Resource shocks, employment, and gender: evidence from the collapse of the UK coal industry*

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Abstract

This paper examines the effect of resource shocks on non-primary employment by gender. Using a new dataset from the closure of coal mines in UK, we show that the effects are different for men and women: when a mine closes, employment in manufacturing and services increases for men, but decreases for women. Population size and wages are also negatively affected. The effects are sizeable and persist more than 20 years after mine closures. These results are consistent with men and women being substitutes, and highlight the importance of considering gender issues when assessing the economic impact of natural resources.

1 Introduction

The effect of natural resources on local economies is usually thought in terms of a sectoral reallocation of labor: a booming extractive sector might increase local wages and attract workers from other industries. With this framework in mind, recent studies examine the effects of resources shocks on employment in non-primary sectors, specially manufacturing (Black et al., 2005b; Michaels, 2011; Allcott and Keniston, 2013; Jacobsen and Parker, 2014; Marchand, 2012).

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However, extractive industries have an important feature: most of their workers are men. This gender imbalance implies that the effect of resource shocks on non-primary employment can be qualitatively different for men and women.[1] This possibility has been neglected in the academic and policy debate on the local economic effects of natural resources. Yet, understanding these gender-specific effects is important given the evidence linking women's relative labor opportunities to a host of other outcomes such as their political influence, intra-household bargaining power, fertility and children's well-being (Aizer, 2010; Cherchye et al., 2012; Ross, 2012; Del Bono et al., 2012; Majlesi, 2014).

This paper addresses this limitation by examining the effects of resource shocks on non-primary employment by gender. Our main contribution is to show how resource shocks affect men and women differently. In particular, our findings suggest that when a mine closes, non-primary employment increases for men, but *decreases* for women. The effects are sizeable and persistent. This crowding out of women is consistent with evidence of men and women being substitutes in non-primary sectors (Acemoglu et al., 2004).

Our empirical analysis uses the case of closure of coal mines in the UK. This was one of the fastest and most acrimonious of all de-industrialization processes in the developed world (Beatty and Fothergill, 1996; Glyn and Machin, 1997; Foden et al., 2014). In a few decades the industry collapsed. Mining employment fell from almost 240,000 workers in 1981 to around 60,000 in 1991. By 2011, the industry employed only 6,000 workers. Most of these workers were men: in mining districts at the start of the 1980s, only 10% of workers in the primary sector were women. This figure is similar to the gender composition observed in extractive industries today. For instance, in the U.S. and Canada, the share of women in mining (including oil and gas) in 2011 was 13.2% and 19% respectively (US Bureau of Labor Statistics, 2012; Statistics Canada, 2012).

To examine the effect of mine closures, 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. These data allow us to explore both the short and long run effects. Our identification strategy is a difference-in-difference approach that uses number of mines closed as a treatment, and compares the evolution of employment in districts close to coal mines to districts farther away.

We start by examining the effect on total population and employment. Similar to previous

[1] We formally develop this argument in Section 2.2.

studies, we find that mine closures are associated with a persistent reduction in population size, participation rates, and number of workers. We find, however, no evidence of procyclical manufacturing employment as documented by Allcott and Keniston (2013) in the US. Instead, local manufacturing employment, in absolute and relative terms, seems to increase after mine closures. This finding is supportive of the sectoral reallocation of labor between mining and tradable sectors predicted by Dutch disease models.

Next, we examine differentiated effects on employment by gender in non-primary sectors. For the case of manufacturing, we find robust evidence that 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. We document a similar pattern in service, non-tradable, industries although the magnitudes are much smaller. These effects persist more than 20 years after the closure of mines.

The magnitude of the effect is economically significant. For the average mining district, mine closures reduced the share of women in manufacturing by 3 percentage points. This reduction represents around 9.5%, or 0.4 standard deviations, of the initial values. Note that this effect is simultaneous to a secular decline of the manufacturing sector in the UK. This means that the reallocation of male workers at the expense of women partially attenuated the increase in job losses for males and exacerbated it for women in mining districts.

An interpretation of these results is that men and women are imperfect substitutes in non-primary sectors. Then, by increasing supply of men, mine closures would reduce local wages, and demand for female labor. Consistent with this interpretation, we observe a reduction in local wages for both men and women, and negative effects on women's population and employment.

This paper relates to several strands of the literature. First, it contributes to a growing literature studying the local economic effect of natural resources (Black et al., 2005a; Aragón and Rud, 2013; Allcott and Keniston, 2013; Jacobsen and Parker, 2014; Fleming and Measham, 2014), and, more broadly, to studies of local labor markaets This literature is related to broader resaerch on local labor markets (Carrington, 1996; Moretti, 2011).

Second, this paper complements and expands findings by Ross (2008), Kotsadam and Tolonen (2015) and Black et al. (2005b) on the effect of natural resources on women. Using cross-country regressions, Ross (2008) argues that oil abundance reduces female labor participation because of the Dutch Disease and generous government transfers. Using the case of Sub-Saharan Africa, Kotsadam and Tolonen (2015) find evidence of sectoral reallocation due to resource booms: when a mine opens, women shift from agriculture to the service sector or out of the labor force. Finally, Black et al. (2005b) find that resource booms are associated with an increase in the male-female ratio in the working-age population. Consistent with that result, we find that the closure of mines generated a a relative decrease in the male-female ratio population.

Finally, this paper relates to a literature studying the economic effects of the de-industrialization in developed countries. This literature finds substantial evidence that the large scale loss of manual, mostly male, jobs in industrialized countries that started in the 1970s and accelerated during the 1980s has affected displaced workers along many dimensions, such as loss of life-time earnings, labor force participation, migration or loss of specific human capital.[2] This study highlights how these male-biased shocks can also affect women in the rest of the economy.

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 understand its impact on local labor markets. Section 3 discusses the data and empirical strategy. Sections 4 and 5 present the empirical results. Section 6 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). Coal mining was also an important source of manual jobs for unskilled men. 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 (Surrey, 1992) and employed more than 700,000 miners, mostly men.[3]

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

[2] See Kletzer (1997), Louis S. Jacobson (1993), Couch and Placzek (2010), Hijzen et al. (2010) and Carrington (1993), among others. For evidence on the effect of the UK coal bust on labor participation and migration, see Beatty and Fothergill (1996) and Beatty et al. (2007).

[3] 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.

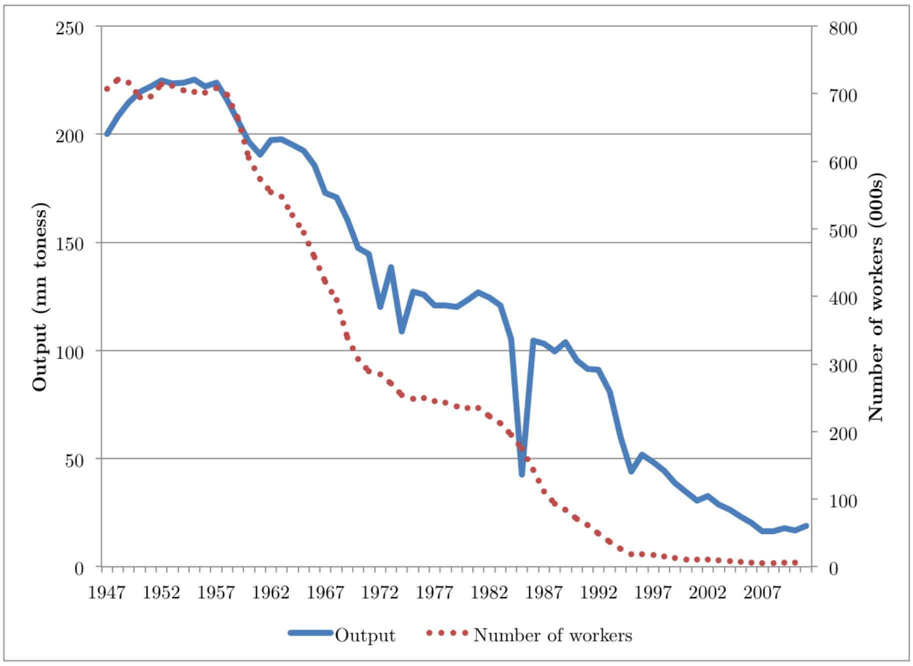


Figure 1: Output and number of workers in UK coal mines

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 the 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 and started a period of accelerated mine closures.[4]

[4]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

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).[5] 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. Mine closures were 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.

Subsequently, communities in former mining areas have been targeted by several regeneration programs and regional aid.[6] These initiatives have mostly focused on four types 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).[7] 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 sizable change in unemployment, but instead document an increase in emigration, and number of economically inactive men in the coalfields (Beatty and Fothergill, 1996; Fieldhouse and Hollywood, 1999).[8] This withdrawal of men from the labor force was mostly through early

interests by preventing coal getting to power stations.

[5]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 first. This implies that pit productivity, driven by geological factors and market access, explains timing of most 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.

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

[7]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.

[8]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.

retirement or being classed as 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 Corden 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 manufacturing, denoted a and b respectively. All firms produce tradable goods with prices normalized to 1. Labor is the only variable factor of production and there are two types of workers: men (M) and women (F). Men can work in both mining and manufacturing, but women can only work in manufacturing. This asymmetry is a key element of the model and to reflect the empirical observation that primary sectors are dominated by male workers. This feature can be motivated by men having a comparative advantage in physical labor, or by cultural norms than prevent women working on mining.

The unconditional aggregated labor demand of mining firms is $L^a_M(w_M, A_a)$, while for manufacturing firms is $L^b = L^b_M(w_M, w_F, A_b) + L^b_F(w_M, w_F, A_b)$, where A_a and A_b are industry-specific productivity shifters.[9] We model mine closures as an exogenous reduction in labor demand of mining firms, i.e., a drop in A_a. All labor demands are downward sloping, i.e., $\frac{\partial L^a_M}{\partial w_M}, \frac{\partial L^b}{\partial w_i}, \frac{\partial L^b_i}{\partial w_i} < 0$ where $i \in \{M, F\}$.

Each worker provides one unit of labor so population size is equal to labor supply. Let us denote labor supply of men and women as $N_M(w_M)$ and $N_F(w_F)$, respectively. Workers are mobile so in equilibrium they 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).[10]

[9] We assume that manufacturing productivity, A_b is not affected by population size or mining productivity, A_a. This rules out agglomeration spillovers.

[10] 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

Alternatively, we can assume that workers are immobile, have heterogeneous preferences over leisure, and decide whether to work or leave the labor force. Under standard conditions, this would also produce an upward sloping supply curve, but would change the interpretation of N_i 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 market clearing conditions:

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

$$N_F(w_F) = L_F^b(w_M, w_F, A_b). \quad (2)$$

What would be the effect of a demand shock in the mining industry, such as mine closures? To examine that, we take derivatives of the equilibrium conditions with respect to A_a to obtain:

$$\frac{\partial L_M^a}{\partial A_a} + \frac{\partial L_M^b}{\partial w_F}\frac{dw_F}{dA_a} = \frac{dw_M}{dA_a}\left[\frac{dN_M}{dw_M} - \frac{\partial L_M^a}{\partial w_M} - \frac{\partial L_M^b}{\partial w_M}\right] \quad (3)$$

$$\frac{dw_M}{dA_a} = \left[\frac{dN_F}{dw_F} - \frac{\partial L_F^b}{\partial w_F}\right]\left[\frac{\partial L_F^b}{\partial w_M}\right]^{-1}\frac{dw_F}{dA_a}. \quad (4)$$

In general, the sign of the effects of mine closures on population size, wages and sectoral employment are undetermined and depend on parametric assumptions on supply and demand elasticities. However, assuming that men and women are substitutes in the manufacturing sector is sufficient to generate a number of interesting results.[11]

First, the reduction in the demand for workers in the mining sector implies a lower equilibrium wage and male employment. This is a net effect that also accounts for both a reduction in supply of male workers and a reallocation due to the increased demand for men in the manufacturing sector. Then, the substitutability of both types of labor implies that there is a drop in the demand for female labor in the manufacturing sector. This, in turn, reduces both equilibrium wages and female employment.[12]

additional wedge between wages across locations and would not affect the qualitative predictions.

[11] See Appendix C for all proofs.

[12] If instead we assume that they are complements (i.e. $\frac{\partial L_M^b}{\partial w_F}, \frac{\partial L_F^b}{\partial w_M} < 0$), the model would only predict that $\frac{dw_M}{dA_a}$ and $\frac{dw_F}{dA_a}$ have opposite signs. But, without making more parametric assumptions, we could not obtain any testable prediction. In particular, the effect of mine closures on population size, sectoral employment, or wages could be positive or negative.

The following summarizes the main predictions of the model:

1. **Effect on population and employment**: Decrease in population of men and women (N_M, N_F), Note that N can also be interpreted as number of workers or participation rates. The model is mute, however, in terms of share of women in total population. The sign of this effect depends on the value of men and women's elasticity of supply. However, under the assumption that both elasticities are similar, we could expect an increase in population share of women.

2. **Crowding out effects**: There are two types of labor reallocation. First, reallocation of workers from mining to manufacturing (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 (Corden and Neary, 1982).[13] Second, crowding out of women in the manufacturing sector: increase of male workers (L^b_M), but *decrease* in number of female workers (L^b_F). This implies a reduction in the share of female manufacturing workers ($\frac{L^b_F}{L^b}$). Later we use this variable as our main indicator of this crowding out effect. Note that this result is driven by the gender bias in mining and substitutability of men and women, not by changes on relative wages.

3. **Effect on wages**: Reduction of wages of male and female manufacturing workers (w_M, w_F). The effect on relative wage is, however, unclear and depends on parametric assumptions.[14]

In Section 4 we evaluate empirically these predictions.

[13] In this simple model, mine closures unambiguously lead to an increase in the number of manufacturing 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. In that case, the productivity in the non-mining sector would depend of population size $A_b = A_b(N)$. In that case, the decline in population due to mine closures would negatively affect manufacturing 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.

[14] A sufficient condition for mine closures to increase women's relative wage ($\frac{w_F}{w_M}$) is $\eta_F > \epsilon^c_F + \epsilon^p_F$, where ϵ^p_F and ϵ^c_F are the own and cross wage elasticity of female labor demand, and η_F is the elasticity of female labor supply.

3 Methodology

3.1 Data

Our analysis uses three sources of data: a self-constructed data set of British coal mines since 1981, four rounds of the UK Population Census (1981, 1991, 2001 and 2011), and confidential data from the UK Labour Survey.

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 late 1970s in England and Wales.[15] 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 more than 200 coal mines.

Demographic and employment data We use information from the UK Census on population and employment status for years 1981-2011.[16] The raw data is disaggregated 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.[17]

We construct several demographic employment variables, such as population, participation and unemployment rates, and number of workers by gender and industry. We group industries in three broad sectors: primary, manufacturing, and services. The primary sector includes mining plus agriculture, forestry, fishing, energy and water supply.[18] Services include distribution and catering, transport and construction, and others.

We complement these data with confidential microdata from the UK New Earnings Survey Panel Dataset (Office for National Statistics, 2015). This dataset contains annual payroll in-

[15]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 ten miners, adding up to less than 1,000 miners in total.

[16]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, which difficult geographical comparisons over time.

[17]Results are robust to alternative sample definitions.

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

formation of individual workers for years 1975 to 2011. This dataset has higher frequency and longer time coverage than the Census. However, it has lower geographical resolution: counties instead of districts.[19] For that reason, we use this dataset only in our wage regressions and prefer to use Census data for our main results

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 men. 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.[20] Third, unemployment rates are lower in 2011 for both women and men. Finally, the number of workers in the primary sector falls sharply between 1981 and 2011 for men, but not for women.

Ancillary data We 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 nine 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.[21]

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 (D-i-D) 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

[19] This dataset has information on districts only since late 1990s.

[20] OECD estimates show labor force participation in 2011 to be 82.5 for men and 70.4 for women in all of the UK.

[21] 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	Women	Men	Total	Women	Men
	(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
No. of workers ('000s)						
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
Wage of manual workers						
Primary	1.9	1.6	1.9	8.1	7.4	8.3
Manufacturing	2.5	1.8	2.7	10.1	7.9	10.7
Services	2.1	1.5	2.4	7.6	7.0	8.3

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. Wage refers to median hourly wage. Wage is measured in British pounds. Number of districts is 174.

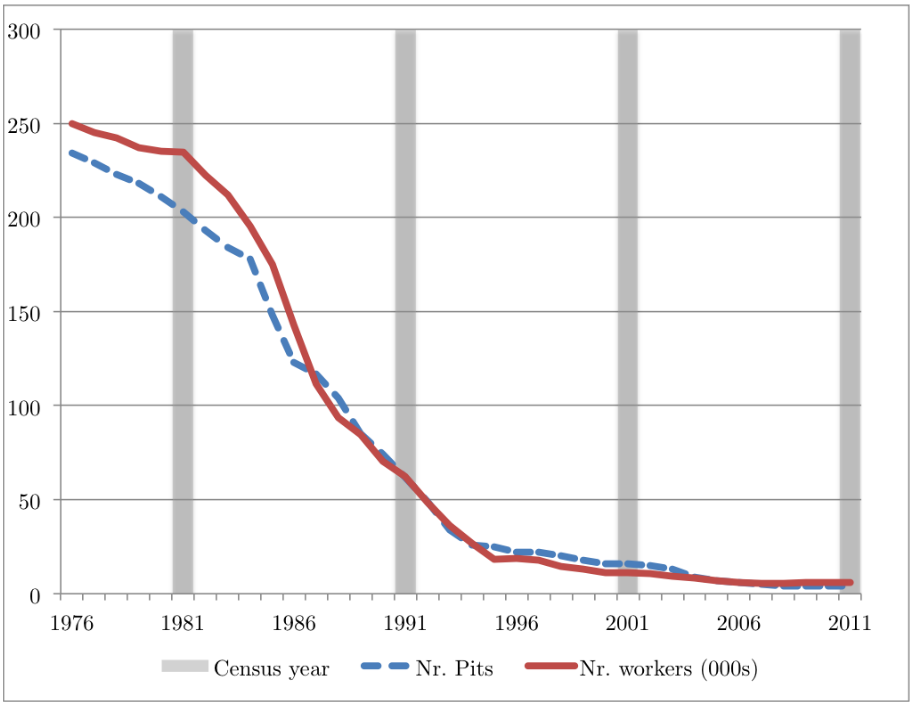
a dramatic acceleration in mine closures and loss of mining jobs. We treat this event as a significant, negative shock, to local labor markets. Figure 2 displays the evolution of number of mines and miners, and highlights the years for which we have Census information. Most of mine closures occurred 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.

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.[22] 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

[22] In Section 5, we also explore alternative sample definitions, and more flexible specifications of distance to mines.

Figure 2: Coal mines and miners: 1976-2011



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.

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 use the number of mines closed since 1981 in a given district.[23] Formally, we estimate the following regression model:

$$y_{dt} = \beta mine\ closures_{dt} + \eta_d + \rho_t + \epsilon_{dt}, \tag{5}$$

where the unit of observation is district d in year t and *mine closures* is the number of mines closed. The baseline specification includes year and district fixed effects and cluster the errors by county to account for possible serial and spatial correlation.[24]

[23]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. All of our results are similar when using number of miners laid-off instead of number of mines closed (see Appendix B).

[24]There are 68 counties in the sample. We also check the robustness of the results to using Conley standard errors.

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

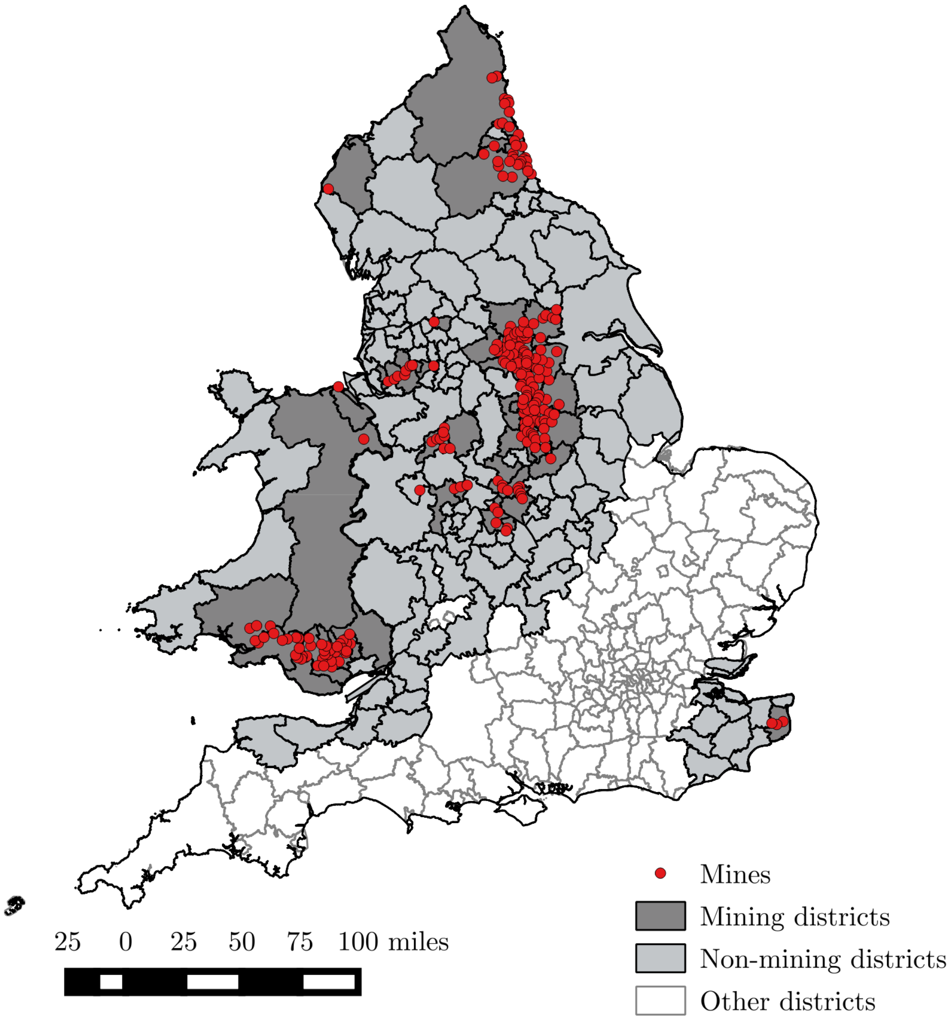


Table 2: Main characteristics of average mining and non-mining districts in 1981

	Mining		Non-mining		p-value
	Mean	S.D.	Mean	S.D.	(1)=(3)
	(1)	(2)	(3)	(4)	(5)
No. 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
No. 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.

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. The most important outcome is the share of female manufacturing workers.[25] This variable is a function of the female-to-male ratio, and captures the extent of the substitution of male for female workers in the manufacturing sector.[26]

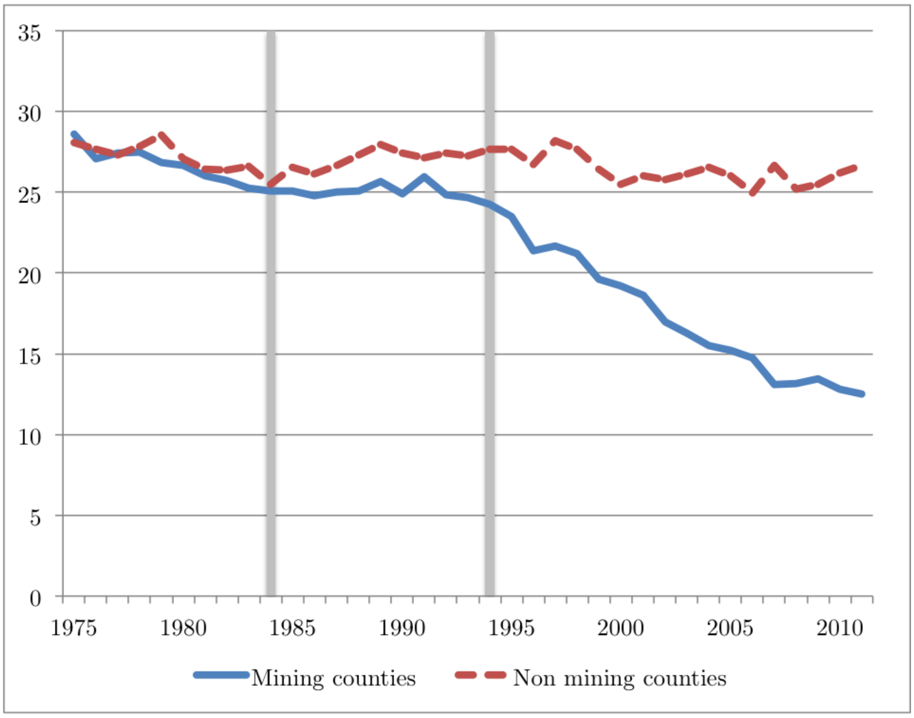
The validity of our identification strategy relies on the assumption that, in the absence of mine closures, employment outcomes in both mining and non-mining districts would have followed the same trend. To explore the validity of this assumption we use annual data from the New Earnings Survey to examine differences between mining and non-mining counties on our main outcome, i.e., share of female manufacturing workers.

The results, displayed on Figure 4, suggest that after 1984, when mine closures started, there was a significant reduction on this outcome in mining counties relative to non-mining counties. This phenomenon seems to accelerate after 1994, when the industry was privatized

[25]This variable is equal to (manufacturing female workers)/(total manufacturing workers).

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

Figure 4: Share of female manufacturing workers



Notes: Vertical lines indicate years 1984 and 1994.

and most mines finally closed. This is prima facie evidence of the crowding out effect discussed above. Importantly, between the 1970s and early 1980s this outcome follows similar trends in both groups. We interpret this finding as evidence supportive of the validity of our identification assumption. In the empirical analysis, however, we examine the importance of several confounding factors that could violate this assumption.

4 Main results

4.1 A gender biased shock with broad effects

We start by examining whether the closure of mines was indeed a gender biased shock. To do so, we estimate the effect of mine closures on number of primary workers. We find that mine closures reduced the number of men in primary sectors (see column 1 in Table 3). For example, each mine closure reduced number of male workers by almost 1,000. This is consistent with the average size of coal mines. In contrast, the number of female workers decreased by less than

20.[27] Note that the primary sector includes mining and other industries such as agriculture, logging, energy and water. Thus, the estimates include jobs lost due to mine closures net of any labor reallocation within the primary sector.

We also examine the effect of mine closures on population size and employment outcomes by gender. These effects of resource shocks have been previously studied in the context of U.S., Canada and Australia, although mostly without distinguishing by gender (Black et al., 2005b; Michaels, 2011; Marchand, 2012; Jacobsen and Parker, 2014; Fleming and Measham, 2014).

We find that mine closures reduce population size, number of workers, and participation rates of both men and women. This result is consistent with the reduction in labor supply (either through emigration or leaving the labor force) associated to the negative demand shock and lower local wages. It also highlights that resource shocks, specific to men, can create negative spillovers to female workers in the rest of the economy. We examine this crowding out effect in more detail next.

Table 3: Effect of mine closures on primary employment, population and employment

	No. primary workers '000s (1)	ln(pop.) (2)	ln(nr. workers) (3)	Particip. rate (4)	Unemploy. rate (5)
A. Men					
No. of mines closed since 1981	-1.045***	-0.006**	-0.009***	-0.225***	-0.003
	(0.066)	(0.002)	(0.003)	(0.074)	(0.075)
B. Women					
No. of mines closed since 1981	-0.017	-0.004*	-0.006*	-0.178**	-0.011
	(0.015)	(0.002)	(0.003)	(0.079)	(0.047)

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. Panel A reports estimates using outcomes for men, while Panel B uses outcomes for women. Primary sector includes mining plus agriculture, forestry, fishing, energy and water supply. Number of primary workers is measured in thousands. Number of observations = 696, number of districts=174.

[27] Similar results are obtained using number of miners laid-off. For this reason in the rest of the analysis we use number of mines closed as our preferred measure of the demand shock. Results using number of miners laid-off are available in Appendix B.

4.2 Crowding out effects by industry and gender

As discussed in Section 2.2, mine closure can re-allocate labor from primary to non-primary tradable sectors, as in Dutch-disease models. However, the strong male-bias of the resource shock also creates scope for a differentiated effect by gender: laid-off males crowd out women in the rest of the economy. This would translate into a reduction in the absolute and relative number of female workers in non-primary sectors.[28]

Table 4 explores these crowding out effects.[29] First, we find evidence of labor reallocation from primary to non-primary sectors: despite a reduction in total number of workers, there is a slight increase in number of manufacturing workers (column 1). 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).[30]

Second, we find evidence consistent with the crowding out of women in non-primary sectors. Mine closures have gender-specific effects on manufacturing employment (panel A): they *increase* the number of male workers, but *decrease* the number of females workers. This translates into a reduction of around 0.78 percentage points in the share of female manufacturing workers for every mine closed. This is a sizable reduction. For the average mining district, it represents a total reduction of around 3 percentage points, or almost 0.4 standard deviations, over the period 1981-2011.[31]

We find similar effects in the service sector (panel B), although there is no significant reduction of female workers. Interestingly, we do not observe crowding out of women in other male-dominated industries, such as construction and transportation (panel C), but only in activities in which men and women seem to be more substitutable, such as retail, catering and other services (panel D).[32]

This crowding out of women is the main finding of this paper. These findings demonstrate how resource shocks can affect a local economy not only by reallocating labor across industries,

[28]In Section 5.4 we also examine possible differentiated effects by type of job.

[29]We present results both for the census data and for sample data taken from the UK New Earning Survey, that we use to analyse wage effects.

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

[31]The average share of female manufacturing workers in mining districts in 1981 was 31.4% , with a standard deviation equal to 6.5 (see Table 2).

[32]In 1981, construction and transportation services had a very small share of female workers (around 12%). similar to primary sectors (around 10%). In contrast, the share of women in manufacturing and retail, catering and other services were 30% and 50% respectively.

but also reallocating jobs between men and women. As we find in the UK case, this reallocation of labor can attenuate the negative shock on male employment, but also create negative spillovers on women.[33] This crowding out effect has been so far neglected in the academic and policy debate but it is likely to occur with shocks to other male-dominated activities.

Table 4: Effect of mine closures on employment in non-primary sectors

	ln(no. of workers)			% female workers	% female workers
	Total	Women	Men		
	(1)	(2)	(3)	(4)	(5)
A. Manufacturing					
No. of mines closed since 1981	0.011*	-0.015**	0.022***	-0.782***	-0.202**
	(0.006)	(0.006)	(0.007)	(0.140)	(0.075)
B. Services					
No. of mines closed since 1981	0.007	-0.002	0.010**	-0.278***	-0.082**
	(0.005)	(0.004)	(0.005)	(0.064)	(0.035)
C. Construction and transportation					
No. of mines closed since 1981	0.011*	0.010	0.011*	-0.013	0.015
	(0.007)	(0.008)	(0.007)	(0.062)	(0.054)
D. Retail, catering and other services					
No. of mines closed since 1981	0.003	-0.002	0.009**	-0.277***	-0.13***
	(0.004)	(0.004)	(0.004)	(0.055)	(0.041)

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. Panels A to D report estimates using outcomes for different sectors. Services include construction and transportation, retail, catering and other services. The share of females in column 4 is calculated using the information form the UK Census while the share of females in column 5 is calculated using the the information from the UK New Earning Survey. Number of observations = 696, number of districts=174.

4.3 Effect on wages

Our analytical framework suggests that the crowding out effects (both across industries and gender) are driven by the reduction of wages. To explore this prediction, we estimate the baseline regression (5) with log of hourly wage as outcome variable, and use data at worker

[33] A back-of-the-envelope calculation suggests that for every 1,000 miners laid-off the number of male manufacturing workers increased by around 330 while female manufacturing workers decreased by 100.

level from the UK New Earnings Survey.[34] We split the results by industry of occupation and gender.

Table 5 displays the results of these wage regressions. Consistent with the previous effects on non-primary employment, we find that mine closures reduce wages in non-primary sectors. In manufacturing the reduction is similar for both men and women, while in services it is only significant for men. Analogously to Table 4 we split the service sector into construction and transportation (column 3 and 4) and retail, catering and other services (column 5 and 6). Consistent with the results above we do not find a significant effect on wages in construction and transportation. On the other hand, we do find that the mine closures have a negative and significant effect on men's wages in retail, catering, and other industries in which men and women seem to be more substitutable.

Table 5: Effect on wages

	Dep. variable = Ln(wage)					
	Manufacturing workers		Service workers			
			Const. & Transport		Retail, Catering & Other	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
No. of mines	-0.0017**	-0.0015**	0.0003	-0.0002	-0.0003	-0.0016*
closed since 1975	(0.0007)	(0.0006)	0.0012	0.0006	0.0004	0.0009
No. Obs.	212,321	614,735	56,900	279,470	589,678	501,979

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 country-by-year and county fixed effects, county-specific trends, and individual controls such as: age and its square, occupation and industry dummies and indicators of full time job, junior position, being a experienced worker, having an additional job, and being under a national or subnational wage agreement. Columns 1 to 2 use a sample of manufacturing workers. In column 3 to 6 we split the service sector (excluding government, health and education and research workers) into construction and transportation (column 3 and 4) and into retail, catering and other services (column 5 and 6). Sample includes only counties located within 30 miles of a mine for years 1975 to 2011. Number of counties = 38.

Figure 5 exploits the richness of the wage data and depicts the differences in manufacturing wages between mining and non-mining counties for years 1975 to 2011.[35] There are two important observations. First, consistent with the previous results, there is a significant reduction

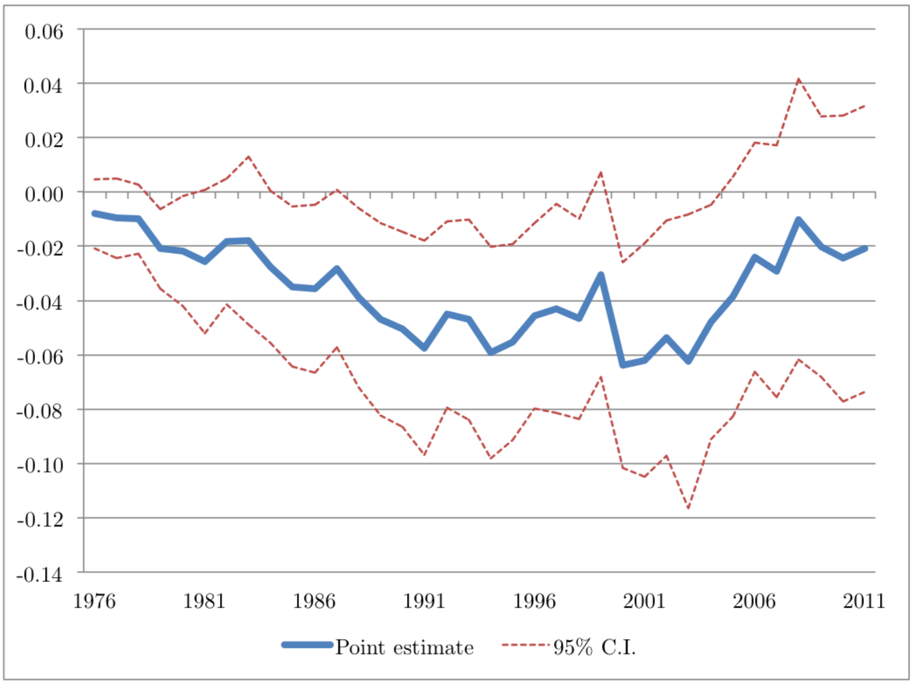
[34]In particular, we split the sample between men and women, and estimate the following wage regression:

$$\ln w_{ict} = \beta mine\ closures_{ct} + \delta X_{ict} + +\epsilon_{ict}, \tag{6}$$

where the unit of observation is worker i, in county c, in year t. w_{ict} is the hourly wage, $mine\ closures_{ct}$ is the number of mines closed since 1975, and X_{ict} is a rich set of covariates (see notes of Table 5 for further details.).

[35]We estimate the log of wages on the interaction of year dummies with an indicator of being in a mining county. Figure 5 depicts the points estimates and confidence interval.

Figure 5: Difference of manufacturing wages between mining and non-mining counties



in wages starting in mid 1980s. Second, this negative effect is transitory. The wage difference persists until early 2000s but then it closes. In the last years of our sample there is no significant wage difference between both types of counties. A similar dynamic, temporary, response of regional wages to an employment shock has been documented in the U.S. case (Blanchard and Katz, 1992, p. 40).

5 Ancillary results

5.1 Persistence

A relevant question is whether the effect of mines closures is short-lived or persists over time. Despite the effect on wages being temporary, population and employment may adjust in response to mine closures and thus exhibit more persistent effects.

To explore this issue, we estimate a long D-i-D regression comparing years 2001 and 2011 to 1981. The regression uses as main regressor an indicator of mining district interacted with year dummies, and includes both district and year fixed effects. This regression basically estimates the difference in trends between mining and non-mining districts over time, relative to their baseline difference in 1981.

The results (see Table 6) suggest that the effects of mine closures on population, participation rate, and female employment are persistent. For instance, even in 2011, more than 20 years since the end of most mine closures, the proportion of women in mining districts has shrunk by 5.2 percentage points relative to the difference between mining and non-mining districts at the beginning of the sample. We find qualitatively similar effects for population and labor force participation rates. These persistent negative effects are consistent with other studies of the impact of mine closures in the U.K. and U.S. (Beatty et al., 2007; Coalfield Regeneration Review Board, 2010; Jacobsen and Parker, 2014; Foden et al., 2014).

Table 6: Persistence of effects of mine closures

	ln(pop.)	Particip. rate	Manufacturing		
			ln(nr. of workers)		% female workers
			Women	Men	
	(1)	(2)	(3)	(4)	(5)
Mining district ×	-0.033	-2.674***	-0.139**	0.079	-4.574***
year 2001	(0.022)	(0.708)	(0.057)	(0.049)	(0.843)
Mining district ×	-0.048*	-1.135**	-0.168***	0.085	-5.202***
year 2011	(0.026)	(0.538)	(0.063)	(0.060)	(0.862)
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 OLS, 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".

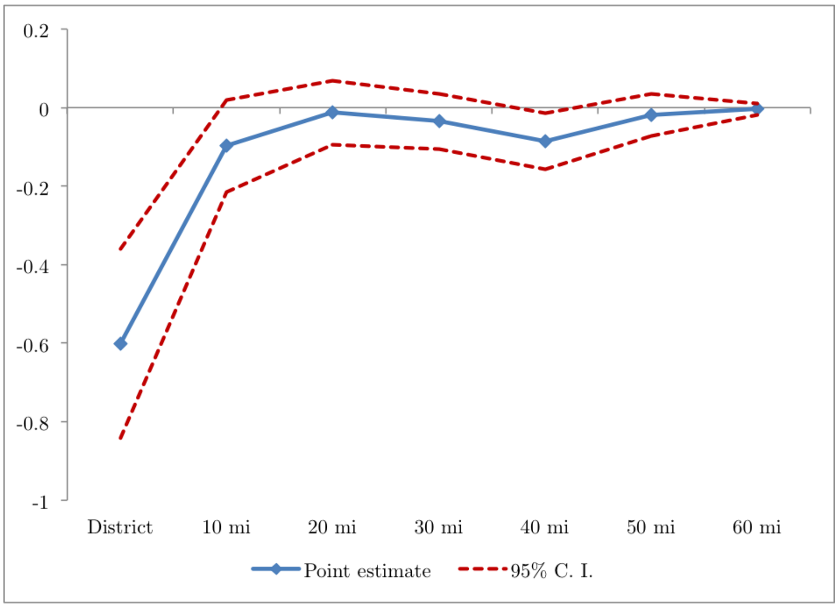
5.2 Role of distance

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 regression (5) using 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.[36] Figure 6

[36] Results are similar when using the baseline sample.

displays the estimated effect of mine closures on share of female manufacturing workers.[37] Note that the magnitude 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.[38]

Figure 6: 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.1 for further details.

5.3 Robustness checks

Table 7 checks the robustness of the main results. We focus on our main outcome, i.e, the share of female manufacturing workers.[39] Columns 1 and 2 change the sample definition. Column 1 uses all districts in England and Wales, while column 2 uses a narrower sample: only the sample of mining districts. This last column exploits only the timing of mine closure among mining districts, and thus makes both treated and comparison groups more similar.

An important threat to our identification strategy is the presence of time-varying omitted variables related to mine closures. One such confounding variable is the regeneration policies targeted to former coalfields, but could also be due to different trends linked to initial differences

[37]Table A.1 in the Appendix presents full regression estimates on role of distance for other outcome variables.

[38]These results suggest that our baseline regressions may actually underestimate the effects since they include in the control group districts within 10 miles. These districts are also negatively affected by mine closures.

[39]See Table A.2 in Appendix for robustness checks using other outcomes.

in mining areas. We address this concern in two ways (columns 3 and 4). First, we include the amount transferred 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 a rich set of non-parametric trends by several initial characteristics, such as population, distance to London and employment conditions, as well as region-by-year fixed effects. This last specification accounts for all factors that change over time at regional level, including local policies.

Further, we explicitly account for the concern that the timing of the mine closures might be endogenous, for instance for political reasons, by instrumenting for the number of mines closed since 1981. Our instrument is an interaction of the price of coal with number of active mines in 1981.[40] The results are presented in column 5.

Finally, we estimate the baseline regression correcting the standard errors for spatial and serial correlation using the procedure described by Conley (2008) (column 6).[41] However, in all specifications, the results remain similar to the baseline estimates.

Table 7: Robustness checks

	share of female manufacturing workers					
	(1)	(2)	(3)	(4)	(5)	(6)
No. of mines closed since 1981	-0.977***	-0.436***	-0.741***	-0.612***	-0.789***	-0.782***
	(0.176)	(0.104)	(0.142)	(0.120)	(0.159)	(0.148)
Robustness check:	All districts	Only mining districts	EU & UK regional funds	Non-param. trends	IV	Conley S.E.
Observations	1,356	212	696	696	696	696
R-squared	0.293	0.699	0.530	0.740	0.521	0.097
No. districts	339	53	174	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 1-2 change the sample definition. The baseline sample refers to districts within 30 miles of a mine. Column 3 includes the log of UK and EU regional funds as proxy for regeneration policies. Column 4 includes region-by-year fixed effects and interaction of year fixed effects with quartiles of distance to London and indicators of above-the-median values in 1981 of population size, manufacturing and service employment, and share of female manufacturing and service workers. In column 5 we instrument the number of closed mines with the price of coal nteracted with the number of active mines on the district in 1981. The first stage F-test is 1,722. Column 6 estimates the baseline regression with standard errors corrected for spatial and serial correlation using the procedure described by Conley (2008).

[40]The global price of coal is reported for a variety types by EIA (2015).

[41]We use ado file OLS_HAC developed by Hsiang (2010). We set the maximum distance to 30 miles and use one period lag.

5.4 Manual vs non-manual workers

So far we have focused on the gender bias of mine closures. However, most of the mine workers were not only men, but also were manual workers.[42] To the extent that manual and non-manual workers are substitutes, we would also expect heterogeneous effects by type of job, and crowding out of non-manual workers. We examine this possibility in this section. To do so, we replicate Table 4 distinguishing between manual and non-manual workers, instead of women and men.[43]

In contrast to the baseline results, we find no evidence of a sizable crowding out effect (see Table 8). In the manufacturing sector, mine closures increase employment of both manual and non-manual workers, and there is no significant decrease in the share of non-manual workers. In the service sector, the results suggest some substitution of manual for non-manual workers. However, the decrease of non-manual workers, in absolute and relative terms, is statistically insignificant or has a small magnitude. We interpret these findings as evidence that there is more substitutability within the work force across genders than across manual versus non-manual workers.[44]

Table 8: Effect of mine closures on manual and non-manual employment

	ln(nr. of workers)		% non-manual
	Non-manual	Manual	workers
	(1)	(2)	(3)
A. Manufacturing			
No. of mines closed	0.014*	0.011*	-0.001
since 1981	(0.007)	(0.006)	(0.001)
B. Services			
No. of mines closed	-0.002	0.005	-0.002**
since 1981	(0.004)	(0.004)	(0.001)

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 as in Table 4. Panels A and B report estimates using outcomes for different sectors. Sample includes districts within 30 miles of a mine active in 1981. Number of observations = 696, number of districts=174.

[42] See Table A.3 in the Appendix.

[43] Manual jobs correspond to the following types of occupations: (1) skilled trades, (2) personal services, (3) sales and customer service, (4) process, plan and machine operators, and (5) elementary occupations. In contrast, non-manual jobs include managers, professionals, and administrative staff. Due to data limitations, we cannot distinguish workers by education level.

[44] We also check that our baseline results are not driven by changes in number of manual and non-manual workers. See Table A.5 in the Appendix.

5.5 Age profiles by gender

An important aspect of the substitutability in the manual sector may be linked to experience. In particular, the skills that displaced male workers may bring from the resource sector may not be directly transferable to the manufacturing sector. In Table 9 we explore this issue by using age as a proxy for experience.

We find that while there is no age profile in displaced men from the primary sector, there is an age profile in the crowding out of women in the manufacturing sector.[45] In particular, Panel B shows that men of all age groups get jobs in manufacturing, but that the displacement of women is decreasing in age. A similar pattern is found for retail, distribution and catering jobs where younger women are more likely to lose their jobs at the hand of older men. The evidence shows that older, and probably more experienced, women are less likely to lose their manufacturing and service jobs. For men, there is a clear age profile in the services sector, as young men are not as likely to find jobs as their older counterparts.

5.6 Other demographic changes

The change on wages and employment conditions could also trigger changes on population composition and affect other outcomes, such as fertility and marriage. To explore this, we examine whether mine closures are associated to other demographic changes (see table 10).

First, we do find a significant change 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, and in line with results by Black et al. (2005b).[46] Second, we do not find significant changes in age composition: the relative size of prime age population does not drop significantly, even though the point estimate is negative.[47] We also find a significant reduction in the share of population, both men and women, 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 reduces their fertility.

[45]Mine closures reduce number of male primary workers of all ages in a similar proportion, see Table A.4 in the Appendix.

[46]They find that booms are associated with an increase in the population of men relative to women.

[47]This may be explained by the fact that we do observe a large reduction in the population numbers of over 45. These unreported results, available upon request, may be capturing a reduction in a cohort that may have suffered the shock but where subsequently replaced as 'prime age' by younger workers who have never left.

Table 9: Heterogeneous effects by age

	Dep. variable = ln(number of workers in sector)					
	Women			Men		
	16-29	30-44	45-59	16-29	30-44	45-59
	(1)	(2)	(3)	(4)	(5)	(6)
A. Manufacturing						
No. 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)
B. Services						
No. 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)
C. Construction and transport						
No. of mines	0.012	0.009	0.008	0.010	0.015**	0.015*
closed since 1981	(0.009)	(0.008)	(0.010)	(0.008)	(0.007)	(0.008)
D. Retail, catering and other services						
No. of mines	-0.000	0.000	-0.006	0.005	0.009**	0.015**
closed since 1981	(0.004)	(0.004)	(0.005)	(0.005)	(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 30 miles of a mine active in 1981. Number of observations = 696, number of districts=174.

We explore this channel by using a proxy of fertility, namely children per women in child-bearing age.[48] The negative and significant effect in column 5 is consistent with a reduction in fertility in areas more affected by mine closures. However, while we find that women have fewer children, we cannot rule out the possibility that this is driven by selective out-migration of women with higher fertility. Finally, consistent with a decrease in male population and worse labor opportunities, we find that mines closures are associated with an increase in share of single, unmarried, individuals.

Table 10: Other demographic changes

	% female pop.	% prime age pop.	% population with tertiary education		Children per woman	% single indiv.
			Women	Men		
	(1)	(2)	(3)	(4)	(5)	(6)
No. mines closed since 1981	0.041***	-0.013	-0.217***	-0.151**	-0.008***	0.229***
	(0.012)	(0.058)	(0.059)	(0.058)	(0.002)	(0.053)

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 is the same as in baseline regression. Columns 1 and 2 use as outcomes the population share of women and prime age individuals (16-44 years old). Columns 3 and 4 use the share of population over 16 years with tertiary education. Column 6 uses the ratio of population age 0 to 15 years to women age 35-44.

6 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 heterogeneous effects. 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 persists over time. In addition, we document persistent negative effects in population size and participation rates, and find evidence of reallocation of labor from mining to manufacturing.

[48] We define this variable as the ratio of children between 0 and 15 to women between 35 and 44 years old.

This last result is similar in flavor to the sectoral reallocation of labor predicted by Dutch disease models.

There are, however, some unsolved issues. First, while informative, our empirical estimates might be context specific. 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, intra-household bargaining power, or human capital investment. Studying these issues warrant further research.

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ONLINE APPENDIX - NOT FOR PUBLICATION

A Additional figures and tables

Table A.1: Effects of mine closures by distance

	ln(pop.)	Particip. rate	Manufacturing ln(nr. of workers) Women	Manufacturing ln(nr. of workers) Men	Manufacturing % female workers
	(1)	(2)	(3)	(4)	(5)
No. 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.

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

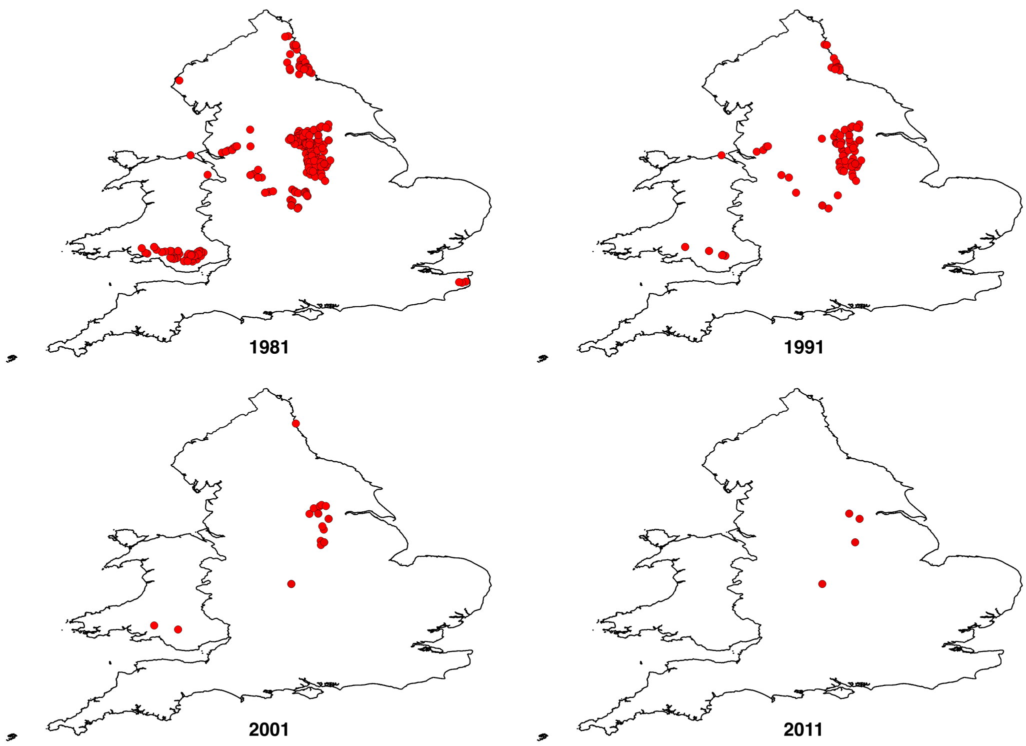

Table A.2: Robustness checks using other outcomes

	Robustness check					
	All districts	Only mining districts	EU & UK regional funds	Non-param. trends	IV	Conley S.E.
Outcome	(1)	(2)	(3)	(4)	(5)	(6)
ln(pop.)	-0.012***	-0.002	-0.004	-0.001	-0.005**	-0.005*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Participation rate	-0.370***	-0.089	-0.186**	-0.051	-0.368***	-0.217***
	(0.077)	(0.076)	(0.071)	(0.066)	(0.1)	(0.078)
ln(manuf. workers)	0.015	0.015*	0.013*	0.012*	0.01	0.011**
	(0.010)	(0.007)	(0.007)	(0.007)	(0.007)	(0.005)
ln(service workers)	0.005	0.005	0.009*	0.012**	0.008	0.007
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
share of female service workers	-0.334***	-0.196**	-0.237***	-0.132**	-0.272***	-0.244***
	(0.064)	(0.075)	(0.068)	(0.064)	(0.067)	(0.060)

Notes: Robust standard errors in parentheses. Standard errors are clustered at county level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Table replicates robustness checks shown in Table 7 using other outcomes. Each estimate is obtained in a different regression. See notes of Table 7 for further details.

Table A.3: Effect of mine closures on employment in primary sector, by gender and type of job

	No. primary workers '000s			
	Men	Women	Manual	Non-manual
	(1)	(2)	(3)	(4)
Panel A				
No. of mines closed since 1981	-1.045***	-0.017	-0.973***	-0.099***
	(0.066)	(0.015)	(0.064)	(0.016)
Panel B				
No. mine workers laid-off since 1981	-1.078***	-0.017	-0.995***	-0.112***
	(0.056)	(0.018)	(0.058)	(0.016)

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 sector includes mining plus agriculture, forestry, fishing, energy and water supply. Panel A reports regressions using number of mines closed as treatment variable, while Panel B uses number of workers laid-off (in thousands). Number of primary workers measured in thousands. Number of observations = 696, number of districts=174.

Table A.4: Effect of mine closures on employment in primary sector, by gender and age

	No. primary workers '000s					
	Females			Males		
	16-29	30-44	45-59	16-29	30-44	45-59
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A						
No. of mines	-0.002	-0.002	-0.012***	-0.317***	-0.330***	-0.293***
closed since 1981	(0.005)	(0.007)	(0.004)	(0.028)	(0.019)	(0.017)
Panel B						
No. mine workers	-0.003	-0.002	-0.011**	-0.330***	-0.337***	-0.302***
laid-off since 1981	(0.006)	(0.007)	(0.004)	(0.024)	(0.018)	(0.014)

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 sector includes mining plus agriculture, forestry, fishing, energy and water supply. Panel A reports regressions using number of mines closed as treatment variable, while Panel B uses number of workers laid-off (in thousands). Number of primary workers measured in thousands. Number of observations = 696, number of districts= 174.

Table A.5: Substitution effects in non-primary sectors, controlling by manual and non-manual employment

	Manufacturing			Services		
	ln(nr. workers)		% female	ln(nr. workers)		% female
	Women	Men	workers	Women	Men	workers
	(1)	(2)	(3)	(4)	(5)	(6)
No. mines closed	-0.026***	0.010***	-0.786***	0.000	0.010***	-0.215***
since 1981	(0.004)	(0.002)	(0.141)	(0.002)	(0.002)	(0.063)
ln(no. manual	0.260***	0.410***		0.623***	0.428***	
workers in sector)	(0.053)	(0.024)		(0.053)	(0.028)	
ln(no. non-manual	0.720***	0.589***		0.405***	0.538***	
workers in sector)	(0.060)	(0.025)		(0.034)	(0.027)	
% non-manual			-6.005			16.502***
workers in sector			(6.032)			(4.702)

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. Number of observations = 696, number of districts = 174.

B Main results using number of miners laid-off

Table B.1: Effect of mine closures on primary employment, population and employment

	No. primary workers '000s (1)	ln(pop.) (2)	ln(nr. workers) (3)	Particip. rate (4)	Unemploy. rate (5)
A. Men					
No. mine workers	-1.078***	-0.006***	-0.010***	-0.243***	0.041
laid-off since 1981	(0.056)	(0.002)	(0.003)	(0.064)	(0.084)
B. Women					
No. mine workers	-0.017	-0.005**	-0.007**	-0.179**	0.016
laid-off since 1981	(0.018)	(0.002)	(0.003)	(0.075)	(0.047)

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. Panel A reports estimates using outcomes for men, while Panel B uses outcomes for women. Primary sector includes mining plus agriculture, forestry, fishing, energy and water supply.. Number of primary workers is measured in thousands. Number of observations = 696, number of districts = 174.

Table B.2: Effect of mine closures on employment in non-primary sectors

	ln(nr. of workers)			% female
	Total	Women	Men	workers
	(1)	(2)	(3)	(4)
A. Manufacturing				
No. of mine workers	0.010*	-0.016**	0.022***	-0.795***
laid-off since 1981	(0.006)	(0.007)	(0.007)	(0.172)
B. Services				
No. of mine workers	0.007	-0.002	0.009**	-0.279***
laid-off since 1981	(0.004)	(0.004)	(0.004)	(0.057)
C. Construction and transportation				
No. of mine workers	0.012*	0.011	0.012*	-0.002
laid-off since 1981	(0.006)	(0.007)	(0.006)	(0.065)
D. Retail, catering and other services				
No. of mine workers	0.002	-0.003	0.008*	-0.272***
laid-off since 1981	(0.004)	(0.004)	(0.004)	(0.055)

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. Panels A to D report estimates using outcomes for different sectors. Services include construction and transportation, retail, catering and other services. Number of observations = 696, number of districts = 174.

Table B.3: Robustness checks

	share of female manufacturing workers				
	(1)	(2)	(3)	(4)	(5)
No. of mine workers laid-off since 1981	-0.982***	-0.482***	-0.755***	-0.558***	-0.795***
	(0.205)	(0.141)	(0.174)	(0.132)	(0.137)
Robustness check:	All districts	Only mining districts	EU and UK regional funds	Non-param. trends	Conley S.E.
Observations	1,356	212	696	696	696
R-squared	0.297	0.704	0.533	0.724	0.105
No. districts	339	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 1-2 change the sample definition. The baseline sample refers to districts within 30 miles of a mine. Column 3 includes the log of UK and EU regional funds as proxy for regeneration policies. Column 4 includes region-by-year fixed effects and interaction of year fixed effects with quartiles of distance to London and indicators of above-the-median values in 1981 of population size, manufacturing and service employment, and share of female manufacturing and service workers. Column 5 estimates the baseline regression with standard errors corrected for spatial and serial correlation using the procedure described by Conley (2008).

Table B.4: Effect of mine closures on manual and non-manual employment

	ln(no. of workers)		% non-manual workers
	Non-manual	Manual	
	(1)	(2)	(3)
A. Manufacturing			
No. of mine workers laid-off since 1981	0.012*	0.010*	-0.001
	(0.006)	(0.006)	(0.001)
B. Services			
No. of mine workers laid-off since 1981	-0.003	0.005	-0.002***
	(0.004)	(0.004)	(0.001)

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 as in Table 4. Panels A and B report estimates using outcomes for different sectors. Sample includes districts within 30 miles of a mine active in 1981. Number of observations = 696, number of districts = 174.

Table B.5: Heterogeneous effects by age

	Dep. variable = ln(no. of workers in sector)					
	Women			Men		
	16-29	30-44	45-59	16-29	30-44	45-59
	(1)	(2)	(3)	(4)	(5)	(6)
A. Manufacturing						
No. of 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)
B. Services						
No. of 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)
C. Construction and transport						
No. of mine workers	0.016**	0.011	0.007	0.011	0.014**	0.016**
laid-off since 1981	(0.008)	(0.008)	(0.009)	(0.008)	(0.006)	(0.007)
D. Retail, catering and other services						
No. of mine workers	-0.002	-0.000	-0.006	0.003	0.009*	0.015***
laid-off since 1981	(0.004)	(0.004)	(0.005)	(0.005)	(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 30 miles of a mine active in 1981. Number of observations = 696, number of districts = 174.

Table B.6: Other demographic changes

	% female pop.	% prime age pop.	% population with tertiary education		Children per woman	% single indiv.
			Women	Men		
	(1)	(2)	(3)	(4)	(5)	(6)
No. of mine workers	0.046***	-0.033	-0.239***	-0.172***	-0.008***	0.211***
laid-off since 1981	(0.011)	(0.054)	(0.047)	(0.050)	(0.002)	(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 is the same as in baseline regression. Columns 1 and 2 use as outcomes the population share of women and prime age individuals (16-44 years old). Columns 3 and 4 use the share of population over 16 years with tertiary education. Column 6 uses the ratio of population age 0 to 15 years to women age 35-44.

C Proofs

Let us define the following terms:

$$A \equiv \frac{\partial L_M^a}{\partial A_a}, B \equiv \frac{\partial L_M^b}{\partial w_F}, C \equiv \frac{dN_M}{dw_M}, D \equiv -\frac{\partial L_M^a}{\partial w_M},$$
$$E \equiv -\frac{\partial L_M^b}{\partial w_M}, F \equiv \frac{dN_F}{dw_F}, G \equiv -\frac{\partial L_F^b}{\partial w_F}, H \equiv \frac{\partial L_F^b}{\partial w_M}.$$

Note that the assumptions of upward sloping labor supplies, downward sloping labor demands, and substitutability of men and women in manufacturing imply that all these terms $(A, B, ..., H)$ are positive. Furthermore, the assumption that $\frac{\partial L^b}{\partial w_i} < 0$ implies that $E > H$ and $G > B$.

Using these definitions, equations (3) and (4) can be written as:

$$A + B\frac{dw_F}{dA_a} = \frac{dw_M}{dA_a}\Big[C + D + E\Big] \tag{7}$$
$$\frac{dw_M}{dA_a} = \frac{(F+G)}{H}\frac{dw_F}{dA_a}. \tag{8}$$

Solving the system we obtain that:

$$\frac{dw_M}{dA_a} = \frac{A}{B}\frac{1}{(\pi - 1)},$$

where $\pi \equiv \frac{(F+G)(C+D+E)}{HB}$. Note that $E > H$ and $G > B$ are sufficient conditions for $\pi > 1$. This implies that $\frac{dw_M}{dA_a} > 0$. This result, together with equation (8), implies also that $\frac{dw_F}{dA_a} > 0$.

In this model, mine closures imply a reduction in A_a. From the previous result we obtain that mine closures would reduce w_M and w_F (prediction 3).

The reduction of wages and upward labor supply imply a reduction of N_F and N_M (prediction 1).

Given the downward sloping labor demands, the reduction of wages also imply an increase in manufacturing workers, L^b. This result, together with the overall decrease in population imply a reduction in mining workers , L^a (prediction 2)

From equation (2), we obtain that the drop of N_F associated to the reduction of A_a would also reduce number of female manufacturing workers L_F^b. However, male manufacturing workers,

L_M^b, should increase since $L^b = L_M^b + L_F^b$ is increasing (prediction 2).

D Data appendix

Mining data Information on the location of mines and the number of workers employed is collected from the Guide to the Coalfields (?). This is an annual publication which contains maps indicating the location of 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 (?). The data for 2011 is provided by Nomis (?). 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 (?). 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 D.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 women in sector s $\in$ (Manufacturing, Services)	Total number of female workers 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 women 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).