Mining closure, gender and employment reallocations: the case of UK coal mines

Fernando M. Aragón* Juan Pablo Rud† Gerhard Toews‡

October 2015

Abstract

This paper examines the heterogenous effect of mining shocks on local employment, by gender. Using the closure of coal mines in UK starting in mid 1980s, we find evidence of substitution of male for female workers in the manufacturing sector. Mine closures increase number of male manufacturing workers but decrease, in absolute and relative terms, number of female manufacturing workers. We document a similar, though smaller, effect in the service sector. This substitution effect has been overlooked in the debate of local impacts of extractive industries, but it is likely to occur in the context of other male-dominated industries. We also find that mine closures led to persistent reductions in population size and participation rates.

1 Introduction

A key question when assessing the long-term impact of extractive industries is how they affect local employment. Several empirical studies, mostly using resource boom and busts, find evidence of positive, albeit small, employment spillovers: resource booms seem to increase wages and employment in non-extractive industries, such as services and manufacturing.[1] This latter

*Department of Economics, Simon Fraser University, Burnaby, British Columbia, V5A 1S6, Canada; Tel: +1 778 782 9107; Email: faragons@sfu.ca

†Department of Economics, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, United Kingdom; Tel: +44 (0)1784 27 6392; Email: juan.rud@rhul.ac.uk

‡Oxford Centre for the Analysis of Resource Rich Economies, Department of Economics, Manor Road Building, Oxford OX1 3UQ, UK; Email: gerhard.toews@economics.ox.ac.uk

[1] See for instance Black et al. (2005b) Michaels (2011), Allcott and Keniston (2013), and Jacobsen and Parker (2014) for evidence from U.S., Marchand (2012) for Canada, and Fleming and Measham (2014) for Australia.

finding, contrary to what is predicted in standard Dutch disease models, has been interpreted as evidence that agglomeration economies or presence of non-tradable goods may offset the crowding out of manufacturing due to higher mining wages (Allcott and Keniston, 2013).

Less is known, however, about differential effects by gender. This is important, because extractive industries are traditionally dominated by males. For instance, in U.S. and Canada, the share of women in mining (including oil and gas) in 2011 was 13.2% and 19% respectively. In India, the share was even smaller, around 4.4%.[2]

This strong gender bias potentially creates heterogeneous effects: while an industry like mining is dominated by males, other industries are not necessarily so. In particular, labor demand shocks in extractive industries may directly affect mostly male workers, but indirectly affect female workers, through the relative wage of female and male workers, for example. In turn, this can create substitution effects in other industries and result in opposite effects on employment by gender. For example, consider the effect of a mine closure. To the extent that workers are mobile across industries, the reduction of demand for male mine workers would reduce the relative wage of males in the manufacturing sector. This change in relative prices could trigger a subtitution effect: manufacturing firms would hire more male workers and reduce the number of female workers.[3]

This paper examines this substitution of male for female workers associated to shocks to primary industries. We exploit the dramatic run-down of the coal industry in the UK during the 1980s. In just a decade, the industry collapsed. Employment, mostly of men, fell from almost 240,000 workers in 1981 to around 60,000 in 1991. By 2011, the industry employed only 6,000 workers.

We use a novel dataset with location and closure date of coal mines, and spatially link it to the UK Census for the period 1981-2011. To identify the effect of mine closures, we use a difference-in-difference approach. In particular, we use number of mines closed as a treatment, and compare the evolution of employment in districts close to coal mines to districts farther away, our treated and control group, respectively.

We start by examining the effect on total population and employment. Similar to previous studies, we find that mine closures are associated to a persistent reduction in population size,

[2]See US Bureau of Labor Statistics (2012), Statistics Canada (2012) and Labour Bureau of India (2012).
[3]We formally develop this argument in Section 2.2.

participation rates, and number of workers. These phenomena are consistent with a negative labor demand shock and drop of local wages. We find, however, no evidence of a reduction in manufacturing employment. Instead, manufacturing employment seems to increase after mine closures. This finding is supportive of the sectoral re-allocation of labor between mining and tradable sectors predicted by Dutch disease models.

Next, we examine substitution of male for female workers in manufacturing. We find robust evidence of substitution by gender. Mine closures *increase* number of male workers but *decrease* number of female workers. As a result, there is a significant drop in the female-to-male ratio of manufacturing workers. The magnitude of the effect is economically significant. For the average mining district, mine closures reduced the share of females in manufacturing by 3 percentage points, or around 0.4 standard deviations. We document similar pattern of substitution of male for female workers in service, non-tradable, industries though the magnitude is much smaller.

Our main contribution is to show how, through a subtitution effect, a shock to extractive industries can affect labor conditions of female workers in the rest of the economy. This side-effect is often neglected in policy debates on the effect of natural resources. However, it is potentially relevant given the link between women's labor opportunities and both their political influence and intra-household bargaining power (Aizer, 2010; Cherchye et al., 2012; Ross, 2012; Majlesi, 2014).

This paper contributes to a growing literature on the local impact of natural resources (Black et al., 2005a; Aragón and Rud, 2013; Allcott and Keniston, 2013), and, more broadly, to the study of local labor markets (Moretti, 2011). More specifically, this paper complements findings by Ross (2008) and Kotsadam and Tolonen (2015). Using cross-country regressions, Ross (2008) argues that oil abundance reduces female labor participation because of the Dutch Disease and generous government transfers which decrease the incentive to work. Using the case of Sub-Saharan Africa, Kotsadam and Tolonen (2015) find evidence of sectoral re-allocation due to resource booms: when a mine opens, women shift from agriculture to the service sector or out of the labor force. Finally, this paper is also related to a literature documenting the effect of the UK coal bust on labor participation and migration (Beatty and Fothergill, 1996; Beatty et al., 2007).

The rest of the paper is structured as follows. Section 2 provides background information on the closure of coal mines in UK, and develops a simple model to understant its impact on local labor markets. Section 3 discuss the data and empirical strategy, while Section 4 presents the main results. Section 5 concludes.

2 Background

2.1 Decline of the coal industry in the UK

Coal played a key role in UK's industrial revolution and subsequent economic growth, and remained an important source of energy well into the 20th century (Fernihough and O'Rourke, 2014). In many parts of the coalfields, coal mining was also an important source of manual, well-paid, jobs. For instance, at its peak of production in 1952, UK coal mines produced more than 200 million tonnes, accounting for 90% of the total of the UK's primary energy consumption,[4] and employed more than 700,000 miners, mostly men.[5]

After WWII the coal industry started a long decline, mostly driven by the increased availability of cheaper substitutes, such as oil, nuclear power and imported coal (see Figure 1). The increase in oil prices in the early 1970s slowed down the decline in production and employment until the early 1980s (Surrey, 1992; NUM, 2014).

With economic recession and the decline of UK's heavy industry as a backdrop, a turning point occurred in 1984 when the UK government, lead by Margaret Thatcher, announced the closure of 20 pits and further plans to close more than 70 additional pits were leaked. This prompted a massive response by the National Union of Mineworkers (NUM) which called for a general strike. The strike, one of the largest in UK's history, was strongly opposed by the Conservative government and was seen as part of a broader policy to diminish the power of British trade unions. For instance, referring to the miners' strike in 1984, Margaret Thatcher said: "We had to fight the enemy without in the Falklands. We always have to be aware of the enemy within, which is much more difficult to fight and more dangerous to liberty" (Thatcher, 1993). The strike ended a year later following a NUM vote to return to work (NUM, 2014).

The government's victory in the strike significantly diminished the NUM's political power

[4]See Surrey (1992)

[5]The industry was heavily dominated by male workers. For example, in 1981, 84% of workers in primary sectors (which include mining plus agriculture, energy, and water supply) in England and Wales were male.

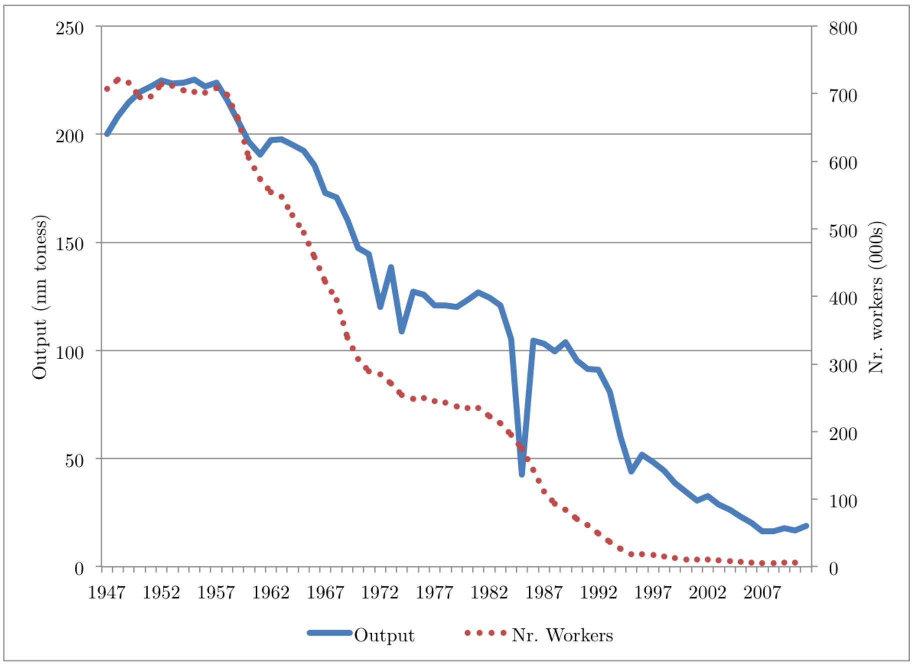


Figure 1: Output and number of workers in UK coal mines

and started a period of accelerated mine closures.[6]

In just two years (1985-1986), 55 coal mines, around a third of existing pits, closed. In the subsequent years (1987-1993) there was around 12 mine closures per year, a rate twice as high as in the period before the miners' strike (1976-1984). By 1994, when the industry was privatized, only 26 mines were operational, out of more than 200 at the beginning of 1980s. By 2011 only four collieries remained open. This, of course, was mirrored by the reduction in number of mine workers that went from more than 200,000 in 1981 to less than 6,000 in 2011. This sharp reduction both in the number of operational pits and employed workers is at the heart of our empirical strategy to examine the effects of a massive reduction in employment in the extractive industry on local labor markets.

Mine closure followed a combination of economic rationality and political considerations. Glyn (1988) and Glyn and Machin (1997) document that less productive, smaller, mines were more likely to be closed. This implies that pit productivity, driven by geological factors and

[6]This was a sharp contrast to the power held by the NUM a decade before. For instance, in February 1972 mass NUM's pickets led by Arthur Scargill forced the closure of the Saltley Coke Depot in Birmingham by sheer weight of numbers. The miners' strike in 1974 is also considered as an important factor on bringing down the Conservative government led by Edward Heath. These events lent substance to the belief that the NUM had the power to make or break British governments, or at the very least the power to veto any policy threatening their interests by preventing coal getting to power stations.

market access, explains most of mine closures. Note, however, that in few cases (such as collieries in mining dense areas), timing of closure might have been influenced by political reasons.

Subsequently, communities in former mining areas have been targeted by several regeneration programs and regional aid.[7] These initiatives have mostly focus on four type of interventions: re-training of local workers, promotion of small and medium size business, development of local infrastructure, and reclamation of former mine sites. Most of these programs started in mid 1980s, with the beginning of the accelerated plan of mine closures, and have been funded by the British government and by structural EU funds (Beatty et al., 2007).[8] Since they are potential confounding factors, it is important to take into account these regeneration policies in both the empirical analysis and interpretation of results.

Despite these regeneration efforts, pit closures seem to have had a negative and persistent effect on mining communities. Previous studies, using labor-accounting methodologies, find no sizeable change in unemployement, but instead document an increase in emigration, and number of economically inactive males in the coalfields (Beatty and Fothergill, 1996; Fieldhouse and Hollywood, 1999).[9] This withdrawal of males from the labor force mostly was through early retirement or being classed permanently sick. This "hidden unemployment", coupled with economic deprivation, persists over time (Beatty et al., 2007; Coalfield Regeneration Review Board, 2010; Foden et al., 2014).

2.2 Analytical framework

This section presents a simple framework to analyze the impact of mine closures on local labor markets. The discussion is based on Moretti (2011), Greenstone et al. (2010) and Cordon and Neary (1982). We treat mine closures as a negative shock to the demand for male workers, and focus on their effect on the allocation of workers between industries.

Consider a local economy with two industries: mining and manufacture, denoted a and b

[7]See Waddington et al. (2001) and Bennett et al. (2000) for a detailed discussion of regeneration policies in the coalfields.

[8]For example, the British Coal Enterprise (BCE), a job-creating agency in coal mining areas was established in 1984. Similarly, since mid 1980s, many areas affected by mine closures where given "assisted area" status and received further regional aid. In mid 1990s, the government started the National Coalfields Programme and the Coalfields Regeneration Trust, aimed to the physical regeneration of coalfield areas and to provide funding for community based projects. In 2004, the Coalfields Funds were set up to promote business in former coalfield areas. Objective 2 EU structural funds were available to finance for infrastructure investment and business subsidies since 1989. From 2000 onwards, poor areas in coalfields also accessed Objective 1 EU funds.

[9]The coalfields are defined as wards where, in 1981, at least 10% of the male population worked in coal mining. In 1981, these areas comprised a population of almost 5 million, or about 8% of the UK total.

respectively. All firms produce tradable goods with prices normalized to one. Labor is the only variable factor of production and there are two types of workers: males (M) and females (F). Males are perfect substitutes in both mining and manufacture, but women can only work in manufacture. This asymmetry captures the idea that males have a comparative advantage in brawn and intends to reflect the empirical observation that primary sectors are dominated by male workers. Because an economy where brawn is productive affects levels and returns to human capital investments, such as skills and education, we also assume that male and females are imperfect substitutes for manufacturing firms.[10]

The unconditional labor demand for mining firms is $L_M^a(w_M, A_a)$, while for manufacture firms is $L^b = L_M^b(w_M, w_F, A_b) + L_F^b(w_M, w_F, A_b)$, where A_a and A_b are industry-specific productivity shifters. All labor demands are weakly decreasing on wages. We model mine closures as an exogenous reduction in labor demand, i.e., a drop in A_a.

Each worker provides one unit of labour, so that labor supply is equal to population size. Let us denote labor supply of males and females as $N_M(w_M)$ and $N_F(w_F)$, respectively, Workers are mobile so in equilibrium workers are indifferent between locations. The indirect utility of a worker depends on local wages and an idiosyncratic preference over locations. This creates an upward sloping supply curve, as in Moretti (2011).[11] Alternatively, we can assume that workers are immobile, have heterogenous preferences over leisure, and decide whether to work or leave the labor force. Under standard conditions, this would produce the same upward slopping supply curve, but change the interpretation of N from population size to labor participation. In the empirical analysis, we explore both possible interpretations.

The equilibrium is defined by wages, w_M and w_F, that solve the following conditions:

$$N_M(w_M) = L_M^a(w_M, A_a) + L_M^b(w_M, w_F, A_b) \quad (1)$$

$$N_F(w_F) = L_b(w_M, w_F, A_b). \quad (2)$$

What would be the effect of a demand shock in the mining industry, such as mine closures?

[10] Pitt et al. (2012), and references therein, document similar gender-specific attributes and propose a Roy Model where these differences arise endogenously in an economy with high returns to brawn.

[11] For simplicity we assume that there is no housing and that there are no amenities. Assuming no housing is equivalent to assuming a perfectly elastic housing supply. Relaxing this assumption does not change the qualitative predictions. As long as housing supply is not perfectly inelastic, the effect of demand shocks on population size is partially offset by an increase in housing costs. Including amenities would simply introduce an additional wedge between wages across locations and would not affect the qualitative predictions.

In this framework, such a negative shock implies a reduction in A_a. To examine that, we take total derivatives on the equilibrium conditions to obtain:

$$\frac{dL_M^a}{dA_a} + \frac{dL_M^b}{dw_F}\frac{dw_F}{dA_a} = \frac{dw_M}{dA_a}\left[\frac{dN_M}{dw_M} - \frac{dL_M^a}{dw_M} - \frac{dL_M^b}{dw_M}\right] \tag{3}$$

$$\frac{dw_M}{dA_a} = \left[\frac{dN_F}{dw_F} - \frac{dL_M^b}{dw_F}\right]\left[\frac{dL_M^b}{dw_M}\right]^{-1}\frac{dw_F}{dA_a}. \tag{4}$$

Given the assumptions on labor demand and supply, it can be shown that: $\frac{dw_M}{dA_a} > \frac{dw_F}{dA_a} > 0$.

Thus, mine closures would reduce wages of both male and females. Furthermore, closures would reduce male's relative wage, $\frac{w_M}{w_F}$. These changes in prices have further implications on population and employment outcomes. In particular, it suggests that mine closures can generate the following effects:

1. A reduction in population size and number of workers (N_M, N_F). This follows from the reduction in wages.

2. A reallocation of workers from mining to manufactures (decrease in L^a, increase in L^b). This result is similar in flavor to the crowding out of manufacturing predicted by Dutch disease models (Cordon and Neary, 1982). This follows from the reduction in wages (which increases L^b) and reduction in total labor supply.[12]

3. A substitution of male for female workers in manufacturing sector (increase in L_M^b, reduction in L_F^b). This is driven by the change in relative wages. Note that there is a reduction in the absolute number of female workers, not only in the female-to-male ratio. This follows from the reduction in w_F, which decreases total supply of female workers.

Before we examine these predictions in the empirical analysis (Section 4), in the next section we describe the data and the empirical strategy.

[12]In this simple scenario, mine closures unambiguously lead to an increase in the number of non-mining workers. However, this prediction may change significantly if we allow for agglomeration spillovers or introduce a non-tradable sector (Greenstone et al., 2010; Moretti, 2011). For instance, consider the presence of agglomeration economies such that $A_b = A_b(N)$. i.e., productivity in the non-mining sector depends of population size. In that case, the decline in population due to mine closures would negatively affect manufacture firms' demand for labor. If agglomeration economies are sufficiently large, this can offset the positive impact of lower wages. Similarly, the decrease in both population size and wages would reduce demand for non-tradable goods. This might offset the reduction in labor costs and have a negative impact on employment in non-tradable sectors.

3 Methodology

3.1 Data

Our analysis uses two sources of data: a self-constructed data set of British coal mines since 1981, and 4 rounds of the UK Population Census (1981, 1991, 2001 and 2011).

Mining data We construct a data set containing information on geographical coordinates, number of miners, and year of closure of all coal mines active in 1981 in England and Wales.[13] Information on location of pits is taken from maps available in the Guide to the Coalfields, while data on number of miners come from this source and Glyn (1988). Year of closure is obtained from Northern Mine Research Society (2013). The complete data set consists of 211 coal mines active in 1981.

Demographic and employment data We use information from the UK Census on population and employment status for years 1981-2011.[14] The raw data is dissaggregated at ward level. Given the continuous changes in wards boundaries, we aggregate the data at district level and merge some districts to ensure comparability over time. In 2011 these adjustments reduce the number of districts from 348 to 339. Note that the main analysis uses only districts in the vicinity of mines (within 30 miles). This further reduces the sample size to 174 districts.[15]

The data include several employment variables, such as number of individuals economically active, employed, or unemployed, but does not include wages or earnings. All variables are disaggregated by gender and age brackets, while the number of employed individuals is further dissagregated by industry.[16]

We group industries in 3 broad sectors: primary, manufacturing, and services. The primary sector includes mining plus agriculture, forestry, fishing, energy and water supply.[17] Services include distribution and catering, transport and construction, and others.

[13] We include only underground mines. Small open-cast mines, numbering less than 100, are not included in our data set. This is mainly because we do not have any information on the location of these mines. However, we expect the importance of these mines to be small as the average number of employees is less than 10 miners, adding up to less than 1,000 miners in total.

[14] We do not extend the analysis to years before 1981 due to substantial changes on local government structure, introduced by the 1972 Local Government Act, that difficult geographical comparison.

[15] Results are robusts to alternative sample definitions.

[16] We re-define age brackets to ensure comparability over time.

[17] We aggregate these industries in one category to facilitate comparison over time.

Table 1 summarizes key variables for 1981 and 2011 for the sample of districts we use in our main analysis. There are some issues that deserve attention for the purpose of our exercise. First, female labor force participation in our sample districts increases substantially, reflecting a well-established secular trend. Most of the additional female employment is directed towards the services sector. Second, while the participation rate in the labor force of women increased, the opposite happened for males. Note that both rates are substantially lower in our sample than the UK average, reflecting poorer labor market outcomes in the north of England, the Midlands and Wales.[18] Third, unemployment rates are lower in 2011 for both female and males. Finally, the number of workers in the primary sector falls sharply between 1981 and 2011 for men, but not for women.

Ancillary data We also collect data on the EU's and the UK's governments' expenditure on regional assistance to industry, as proxies for regeneration policies in the coalfields. The data are obtained from Regional Trends, an annual publication of the Office of National Statistics. The data are disaggregated to the highest tier of sub-national devision in the UK (NUTS 1 areas) - which in our sample results in 9 regions. We obtain measures, in British pounds, of the sum of funds transferred to each region in the 10 years prior to each Census year.[19]

3.2 Empirical strategy

Our aim is to estimate the effect of mine closures on local employment. To do so, we implement a difference-in-difference approach that exploits two sources of variation. First, we use the closure of mines over time. As discussed in Section 2, starting in mid 1980s, there was a dramatic acceleration in mine closures and lost of mining jobs. We treat this event as a significant, negative shock, to local labor markets. Figure 2 displays the evolution of number of mines and miners, and highlights the years for which we have Census information. Most of mine closures occured between mid 1980s and mid 1990s so that by 2001 most mines were already closed. Note that the average coal mine had around 1,000 workers.

[18] OECD estimates show labor force participation in 2011 to be 82.5 for males and 70.4 for females in all of the UK.

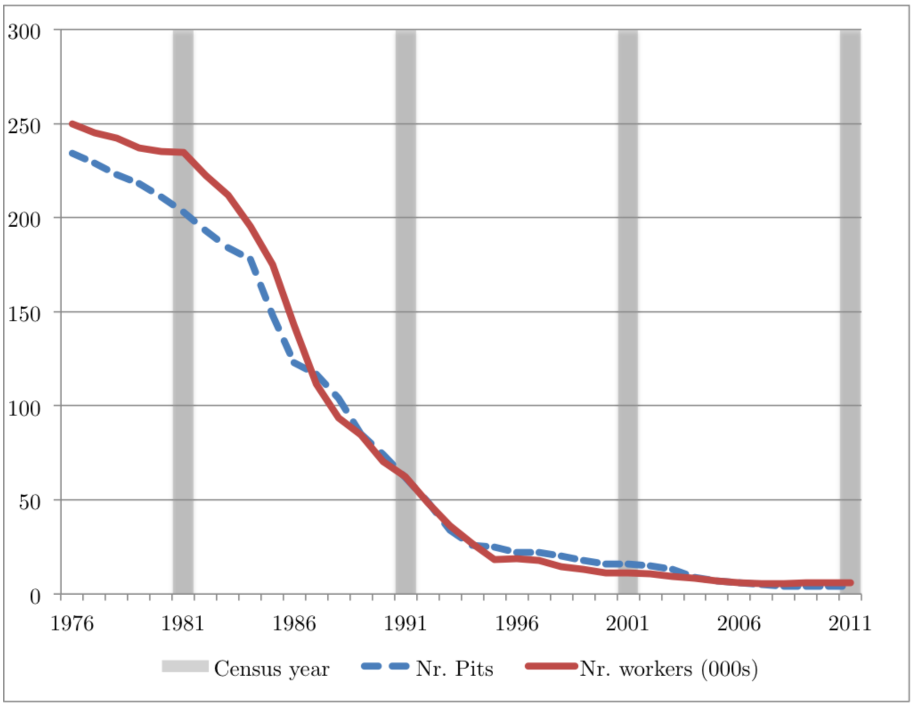
[19] There are two main limitations in these data. First, there is no information for recent years. Data on regional assistance to industry from the UK government covers the period 1972-2003, while the allocation of EU funds is reported from 1975-2006. We treat the remaining years as missing. Second, data on EU funds are not reported on the sub-national level between 1989-1990 and 1991-1993. To resolve this problem we assume that the flows of funds are persistent and extrapolate the regional allocation from previous years.

Table 1: Main employment indicators for average district, by gender, 1981 and 2011

	1981			2011		
	Total	Female	Male	Total	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Population ('000s)	164.1	84.0	80.0	179.4	91.2	88.2
Labor force('000s)	76.7	29.6	47.1	90.0	42.1	47.9
Nr. of workers ('000s)	68.2	27.2	41.0	82.8	39.2	43.6
Primary	4.3	0.6	3.7	2.2	0.5	1.7
Manufacturing	21.0	6.0	15.0	9.0	2.1	6.9
Services	42.4	20.4	22.0	71.6	36.6	35.0
Participation rate (%)	60.5	44.6	77.6	62.2	56.7	67.9
Unemployment rate (%)	9.9	7.5	11.4	7.2	6.2	8.1

Note: Primary includes mining plus agriculture, forestry, fishing, energy and water supply. Services includes distribution and catering, transport, construction, and other industries. Sample includes only districts within 30 miles of a mine active in 1981. Number of districts is 174.

Figure 2: Coal mines and miners: 1976-2011



Second, we use distance to coal mines to identify mining and non-mining districts. Mining districts are districts with an active mine in 1981, while non-mining districts are neighboring, mine-less, districts. We restrict the sample to districts with any part of its territory within 30 miles of a mine active in 1981.[20] Figure 3 displays a map with the location of mines in 1981, mining and non-mining districts. Note that coal mines were predominately located in the North East of England, in the Midlands, and South of Wales.

Table 2 provides baseline characteristics for mining and non-mining districts in 1981. The average mining district had around 4 active mines in 1981. Moreover, its manufacturing and service sector employed relatively more women, and it has a slightly larger population. However, both types of district had similar participation rates, and size of non-primary sectors, measured by number of workers.

Table 2: Main characteristics of average mining and non-mining districts in 1981

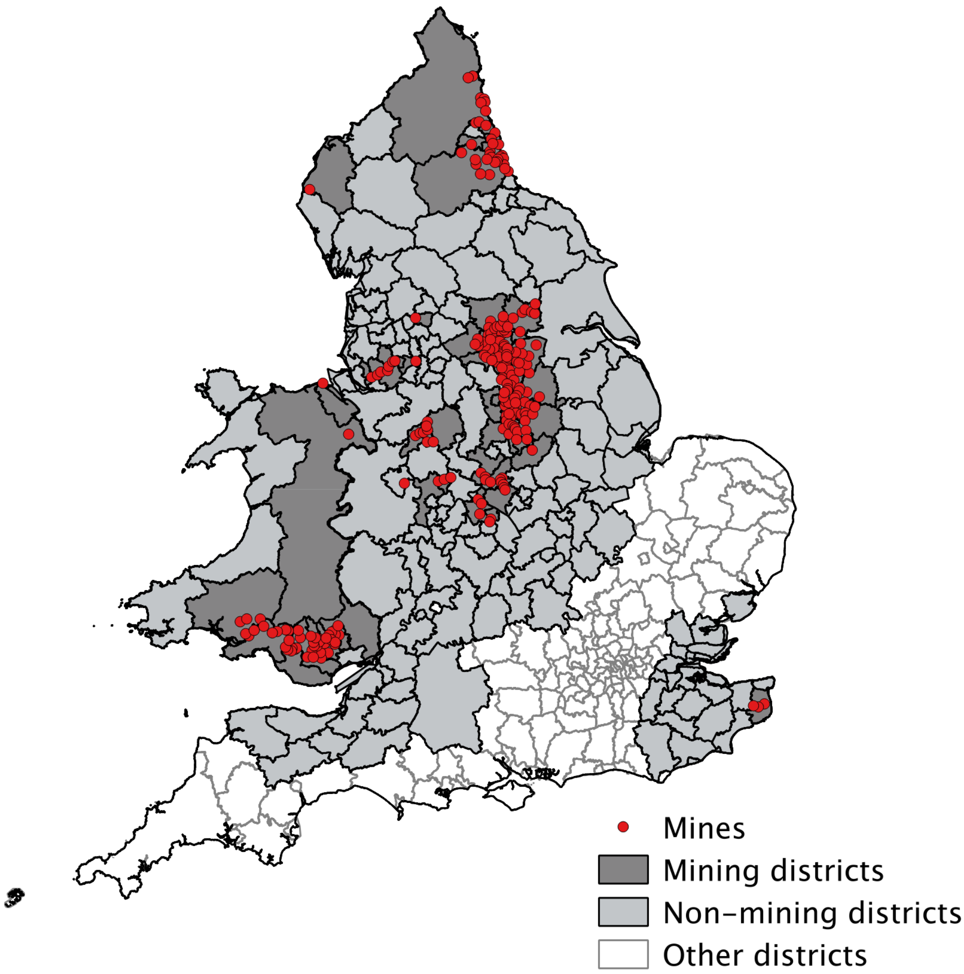
	Mining		Non-mining		p-value
	Mean	S.D.	Mean	S.D.	(1)=(3)
	(1)	(2)	(3)	(4)	(5)
Nr. active mines	3.7	3.5	0.0	0.0	
Population ('000s)	186.7	133.3	153.6	128.0	0.126
Participation rate (%)	60.6	2.6	60.5	3.7	0.907
Unemployment rate (%)	10.7	3.7	9.6	3.6	0.073
Nr .of workers ('000s)					
Primary	7.3	6.0	2.9	2.2	0.000
Manufacturing	23.3	15.8	20.0	19.1	0.232
Services	45.8	36.1	40.8	33.1	0.387
% female workers in:					
Primary	10.5	4.4	17.8	5.8	0.000
Manufacturing	31.4	6.5	27.1	4.4	0.000
Services	48.9	2.9	46.8	3.4	0.000
Number of districts	53.0		121.0		

Note: Column 5 displays the p-value of a mean comparison test of columns 1 and 3.

Our empirical strategy basically compares the evolution of outcomes in mining districts relative to non mining districts, treatment and control groups respectively. As a treatment, we

[20]We also explore a alternative sample definitions, and more flexible specifications of distance to mines.

Figure 3: Map of mines and districts: England and Wales



use the number of mines closed since 1981 in a given district.[21] Alternatively we also report results using number of miners laid-off. Formally, we estimate the following regression model:

$$y_{it} = \beta mine\ closures_{it} + \eta_i + \rho_t + \epsilon_{it}, \tag{5}$$

where the unit of observation is district i in year t and *mine closures* is the measure of mine closures, i.e., number of mines clsoed or number of miners laid-off. The baseline specification includes year and district fixed effects, and cluster the errors by county.[22]

Based on the discussion in Section 2.2 we focus on demographic and employment outcomes, such as population size, participation rates, and number of workers by sector. An important outcome is the share of females among manufacturing workers. This variable is a function of the female-to-male ratio, and captures the extent of the substitution effect of male for female workers.[23]

The validity of our identification strategy relies on the assumption that, in the absence of mine closures, employment outcomes in both mining and non-mining districts would have followed the same trend. We cannot explore the validity of this assumption due to data limitations.[24] In the empirical analysis, however, we examine the importance of several confounding factors that could violate this assumption.

4 Results

4.1 Main results

We start by examining the effect of mine closures on the local population, without distinguishing by gender (see columns 1 to 6 of Table 3). There are two important findings. First, similar to previous studies of resource booms and busts, we find that mine closures reduce population size and participation rates (Black et al., 2005b; Michaels, 2011; Jacobsen and Parker, 2014). This result is consistent with the reduction in labor supply associated to lower local wages.

[21]Note that using "number of mines closed since 1981" is equivalent to using "number of active mines in a given year". The signs are, however, reversed

[22]There are 75 counties in the sample. We cluster the errors at this level to account for possible serial and spatial correlation. We also check the robustness of the results to using Conley standard errors.

[23]We use share of female manufacturing workers instead of the input ratio for simplicity of exposition. Results using the input ratio are similar.

[24]We only have information for one period before the beginning of mid 1980s closures.

There is, however, no significant effect on unemployment rates. Second, we find evidence of labor re-allocation from primary sectors to manufacturing. Note that, despite a reduction in total number of workers, there is a slight increase in number of manufacturing workers This negative relation between mining and manufacturing employment is similar in flavor to the so-called reverse Dutch disease, and contrasts to studies that find a positive relation (Allcott and Keniston, 2013).[25]

Coal mining was a male-dominated industry. For that reason, we treat mine closures as a negative shock to demand for male workers. We empirically examine this assumption in columns 7 and 8 of Table 3. In particular, we estimate the effect of mine closures on number of male and female workers in the primary sector. We find that each mine closure reduced number of male workers in the primary sector by around 1,000 (column 7). This is consistent with the average size of coal mines. In contrast, the number of female workers decreased by less than 20 (column 8).[26] Similar results are obtained using number of workers laid-off (see Table 3, Panel B).

As discussed in Section 2.2, this strong male-bias, and change in relative wages, creates scope for a differentiated effect by gender. In particular, it can create a substitution effect in non-primary sectors that can negatively affect female workers. Table 4 explores this prediction.

We find that mine closures had a differential effect on manufacturing employment by gender. They *increase* number of male workers, but *decrease* number of females workers (columns 1 and 2). This translates into a reduction of around 0.78 percentage points in the share of female manufacturing workers for every mine closed (column 3). This is a sizable reduction. For the average mining district, this represent a reduction of around 3 percentage points, or almost 0.4 standard deviations, over the period 1981-2011.[27] We find similar pattern of substitution of male for female workers in the service sector (columns 4 to 6), though the magnitude is smaller and there is no significant reduction of female workers.

This result highlights the importance of taking into account gender differences when assessing the impact of primary industries, and other male-dominated activities, on local labor markets. As we find in the UK case, re-allocation of labor across industries (from mining to

[25] A posible explanation for this different result is that agglomeration economies of coal mining in the UK might not have been very important.

[26] Note that the primary sector includes other industries besides mining, such as agriculture, logging, energy and water. Thus, the estimates include jobs lost due to mine closures net of any labor re-allocation within the primary sector.

[27] The average share of female manufacturing worker in mining districts in 1981 was 31.4% , with a S.D equal to 6.5 (see Table 2).

Table 3: Effect of mine closures on population and employment

	ln(pop.)	Particip. rate	Unemploy. rate	ln(nr. workers)			Nr. workers in primary sector	
				Primary	Manufact.	Services	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A								
Nr. of mines	-0.005**	-0.217***	-0.015	-0.131***	0.011*	0.004	-1,045.0***	-17.0
closed since 1981	(0.002)	(0.072)	(0.063)	(0.017)	(0.006)	(0.004)	(65.974)	(15.416)
Panel B								
Nr. mine workers	-0.005**	-0.229***	0.023	-0.131***	0.010*	0.004	-1,077.9***	-17.0
laid-off since 1981	(0.002)	(0.066)	(0.068)	(0.017)	(0.006)	(0.004)	(55.8)	(18.31)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Sample includes districts within 30 miles of a mine. Primary includes mining plus agriculture, forestry, fishing, energy and water supply. Services includes distribution and catering, transport, construction, and other industries. Panel A reports regressions using number of mines clossed as treatment variable, while Panel B uses number of workers laid-off (in thousands). Number of observations = 696, number of districts=174.

manufacturing) can attenuate the negative effect on male employment, but create a negative spillover on female workers.

Table 4: Substitution effects in non-primary sectors

	Manufacturing			Services		
	ln(nr. of workers)		% female	ln(nr. of workers)		% female
	Female	Male	workers	Female	Male	workers
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A						
Nr. of mines closed	-0.015**	0.022***	-0.782***	-0.002	0.010**	-0.278***
since 1981	(0.006)	(0.007)	(0.140)	(0.004)	(0.005)	(0.064)
Panel B						
Nr. mine workers	-0.016**	0.022***	-0.795***	-0.002	0.009**	-0.279***
laid-off since 1981	(0.007)	(0.007)	(0.172)	(0.004)	(0.004)	(0.057)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Sample includes districts within 30 miles of a mine active in 1981. Panel A reports regressions using number of mines clossed as treatment variable, while Panel B uses number of workers laid-off (in thousands). Number of observations = 696, number of districts=174.

Robustness checks Table 5 checks the robustness of the main results, using share of female manufacturing workers as the main outcome. Columns 1 to 3 change the sample definition. Column 1 uses all districts in England and Wales, while column 2 uses a narrower sample: districts within 10 miles of a mine. Column 3 uses only the sample of mining districts. This last column exploits only the timing of mine closure among the treated group. The results, however, remain similar in either specification.

An important confounder is the presence of regeneration policies targeted to former coalfields. We examine its importance in two ways (columns 4 and 5). First, we include the amount transfered to each region by the two most important programs aimed to the coalfields: UK regional aid and EU structural funds. Second, we use a more flexible specification that includes county-by-year fixed effects. This last specification accounts for all factors that change over time at county level, including regional policies. In both cases, the results remain robust.

Finally, column 6 estimates the standard errors correcting for spatial and serial correlation using the procedure described by Conley (2008).[28]

[28]We use ado file OLS_HAC developed by Hsiang (2010). We set the maximum distance to 30 miles and use 1

Table 5: Robustness checks

	% female manufacturing workers					
	(1)	(2)	(3)	(4)	(5)	(6)
Nr. of mines closed since 1981	-0.977***	-0.640***	-0.436***	-0.825***	-0.741***	-0.782***
	(0.176)	(0.120)	(0.104)	(0.130)	(0.142)	(0.148)
ln(UK and EU regional funds)					0.425***	
					(0.125)	
Sample	All districts	< 10 miles of a mine	Mining districts	Baseline	Baseline	Baseline
County-year F.E.	No	No	No	Yes	No	No
Conley S.E.	No	No	No	No	No	Yes
Observations	1,356	468	212	696	696	696
R-squared	0.293	0.606	0.699	0.621	0.530	0.097
Nr. districts	339	117	53	174	174	174

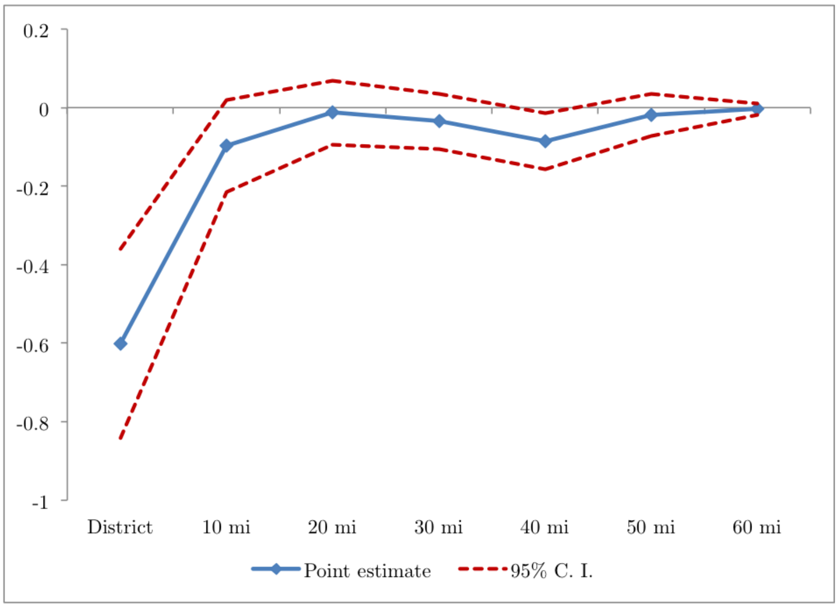
Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Columns 1-3 change the sample definition. The baseline sample refers to districts within 40 miles of a mine. Column 4 includes county-by-year fized effects. Column 5 includes a proxy for regeneration policies. Column 6 estimates the baseline regression with standard errors corrected for spatial and serial correlation using the procedure described by Conley (2008).

4.2 Additional results

4.2.1 Distance and persistence

The baseline results assume that the effect of mines closures decrease with distance to the mine. This motivates the use of districts farther away as control group. To examine empirically this assumption, we estimate the baseline regresion (5) using as measure of mine closures the number of mine closed since 1981 at different distance brackets of a district (i.e. in district, within 10 miles, between 10-20 miles, etc.). We also use a broader sample to include all districts in England and Wales.[29] Figure 4 displays the estimated effect of mine closures on share of female manufacturing workers.[30] Note that the magnitud of the effect decreases rapidly with distance. The effect of mine closures in a district is negative and significant. In contrast, mine closures in areas further away have a negligible effect.

Figure 4: Effect of mine closures on share of female manufacturing workers, by distance



Notes: Estimates are obtained from a regression of share of female manufacturing workers on number of mines closed since 1981 at different distance brackets. See Table A.2 for further details.

A relevant question is whether the effects of mines closures are short-lived or persist over time. To do so, we estimate the baseline regression using as main regressors interaction of

period lag.

[29]Results are similar using the baseline sample

[30]Table A.2 in the Appendix presents full regression estimates for several outcome variables.

being a mining district with year dummies. The regression includes both district and year fixed effects, so the ommited category is the interaction term mining district × being in a year before 2001. This regression basically estimates the difference in trends between mining and non-mining districts over time, relative to their baseline difference in 1981-1991.

The results (see Table 6) suggest that the negative effects of mine closures on population, participation rate and female employment are persistent. For instance, even in 2011, more than 20 years since the bulk of mine closures, mining districts have a share of female manufacturing workers almost 4.6 percentage points smaller than non-mining districts, as well as smaller population and lower participation rates.[31]

Table 6: Persistence of effects of mine closures

	ln(pop.)	Particip. rate	Manufacturing		
			ln(nr. of workers)		% female workers
			Female	Male	
	(1)	(2)	(3)	(4)	(5)
Mining district ×	-0.028*	-1.547***	-0.097**	0.086**	-3.871***
year 2001	(0.014)	(0.510)	(0.043)	(0.034)	(0.626)
Mining district ×	-0.044**	0.023	-0.132**	0.094**	-4.640***
year 2011	(0.019)	(0.406)	(0.051)	(0.046)	(0.632)
Observations	696	696	696	696	696
R-squared	0.235	0.653	0.778	0.704	0.539

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using ordinary least squares, and include district and year fixed effects. Sample is the same as in baseline regression. Mining district is an indicator equal to 1 if the district contains at least one mine. "year 2001" is an indicator equal to 1 if year is 2001, likewise for "year 2011".

4.2.2 Differentiated effects by age

Next, we turn our attention to heterogenous effects by age. To do so, we construct outcome variables (such as population size, participation rate, and number of workers) for different age brackets and gender. We focus on population in working age, i.e., 16 to 59 years old.

Table 7 presents the results. Each estimate is obtained from a different regression and each

[31] These persistent negative effects are consistent with other studies of the impact of mine closures on the British coalfields (Beatty et al., 2007; Coalfield Regeneration Review Board, 2010; Foden et al., 2014). Studying busts in coal towns in U.S., Jacobsen and Parker (2014) also find persistent negative effects on local employment and income.

column defines the outcome variable for a specific age-gender group.[32]

There are three important observations. First, population drops for all groups, but the magnitude is smaller for 30-44 year olds. Second, participation rates goes down for all age groups among males, but there is no significant change for females. Finally, males of all ages seem to replace females in manufacturing, mostly young and middle age women (age 16-44). This suggests that experienced female workers are less likely to be displaced. The service sector shows the same signs, even though it seems to be absorbing older male workers and displacing older females. Magnitudes are smaller.

Table 7: Heterogeneous effects by age

	Females			Males		
Age group	16-29	30-44	45-59	16-29	30-44	45-59
	(1)	(2)	(3)	(4)	(5)	(6)
A. Outcome: ln(population)						
Nr. of mines	-0.007**	-0.002	-0.008**	-0.007**	-0.003	-0.008**
closed since 1981	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
B. Outcome: participation rate						
Nr. of mines	-0.023	-0.038	-0.030	-0.305***	-0.179***	-0.274***
closed since 1981	(0.136)	(0.115)	(0.134)	(0.106)	(0.063)	(0.077)
C. Outcome: ln(nr. workers in manufacturing sector)						
Nr. of mines	-0.019***	-0.015**	-0.007	0.023***	0.024***	0.028***
closed since 1981	(0.007)	(0.006)	(0.009)	(0.007)	(0.007)	(0.009)
D. Outcome: ln(nr. workers in service sector)						
Nr. of mines	0.001	0.001	-0.005	0.006	0.011**	0.015**
closed since 1981	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.006)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Sample includes districts within 40 miles of a mine active in 1981. Number of observations = 696, number of districts=174.

[32]For instance in panel A, column 1, the estimate -0.007 is obtained from a regression of ln(population of females age 16-29) on the measure of mine closures.

4.2.3 Other demographic changes

While the simple model we presented did not explicitly account for gender-specific location preferences or skill differentials, a simple extension would allow for migration effects to vary along these dimensions. To explore this, we examine whether mine closures are associated to other demographic changes (see table 8).

First, we do find significant changes in gender composition: there is a drop in the share of women in total population. This is consistent with a relatively larger emigration of men. However, we do not find significant changes in the relative size of prime age population. We also find a significant reduction in the share of population, both male and female, with tertiary education. This reduction in education may be due to selective migration of more qualified individuals or changes in local education conditions, such as lower returns or lower income. We cannot separate these possible channels.

Del Bono et al. (2012) document that job displacement of women can affect their fertility decisions. We explore this channel by using a proxy of fertility, namely children per women in child-bearing age.[33] The direction of the effect is as expected, i.e., a reduction in fertility in areas more affected by mine closures, and significantly different from zero.

Table 8: Other demographic changes

	Prime age pop.		% female	Pop. with tertiary educ.		Children
	Females	Males	population	Females	Males	per woman
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A						
Nr. of mines closed	-0.038	0.016	0.041***	-0.217***	-0.151**	-0.008***
since 1981	(0.064)	(0.053)	(0.012)	(0.059)	(0.058)	(0.002)
Panel B						
Nr. mine workers	-0.059	-0.001	0.046***	-0.239***	-0.172***	-0.008***
laid-off since 1981	(0.059)	(0.050)	(0.011)	(0.047)	(0.050)	(0.002)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using ordinary least squares, and include district and year fixed effects. Sample is the same as in baseline regression. Columns 1 and 2 use as outcomes the share of total population of female and males in prime age (16-44). Column 3 uses the share of women in total population. Columns 4 and 5 use the share of population over 16 years old with tertiary education. Column 6 uses the ratio of population age 0 to 15 years to women age 35-44.

[33] As we can only use a measure of children between 0 and 15, we include women between 35 and 44 years old only.

5 Conclusion

This paper highlights the importance of considering heterogeneous effects by gender when assessing the impact of extractive industries on local labor markets. This heterogeneity arises because extractive industries are heavily male-dominated. Thus, shocks to their labor demand (such as mine closures) have the potential to create differentiated effects on male and female workers.

Using the case of coal mines in UK, we find evidence of such substitution effect. Mine closures increased number of male workers in manufacturing, but decrease female employment, in relative and absolute terms. The magnitude of the change is economically significant and persist over time. In addition, we document persistent negative effects in population size and participation rates, and find evidence of re-allocation of labor from mining to manufacturing. This last result is similar in flavour to the sectoral re-allocation of labor predicted by Dutch disease models.

There are, however, some unsolved issues. First, due to data limitations, we are unable to explore the effect on local wages. Second, we examine the effect on local economies, not on displaced individuals. The effect of labor displacement on individuals may be different. Finally, we do not examine other relevant possible effects such as changes in productivity and agglomeration economies. Studying these issues warrant further research.

References

Aizer, Anna, "The Gender Wage Gap and Domestic Violence," *The American Economic Review*, 2010, pp. 1847–1859.

Allcott, Hunt and Daniel Keniston, "Dutch Disease or Agglomeration? The local Economic effects of natural resource booms in modern America," Technical Report, Working Paper 2013.

Aragón, Fernando M. and Juan Pablo Rud, "Natural resources and local communities: evidence from a Peruvian gold mine," *American Economic Journal: Economic Policy*, 2013, *5* (2), 1–25.

Beatty, Christina and Stephen Fothergill, "Labour market adjustment in areas of chronic industrial decline: the case of the UK coalfields," *Regional studies*, 1996, *30* (7), 627–640.

___ , ___ , and Ryan Powell, "Twenty years on: has the economy of the UK coalfields recovered?," *Environment and Planning A*, 2007, *39* (7), 1654.

Bennett, Katy, Huw Beynon, and Ray Hudson, *Coalfields regeneration: Dealing with the consequences of industrial decline*, The Policy Press, 2000.

Black, D., T. McKinnish, and S. Sanders, "The Economic Impact of the Coal Boom and Bust," *The Economic Journal*, April 2005, *115*, 449–476.

Black, Dan, Terra McKinnish, and Seth Sanders, "The Economic Impact Of The Coal Boom And Bust*," *The Economic Journal*, 2005, *115* (503), 449–476.

Bono, Emilia Del, Andrea Weber, and Rudolf Winter-Ebmer, "Clash of Career and Family: Fertility Decisions After Job Displacement," *Journal of the European Economic Association*, 2012, *10* (4), 659–683.

Cherchye, Laurens, Bram De Rock, and Frederic Vermeulen, "Married with children: A collective labor supply model with detailed time use and intrahousehold expenditure information," *The American Economic Review*, 2012, *102* (7), 3377–3405.

Coalfield Regeneration Review Board, "A Review of Coalfields Regeneration," Technical Report 2010.

Conley, Timothy G., "Spatial Econometrics," in Steven N. Durlauf and Lawrence E. Blume, eds., *The New Palgrave Dictionary of Economics*, Basingstoke: Palgrave Macmillan, 2008.

Cordon, W. M. and J. P. Neary, "Booming Sector and Deindustrialisation in a Small Open Economy," *The Economic Journal*, December 1982, *92* (368), 825–848.

Fernihough, Alan and Kevin Hjortshøj O'Rourke, "Coal and the European Industrial Revolution," Technical Report, National Bureau of Economic Research 2014.

Fieldhouse, Edward and Emma Hollywood, "Life after mining: hidden unemployment and changing patterns of economic activity amongst miners in England and Wales, 1981–1991," *Work, Employment and Society*, 1999, *13* (03), 483–502.

Fleming, David A. and Thomas G. Measham, "Local Economic Impacts of an Unconventional Energy Boom: the Coal Seam Gas Industry in Australia," *Australian Journal of Agricultural and Resource Economics*, 2014.

Foden, Mike, Steve Fothergill, and Tony Gore, "The State of the Coalfields: Economic and social conditions in the former mining communities of England, Scotland, and Wales," Technical Report, Centre for Regional Economic and Social Research, Sheffield Hallam University 2014.

Glyn, Andrew, "The Economic Case against Pit Closure," in Dvid J. Cooper and Trever Hopper, eds., *Debating Coal Closures: Economic Calculation in the Coal Dispute, 1984-5*, Cambridge University Press, 1988.

—— **and Stephen Machin**, "Colliery closures and the decline of the UK coal industry," *British Journal of Industrial Relations*, 1997, *35* (2), 197–214.

Greenstone, Michael, Richard Hornbeck, and Enrico Moretti, "Identifying agglomeration spillovers: Evidence from winners and losers of large plant openings," *Journal of Political Economy*, 2010, *118* (3), 536–598.

Hsiang, Solomon M, "Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America," *Proceedings of the National Academy of Sciences*, 2010, *107* (35), 15367–15372.

Jacobsen, Grant D. and Dominic P. Parker, "The Economic Aftermath of Resource Booms: Evidence from Boomtowns in the American West," *The Economic Journal*, 2014, pp. n/a–n/a.

Kotsadam, Andreas and Anja Tolonen, "African Mining, Gender, and Local Employment," Policy Research Working Paper 7251, World Bank Group 2015.

Labour Bureau of India, "Statistical Profile of Women Labor 2012-2013," accessed on July 15, 2015 at `http://labourbureau.nic.in/Statistical_Profile_2012_13.pdf`. 2012.

Majlesi, Kaveh, "Labor Market Opportunities and Women's Decision Making Power within Households," Technical Report, Lund University, Department of Economics 2014.

Marchand, Joseph, "Local Labor Market Impacts of Energy Boom-bust-boom in Western Canada," *Journal of Urban Economics*, 2012, *71* (1), 165–174.

Michaels, Guy, "The Long Term Consequences of Resource-Based Specialisation*," *The Economic Journal*, 2011, *121* (551), 31–57.

Moretti, Enrico, "Local labor markets," *Handbook of labor economics*, 2011, *4*, 1237–1313.

National Coal Board, *Guide to the coalfields*, Colliery Guardian Co., 1970-1993.

Northern Mine Research Society, "List of collieries," accessed on November 2013 at `http://nmrs.org.uk/resources/NMRSWEBNationalisedfrom%201947.pdf` 2013.

NUM, "NUM History," `http://www.num.org.uk/page/History-NumHistory` 2014. Accessed: 2014-08-03.

Office for National Statistics, "Official Labour Market Statsitics," accessed on May 2014 at `https://www.nomisweb.co.uk` 2014.

—— , "Regional Trends," accessed on August 2014 at `http://www.ons.gov.uk/ons/rel/regional-trends/regional-trends/index.html` 2014.

Pitt, Mark M., Mark R. Rosenzweig, and Mohammad Nazmul Hassan, "Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy," *American Economic Review*, 2012, *102* (7), 3531–60.

Ross, M. L., *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*, Princeton University Press, 2012.

Ross, Michael L, "Oil, Islam, and women," *American Political Science Review*, 2008, *102* (01), 107–123.

Statistics Canada, "Table 282-0008: Labour Force Survey Estimates (LFS), by North American Industry Classification System (NAICS), Sex and Age Group," Accessed on July 15, 2015 at `http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=2820008`. 2012.

Surrey, John, "Technical change and productivity growth in the British coal industry, 1974–1990," *Technovation*, 1992, *12* (1), 15–39.

Thatcher, Margaret, *The Downing Street Years*, HarperCollins, 1993.

UK Data Service, "UK Census aggregate data," accessed on November 2013 at `http://casweb.mimas.ac.uk/` 2013.

US Bureau of Labor Statistics, "Table 18: Employed Persons by Detailed Industry, Sex, Race, and Hispanic or Latino Ethnicity," Accessed on July 15, 2015 at `http://www.bls.gov/cps/cpsaat18.pdf`. 2012.

Waddington, David, Chas Critcher, Bella Dicks, and David Parry, *Out of the Ashes?: The Social Impact of Industrial Contraction and Regeneration on Britain's Mining Communities*, The Stationary Office, 2001.

APPENDIX

A Additional figures and tables

Table A.1: Robustness checks using nr. of mine workers laid-off

	% female manufacturing workers					
	(1)	(2)	(3)	(4)	(5)	(6)
Nr. mine workers laid-off since 1981	-0.982***	-0.659***	-0.482***	-0.811***	-0.755***	-0.795***
	(0.205)	(0.152)	(0.141)	(0.148)	(0.174)	(0.137)
ln(UK and EU regional funds)					0.419***	
					(0.125)	
Sample	All districts	< 10 miles of a mine	Mining districts	Baseline	Baseline	Baseline
County-year F.E.	No	No	No	Yes	No	No
Conley S.E.	No	No	No	No	No	Yes
Observations	1,356	468	212	696	696	696
R-squared	0.297	0.610	0.704	0.621	0.533	0.105
Nr. districts	339	117	53	174	174	174

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Columns 1-3 change the sample definition. The baseline sample refers to districts within 40 miles of a mine. Column 4 includes county-by-year fized effects. Column 5 includes a proxy for regeneration policies. Column 6 estimates the baseline regression with standard errors corrected for spatial and serial correlation using the procedure described by Conley (2008).

Table A.2: Effects of mine closures by distance

	ln(pop.)	Particip. rate	Manufacturing ln(nr. of workers) Female	Manufacturing ln(nr. of workers) Male	Manufacturing % female workers
	(1)	(2)	(3)	(4)	(5)
Nr mines closed since 1981:					
In district	-0.008***	-0.207**	-0.009	0.019**	-0.601***
	(0.003)	(0.098)	(0.008)	(0.008)	(0.121)
Between 0-10 miles	0.000	-0.040	0.001	0.005	-0.098
	(0.002)	(0.029)	(0.003)	(0.004)	(0.059)
Between 10-20 miles	-0.003	-0.042*	-0.007**	-0.006**	-0.013
	(0.002)	(0.024)	(0.003)	(0.002)	(0.041)
Between 20-30 miles	0.001	0.024	0.005	0.007**	-0.034
	(0.002)	(0.027)	(0.003)	(0.003)	(0.035)
Between 30-40 miles	-0.003**	-0.052**	-0.008**	-0.004	-0.086**
	(0.002)	(0.025)	(0.004)	(0.003)	(0.036)
Between 40-50 miles	0.002	-0.007	0.004	0.005*	-0.018
	(0.001)	(0.015)	(0.003)	(0.003)	(0.027)
Between 50-60 miles	-0.000	-0.019**	0.001	0.001	-0.004
	(0.000)	(0.008)	(0.001)	(0.001)	(0.007)
Observations	1,356	1,356	1,355	1,356	1,356
R-squared	0.377	0.700	0.738	0.695	0.345
Number of districts	339	339	339	339	339

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Sample includes all districts in England and Wales. Regressors are variables measuring the number of mines closed since 1981 at different distance brackets of a district. Distance brackets are: district, outside district but within 10 miles, outside district but between 10 and 20 miles, and so on.

Table A.3: Heterogeneous effects by age, using nr. of mine workers laid-off

	Females			Males		
Age group	16-29	30-44	45-59	16-29	30-44	45-59
	(1)	(2)	(3)	(4)	(5)	(6)
A. Outcome: ln(population)						
Nr. mine workers	-0.008***	-0.003	-0.008**	-0.008***	-0.004	-0.008**
laid-off since 1981	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
B. Outcome: participation rate						
Nr. mine workers	-0.061	-0.002	0.000	-0.301***	-0.176***	-0.284***
laid-off since 1981	(0.135)	(0.112)	(0.127)	(0.106)	(0.061)	(0.070)
C. Outcome: ln(nr. workers in manufacturing sector)						
Nr. mine workers	-0.022***	-0.015**	-0.008	0.022***	0.023***	0.027***
laid-off since 1981	(0.007)	(0.007)	(0.009)	(0.007)	(0.007)	(0.009)
D. Outcome: ln(nr. workers in service sector)						
Nr. mine workers	-0.001	0.000	-0.006	0.005	0.010**	0.015***
laid-off since 1981	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS, and include district and year fixed effects. Sample includes districts within 40 miles of a mine active in 1981. Nr. of mine workers laid off is expressed in thousands. Number of observations = 696, number of districts=174.

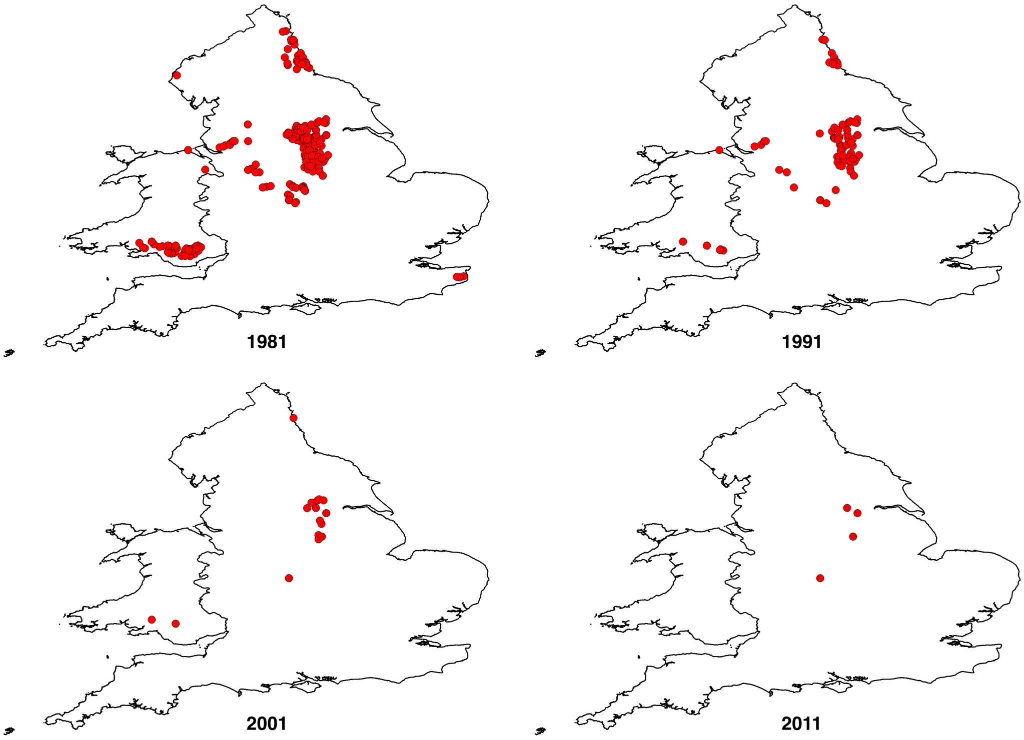


Figure A.1: Map of active mines, by Census year

B Data appendix

Mining data Information on the location of mines and the number of workers employed is collected from the Guide to the Coalfields (National Coal Board, 1970-1993). This is an annual publication which contains maps indicating the location mines and provides information on the number of miners employed below and above the surface. For the remaining years, 2001 and 2011, the timing of mine closures has been taken from the Northern Mine Research Society (Northern Mine Research Society, 2013) and employment numbers have been provided by the Coal Authority and are available on request. The total sample of mines consists of 211 active mines in 1981 of which only 4 remained open in 2011.

UK Census Demographic and employment data on the district level for the years 1981-2001 are provided by the UK Data Service (UK Data Service, 2013). The data for 2011 is provided by Nomis (Office for National Statistics, 2014a). All variables are disaggregated in two dimensions: sex and age. To construct homogenous age bins for all our indicators across time we impose the following structure (the length of the bins differed across indicators): 16-29, 30-44, 45-59. In some cases the construction of age bins required the assumption of a uniform distribution within a bin. For example, the available age groups for the total number of employed males between 30 and 59 in 2001 is 30-39, 40-49 and 50-59. Thus, the age bin 45-59 was calculated by premultiplying 40-49 with 0.5 and adding 50-59. Similar adjustments have been required for other variables. Merging the periods (1981, 1991, 2001 and 2011) required some adjustments due to changes in the borders of the districts. In the case of a change the districts are merged to a level which makes entities comparable over time. In 2011 these adjustments reduce the number of districts from 348 to 339. Thus, our data set consists of 339 cross-sections and 4 periods.

UK and EU regional assistance Data on regional assistance form the EU and the UK to the NUTS1 areas is reported by the Office for National Statistics in yearly publications on regional trends which are provided online since 2000 (Office for National Statistics, 2014b). Assistance to industry from the UK government covers the period 1972-2003. The allocation of funds from the EU to individual regions is reported from 1975-2006. As both, the UK and the EU are still actively allocating funds to assisted areas, we treat the remaining years as missing. Also, data on the allocation of funds from the EU is not reported on the sub-national level between 1989-1990 and 1991-1993. To resolve both issues we assume that the flows of funds are persistent and extrapolate. This does not appear to be a strong assumption because we observe strong persistence of fund flows in the data for the available years. Data for EU funds was not always available on the yearly level, but was reported cumulatively for several years (in 1980 for 1975-1980, and in 1988 for 1981-1988). This is not a serious drawback as we construct 10 years aggregates of funds flowing into assisted regions. The complete sample on regional assistance consists of 9 regions and 4 periods.

Table B.1: Variables

Variable	Notes
Number of active mines	Sum of mines which are active in district i in period t.
Number of active miners	Sum of total employees across all mines in district i in period t.
Population	Sum of individuals registered in district i.
Labor Force	Sum of individuals over 16 who are registered as economically active. The economically active consist of those employed and those unemployed. Since 2001 full-time students are additionally reported to be economically active if applicable. Thus, in 2001 we add all those who reported to be full-time students and economically active to part-time employees. In 2011 the number of full-time students economically active is not reported explicitly and, instead, is added to the individual categories of economic activity.
Workers in sector s $\in$ (Primary, Manufacturing, Services)	Number of individuals registered as employed in sector s. Primary sector: agriculture, fishing, forestry, mining sector and energy and water supply. Services: distribution and catering, transport, construction and other.
Participation rate	Total number of the economically active divided by the total number of individuals above the age of 15 and premultiplied by 100.
Unemployment Rate	The total number of unemployed divided by the total number of individuals registered as economically active and premultiplied by 100. In 1981 unemployment was constructed from two variables: those who reported seeking for a job and those who reported to be temporarily sick. Individuals who reported to be on a government scheme are treated as unemployed (reported in 2001).
Share of females in sector s $\in$ (Manufacturing, Services)	Total number of females divided by the total number of workers in sector s and multiplied by 100.
Prime Age Population	Total number of individuals within the age group of 16-44 divided by the total number of individuals and multiplied by 100.
Share of population with tertiary education	Total number of individuals with a tertiary education divided by the total number of individuals above 16.
Children per women	The total number of individuals between 0 and 15 divided by the total number of females between 30 and 44.
Regional assistance form the EU and the UK	10 year aggregates of regional assistance reported in British Pounds. Information on the amounts allocated by the EU are reported in European Currency Units up to 1997. We use the exchange rates of the years for which the funds are reported to convert the data into British Pounds. Before constructing the 10 years aggregates we use the UK CPI to construct real values (1994 prices).