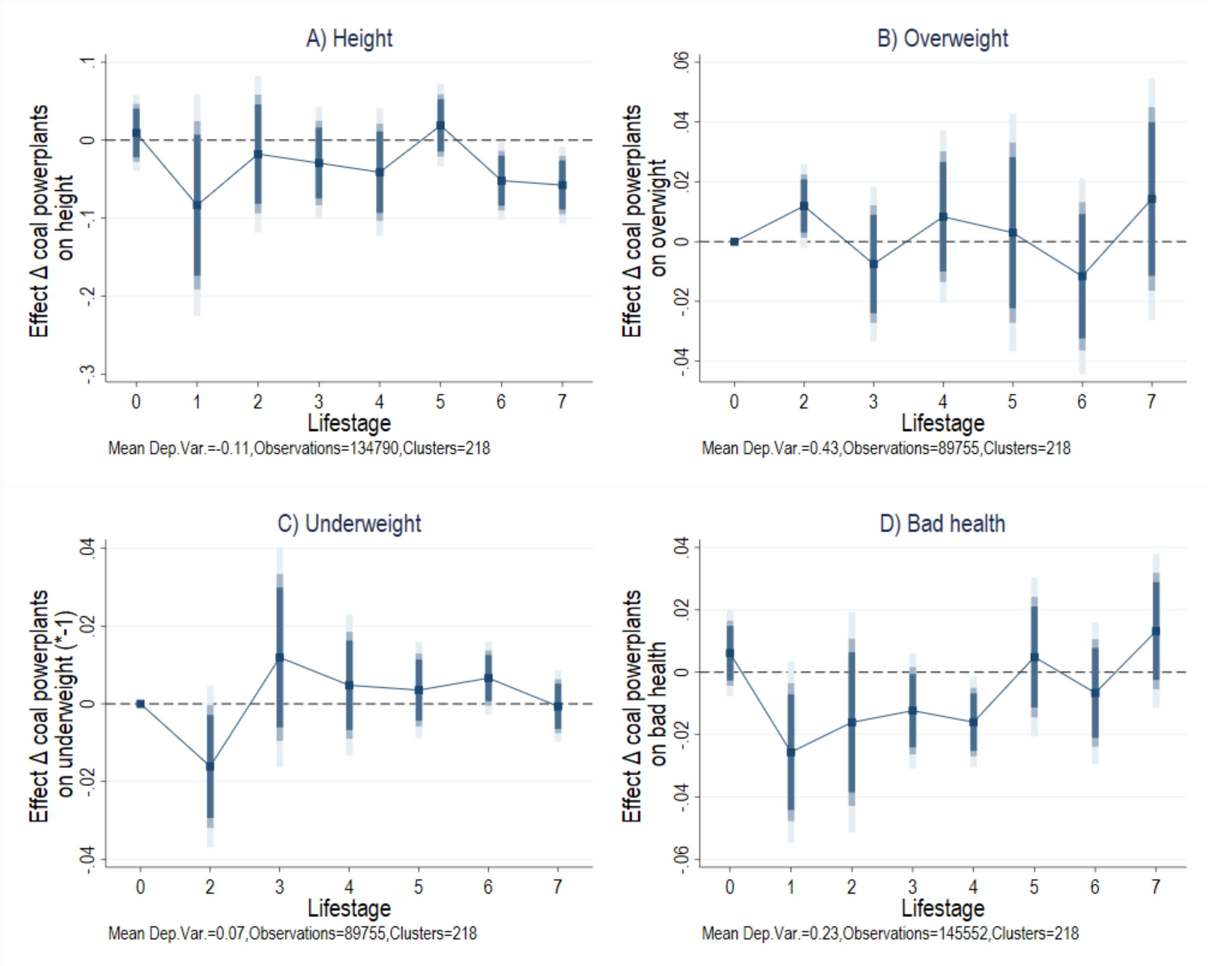


IV. Health



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to pit closures per 1,000 inhabitants during childhood (panel A) and the variables interaction with the endogenous decision of an individual to migrate (panel B) on (i) z-score height, (ii) over- and (iii) underweight, and (iv) bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey. Return to main text.

Figure B.21: Mechanisms: Effect of coal powerplant closures



Notes: The figure depicts coefficient estimates for the effect of a one standard deviation higher exposure to the closure of coal-powerplants within a 20km radius during childhood on (i) z-score height, (ii) over- and (iii) underweight, and (iv) bad health over an individual's life-stages. Life-stages on $x-$axis are: 0 birth; 1 early-; 2 mid-childhood; 3 adolescence; 4 early-; 5 young-; 6 mid-adulthood; 7 late 40s. Baseline controls included. 90%, 95% & 99% confidence intervals depicted. Standard errors clustered on county-survey. Return to main text.

C Data

This section provides detailed information on the harmonized variables constructed across the NCDS and BCS, something that to the best of our knowledge has not been done before to the extent done in our paper. Table C.1 provides a list of the harmonized variables we constructed (column 1), references to the Figures and Tables were these variables were the outcome of interest (2), and the original variable codes in the NCDS (3) and BCS (4). Columns 3 and 4 report in brackets the respective lifestage to which the variable code corresponds (the corresponding age/sweep in the NCDS and BCS are described in the main paper). The below sections provide additional information for the harmonized variables where relevant.

C.1 Height and weight

The measure height is obtained from the waves of the NCDS and BCS. In both the NCDS and BCS wave (at birth) no height is reported and the height data is instead calculated using WHO conversion tables.[40] For all other waves height data for individuals was available in the NCDS and BCS. Different units of measurements are used across the two studies and their sweeps, we harmonize all to be in meters. For example, the information is converted into meters from feet and inches by multiplying with a factor 0.3048 and 0.0254, respectively. As feet and inches are less precise this creates some bunching of the data in certain waves. To obtain as much information as possible we use height data measured by the surveyor as well as individual's self-reported height information as available (using surveyed information and those in meters before exploiting other measures if more than one data source is available). The BCS at age 42 collected height only for very few observations for this reason we use the average height for the individual based on height reported at age 34 and 46. We treat implausible/misreported values as missing. Figure B.2 depicts the average height in centimeters across counties at age 0 and 16 for NCDS and BCS.

Weight data is available for all our waves used in the NCDS, but missing at age 5 in the BCS. For this reason we are unable to estimate the impact of mine closures on weight at lifestage 1 (age 5/7). We construct data to be in kilograms (converting data reported e.g. in stones and pounds). Figure B.3 depicts the average weight in kilograms across counties at age 0 and 16 for NCDS and BCS.

We standardize height and weight data to be in height and weight zScores (using age) and BMI (weight measure with regards to height) using code from Vidmar et al. (2013) and World Health Organization (2006) tables.

C.2 Health outcomes

The measure of bad health is constructed from a set of different available indicators as a dummy variable where 0 indicates good health and 1 indicates bad health (no available response is treated as a missing health outcome).

During childhood no straightforward health measure is available that is consistent between the NCDS and BCS. Accordingly, we construct bad health based on a set of reported illnesses and the incidents of missed school. In the NCDS at age 0 bad health is constructed on some type of fetal distress being recorded (variable: n535) or an illness of the baby being reported (n1831). At age 7 the occurrence of many colds or poor respiration (n470) as well as frequent headaches

[40]See Girl and Boy birth weight-for-length charts: https : //www.who.int/tools/child − growth − standards/standards/weight − for − length − height

(n277) is being used. At age 11 again the occurrence of many colds or poor respiration (n1077) and frequent headaches (n1341) are used. At age 16 the frequent absence from school due to ill-health (n2553) as well as frequent headaches (n2624) are being used.

In the BCS at age 0 bad health is constructed on a number of variables recording fetal distress and illness of the baby (a0325-a0335), e.g. breathing difficulties of the baby or whether any operations needed to be performed. At age 5 the occurrence of wheezing (e087), i.e. breathing problems, as well as frequent headaches is being used (d006). At age 10 again wheezing (b7_1) and frequent headaches (m15) are being used. At age 16 the frequent absence from school due to ill-health (oc1_1) as well as frequent headaches (c5o4) are being used.

From age 23 a consistent variable of self-reported health is available in the NCDS and BCS, where any health outcome worse than "Good" is coded as bad health (usually called: "Fair", or "Poor"), while responses like "Good" and "Excellent" are coded as the individual not being in bad health.

The NCDS (1958) and BCS (1970) provide a wide range of different health outcomes (e.g. depressions, eating disorders, excessive drinking, drug abuse, cancer, diabetes, back pain, migraines, and breathing problems). The detailed variable codes are listed in Table C.1. Depression is the only variable of these that is not consistent in its recording over time. Depression during childhood is recorded based on doctor or mothers assessment of a child being "depressed or miserable", while in later sweeps the individual reports itself whether they are "frequently miserable or depressed". Questions on all these outcomes are only recorded in selected sweeps, we use as much data as is respectively available for our analysis. In addition, health histories are particularly comprehensive recorded and comparable in the NCDS (1958) and BCS (1970) at lifestage 5 (age 33 NCDS and 34 BCS). This is due to a unique set of questions asking whether the individual ever had any of a vast set of health issues at age 33 in the NCDS and age 29 in the BCS (the later is combined with a question on current health at age 34 to obtain this information at lifestage 5 for both studies). Accordingly, there are two ways health data is recorded: (i) whether a health problem ever occurred during an individual's life up to the lifestage 5 and (ii) whether the individual currently has the respective health issue (over the last 12 months or since the last interview) based on each individual sweep where this data is available. Accordingly, we construct two sets of outcomes, first, whether an individual ever had a certain health problem as reported at lifestage 5 (in their 30s) with results from these measures being reported in Table 3 and A.4. Second, for a subset of outcomes where we have comparable data available for a multitude of lifestages we also construct current health outcomes over an individuals lifetime, which is the source of the outcome variables in the remaining health related Figures and Tables.

The only exception are the data on drug abuse and death. The question used for drug abuse in Table A.2 provides information on when drugs first became an issue for the individual's life, which we recode into dummy variables for it being an issue at age 20 and age 30. The special license death data used in Figure 10, Table 2 and A.3 reports year and month of death of individuals, we use the yearly information to look at death rates by year using the Kaplan-Meier failure estimates and Cox proportional hazard models.

C.3 Father miner

In the NCDS the first time father's occupations are recorded in detail is in the age 7 sweep, which provides information whether a father is a miner (variable n189 using GRO 1960 code). Importantly, the coding includes at the point in time unemployed, sick or retired individuals providing a good proxy for whether the individual's father was a coal miner at birth and is part of a family that is involved in coal mining. We also confirm the validity of this variable for father being a miner using whether the mother is from a mining family, namely n525 recorded at birth. Unfortunately this question on whether mother is from a mining family is only asked in the NCDS and not the BCS, which is why we use the more consistent variable n189.

In the BCS the first time father's occupations are recorded in detail is in the age 10 sweep. The available variable (c3_6 & c3_7) provide detailed self-reported occupational descriptions (e.g. coal mining, underground miner, etc) and industry codes for fathers, respectively. Again the variables include at the point in time unemployed, sick and retired individuals. Accordingly, we use this information to construct a proxy variable whether the father was a coal miner at birth.

Table C.1: Harmonized variables sourced from NCDS and BCS

Harmonized outcomes	Dependent Variable in Figures and Tables	Original variables used to construct harmonized outcomes in NCDS	in BCS
Height	Figure 4, 11, 12, 14, B.18, A.6, Table 1	n574(0); dvht(1–3); dvht23(4); n504731(5); htmetre2, htcms2, htfeet2, htinche2(6); DVHT50(7)	a0278(0); f102(1); meb17(2); rd2_1, ha1_2(3); b960433, b960434, b960436, b960437(4); bd7htmtr, bd7htcms, bd7htft, bd7htins(5); B9HTMEES, B9HTCMS, B9HTFEET, B9HTINES(6); B10HTMEES, B10HTCMS, B10HTFEET, B10HTINES(7)
Weight	Figure 5, 6, 11, 12, 14, B.18, A.6, Table 1	n574(0); n337(1); n1515(2); n1953(3); dvwt23(4); n504734(5); wtkilos2, wtstone2, wtpound2(6) DVWT50(7)	a0278(0); meb19_1(2); rd4_1, ha1_1(3); b960443, b960439, b960441(4); b7wtkis2, b7wtste2, b7wtpod2(5); B9WTKIS, B9WTSTE, B9WTPOD(6); B10WGTONLY, B10MWEIGHT, B10WTKIS, B10WTSTE, B10WTPOD(7)
Bad health	Figure 7, 11, 12, 14, B.18, A.6, Table 1	n535, n1831(0); n470, n277(1); n1077, n1341(2); n2553, n2624(3) n5739(4); n503913(5); hlthgen(6); N8HLTHGN(7)	a0325–a0328, a0330–a0332, a0335(0); e087, d006(1); b7_1, m15(2); oc1_1, c5o4(3); b960432(4); b7khlstt(5); B9HLTHGN(6); B10HLTHGN(7)
Mother age	Table 1, A.6	n553(0)	BD1MAGE(0)
Mother educated	Table 1, A.6	n537(0)	a0009(0)
Mother height	Table 1, A.6	n510(0)	a0197(0)
Mother smoker	Table 1, A.6	n502(0)	b0024(0)
Mother married	Table 1, A.6	n545(0)	a0012(0)
Father age	Table 1, A.6	n494(0)	BD1FAGE(0)
Father SC I & II	Table 1, A.6	n492(0)	a0014(0)
Father miner	Table 1	n189(1)	c3_6, c3_7(2)
Father absent	Table 1, A.6	n236(0)	a0015(0)
Birth/HH order	Table 1; A.5	n297(0), n1116(2), n1120(2)	a0163(0), a4a(2)
Father unemployed	Table 1, Figure 13,	n236(0); n188(1); n1172(2); n2383(3)	a0015(0); e203b(1); c2_3(2); t8_1(3)
Father SC (other)	Table 1, Figure 13, Table 4	n236, n492(0); n190(1); n1687(2); n2384(3)	b0018, a0014(0); e197(1); c3_4(2); t11_2(3)
Depression	Figure 8	n137, n436(1); n980, n1451(2); n2525(3); n6018(4); n504240(5); mal03(6); N8MAL03(7)	d033(1); m256(2); rc4_2, pd1_3, c5o3(3) b960460, b960526(4); b7dep12m, b7k1, b7k1(5); B9SCQ41B, B9MHSTL1(6); B10Q28B, B10MHSTL1(7)
Excessive drinking	Figure 9	n2889–n2891(3); n5920(4); n504273(5); drinks(6); N8DRINKS(7)	f57_tot(3); b960567(4); b7drinks(5) B9SCQ32(6); B10DRKFQ(7)
Eating disorder	Figure 9	n130–n131(1); n2510(3); n6034(4); n504256 (5); eatprob, el112m, mal19(6)	d020–d023(1); m30(2); pa3_1(3); b960655(4); eatprob, el112m(5); B9KHPB10(6)
Death date (SL)	Figure 2; Table 10, A.3	DODMTH, DODYR	DODMTH, DODYR
Diabetes ever	Table 3, A.4	n503921(5)	diab(age-29), bd7hpb07(5)
Back pain ever	Table 3, A.4	n504028(5)	cl1age13(age-29), bd7hpb06(5)
contd. below			

Notes: The table reports the harmonized variables, their use, and the variable codes used to construct it from the NCDS and BCS. The sweep (in lifestages) is reported where the data is found is reported in parentheses. Some variables are taken from sweeps specific to one cohort-study due to the best possible fit in terms of age. In these cases age the respective age of individuals is reported in parentheses. SL in parentheses stands for the data being available only under UKDS Special Licence agreement requiring special approval. The remaining data can be obtained via the standard UKDS End User Licence.

contd: Harmonized variables sourced from NCDS and BCS

Harmonized Variable	Dependent Variable in Figures and Tables	Original variables used to construct harmonized outcomes in NCDS	in BCS
Migraine ever	Table 3,A.4	n503927(5)	hhfbane1(age-29), bd7hpb12(5)
Breathing ever	Table 3, A.4	n504017, n504018, n504021(5)	hhfbane1(age-29), bd7hpb01, bd7hpb02(5)
Cancer ever	Table 3, A.4	n503961(5), cancer, cl112m15(6)	cancer(age-29), bd7hpb07(5), B9KHPB07(6)
Weeks off illness	Table 4	n1185(2)	e203a(1)
Retirement & disability	Table 4	n1176–n1180(2)	c8_6–c8_8(2)
Free school meals	Table 4	n858(2)	m126(2)
Taken to pool	Table 4	n1141(2)	m94(2)
Taken to cinema	Table 4	n1143(2)	m91(2)
Taken to library	Table 4	n1144(2)	m95(2)
Shared bedroom	Table 4	n1157(2)	e228c(1)
Open coal heating	Table 4		d6_4(2)
Access hot water	Table 4	n1163(2)	e224(1)
Non-shared bathroom	Table 4	n1159(2)	d3_1(2)
Indoor toilet	Table 4	n1161(2)	
Damp issue	Table 4		d8_1(2)
Education	Table 5	actagel2(6)	b7lftme2(5)
Log pay	Table 5	n500542(5)	b7cnetpd(5)
Benefits	Table 5	n503313(5)	bd8stbe(age-38)
Howe owner	Table 5	n502979(5)	b7ten2(5)
Motherhood age	Table 6	n502023(5)	b7prgy11(5)
Motherhood under 21	Table 6	n502023(5)	b7prgy11(5)
Miscarriage	Table 6		b7preg11(5)
Early birth	Table 6	n502113(5)	b7prgf11(5)
Late birth	Table 6	n502113(5)	b7prgf11(5)
Newborn weight	Table 6	n502017, n502019(5)	b7poun11, b7ounc11, b7kilo11, b7gram11(5)
Newborn disorder	Table 6	n502116(5)	b7prgh11(5)
Drug abuse	Table A.2	n504262(5)	mhage8(age-29)
Migraine & breathing	Figure B.7	n259, n260, n277(1); n1305, n1341(2); n2622, n2624(3); n5762, n5763, n5770, n5771(4); n504018, n504019, n504024, n503927, n503919, n503928(5); wheezy, cl112m(6); N8KHPB01, N8MENS20, N8KHPB10(7)	d006, e087 e072(1); b10_1, b7_20, meb4_26, meb4_31, meb4_36, b11_17(2); ha4_5 ha4_6, ob6_1(3); b960448, b960449, b960512, b960514, b960515(4); b7asth2m, bd7hpb01; bd7hpb12(5); B9KHPB02, B9KHPB10(6); B10KHPB01, B10KHPB12(7)
Region	Figure B.19	Region0NCDS–Region9NCDS	BD1REGN
County (SL)	Figure B.19	N3CTY81–N9CTY81	B3CTY81–B9CTY81

Notes: The table reports the harmonized variables, their use, and the variable codes used to construct it from the NCDS and BCS. The sweep (in lifestages) is reported where the data is found is reported in parentheses. Some variables are taken from sweeps specific to one cohort-study due to the best possible fit in terms of age. In these cases age the respective age of individuals is reported in parentheses. SL in parentheses stands for the data being available only under UKDS Special Licence agreement requiring special approval. The remaining data can be obtained via the standard UKDS End User Licence.