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

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March 2018

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 imperfect substitutes in the labour market, 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 labour: 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 resource shocks on employment in non-primary sectors, specially manufacturing (Black et

*We would like to thank Martina Kirchberger, Krishna Pendakur, Rick van der Ploeg, Tony Venables as well as seminar participants at York University, University of Toronto, McMaster University, NEUDC, CSAE, OxCarre and George Washington University for useful comments and suggestions. We also thank James Haynes for excellent research assistance. A previous version of this paper circulated under the title "Mining closure, gender and employment reallocations: the case of UK coal mines".

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al., 2005; Michaels, 2011; Allcott and Keniston, 2013; Jacobsen and Parker, 2014; Marchand, 2012).

However, extractive industries manifest 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 labour 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 point 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 imperfect substitutes in non-primary sectors (Acemoglu et al., 2004; De Giorgi et al., 2015).

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 the number of mines closed as a treatment, and

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

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 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.[2] Instead, local manufacturing employment seems to increase after mine closures, in relative terms. This finding is supportive of models that predict a negative correlation between employment in the resource and tradable sectors, such as Dutch disease models.[3]

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.

A plausible explanation of these results is that men and women are imperfect substitutes in non-primary sectors. Then, by increasing the supply of men, mine closures would reduce local wages, and the demand for female labour. 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 effects of natural resources (Black et al., 2005; Aragón and Rud, 2013; Allcott and Keniston, 2013; Jacobsen and Parker, 2014; Fleming and Measham,

[2]A possible explanation is that, in our context, coal mining did not create sizeable agglomeration economies.

[3]While much of the literature focuses on the role of currency appreciation in the reallocation of resources, lately the expression Dutch disease has been used to refer to the general observation that the tradable sector shrinks as the resource sector expands (see for example van der Ploeg (2011)).

2014). This literature is related to a broader research on local labour markets (Carrington, 1996; Moretti, 2011).

Second, this paper contributes to a literature studying the gender-specific welfare effects of mining booms. Several, mostly qualitative, studies, find that booms can have negative effects that disproportionately affect women, such as an increase in crime, substance abuse, or sexually transmitted diseases among others (Freudenburg and Jones, 1991; Shandro et al., 2011; Wilson, 2012; James and Smith, 2017). Our finding suggests a potential positive spillover for women: despite not working directly in mining, booms can create job opportunities in non-mining sectors. Other work also studies the effect of booms on women labour outcomes. Using cross-country regressions, Ross (2008) argues that oil abundance reduces female labour participation due to Dutch disease mechanisms 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 labour force. Black et al. (2005) find that resource booms are associated with an increase in the male-female ratio in the working-age population. Consistent with these findings we find that the closure of mines generated a relative decrease in the male-female ratio.

In a related paper, Maurer and Potlogea (2017) examine the effect of oil discoveries in the United States on women's employment before World War II. Similar to our paper, they document a positive effect of mining activity on marriage rates and population size. However, in contrast to our results, they document no significant change in women's participation rates or wages. They interpret this finding as evidence that marriage plays a counterbalancing effect: oil wealth increases marriage rates and withdraws women from the labour force. This potential mechanism does not seem to be quantitatively important in our case. While mine closures are associated with an increase in the share of single individuals, we observe a reduction in labour force participation of women and in their wages.

Finally, this paper relates to a literature studying the economic effects of de-industrialization in developed countries that started in the 1970s and accelerated during the 1980s. This literature finds substantial evidence that the large-scale loss of manual, mostly male, jobs in industrialized countries has affected displaced workers along many dimensions, such as loss of life-time earnings, labour force participation, migration or loss of specific human capital.[4] Our study

[4]See Kletzer (1997), Louis S. Jacobson (1993), Couch and Placzek (2010), Hijzen et al. (2010) and Carrington

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 labour 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 UK's primary energy consumption (Surrey, 1992) and employed more than 700,000 miners, mostly men.[5]

After World War II, 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; National Union of Mineworkers, 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, led 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.[6] The strike ended a year later following a NUM vote to return to work. The government's victory in the strike significantly diminished the NUM's political power and

(1993), among others. For evidence on the effect of the UK coal bust on labour participation and migration, see Beatty and Fothergill (1996) and Beatty et al. (2007).

[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.

[6] 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).

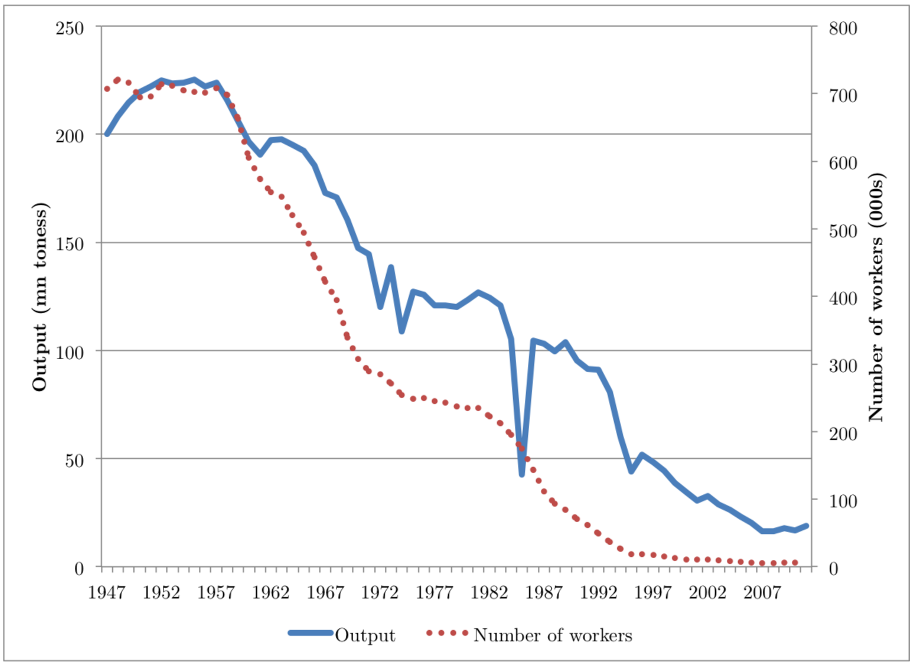


Figure 1: Output and number of workers in UK coal mines

started a period of accelerated mine closures.[7]

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).[8] 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 labour markets.

Subsequently, communities in former mining areas have been targeted by several regen-

[7]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.

[8] 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.

eration programs and regional aid.[9] 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).[10] These policies have the potential to affect both the empirical results and their interpretation and we take them into account in the analysis.

Despite these regeneration efforts, pit closures seem to have had a negative and persistent effect on mining communities. Previous studies, using labour-accounting methodologies, find no sizeable 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).[11] This withdrawal of men from the labour force was mostly through early retirement or by being classed as permanently sick. This "hidden unemployment", coupled with economic deprivation, has persisted 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 analyse the impact of mine closures on local labour 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 female employment.

Consider a local economy with two industries: mining and manufacturing, denoted a and b respectively.[12] All firms produce tradable goods with prices normalized to 1. Labour is the only

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

[10] 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.

[11] 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.

[12] We present an extension of the model including a service sector in Appendix D. The main predictions on wages, population and manufacturing employment remain similar, but the model produces ambiguous predictions regarding employment in the service sector.

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 reflects the empirical observation that primary sectors are dominated by male workers. This feature can be motivated by men having a comparative advantage in physical labour, or by cultural norms than prevent women working on mining.

The unconditional aggregated labour demand of mining firms is $L_M^a(w_M, A_a)$, while for manufacturing firms is $L^b = L_M^b(w_M, w_F, A_b) + L_F^b(w_M, w_F, A_b)$. L_M^b and L_F^b refer to demand for male and female labour in manufacturing, and A_a and A_b are industry-specific productivity shifters.[13] We model mine closures as an exogenous reduction in labour demand of mining firms, i.e., a drop in A_a. All labour demands are downward sloping, i.e., $\frac{\partial L_M^a}{\partial w_M}, \frac{\partial L^b}{\partial w_i}, \frac{\partial L_i^b}{\partial w_i} < 0$ where $i \in \{M, F\}$.

Each worker provides one unit of labour so population size is equal to labour supply. Let us denote labour 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).[14]

Alternatively, we can assume that workers are immobile, have heterogeneous preferences over leisure, and decide whether to work or leave the labour force. Under standard conditions, this would also produce an upward slopping supply curve, but would change the interpretation of N_i from population size to participation in labour markets. 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:

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

$$N_F(w_F) = L_F^b(w_M, w_F, A_b). \tag{2}$$

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

[14]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.

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:

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

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

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 imperfect substitutes in the manufacturing sector is sufficient to generate a number of interesting results.[15]

1. **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 the population share of women.

2. **Crowding out effects**: There are two types of labour reallocation. First, a reallocation of workers from mining to manufacturing (decrease in L^a, increase in L^b).[16] Second, a crowding out of women in the manufacturing sector: an increase of male workers (L_M^b), but a *decrease* in the number of female workers (L_F^b). This implies a reduction in the share of female manufacturing workers ($\frac{L_F^b}{L^b}$). Later we use this variable as our main indicator of this crowding out effect.[17] Note that this result is driven by the gender bias in mining

[15] 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.

[16] 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 labour. 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 labour costs and have a negative impact on employment in non-tradable sectors.

[17] Alternatively we could examine this crowding out using the ratio of female to male workers, $\frac{L_F^b}{L_M^b}$. Note, however that this ratio is equal to $\frac{s}{1-s}$ where $s \equiv \frac{L_F^b}{L^b}$ is the share of female manufacturing workers. We use this later indicator for simplicity of exposition, but results (available upon request) are similar using either indicator.

and substitutability of men and women, not by changes on relative wages.

3. **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.[18]

Intuitively, mine closures free mine workers and increase supply of men in manufacturing jobs. This shift in supply reduce male wages in manufacturing and, due to imperfect substitutability, decrease the demand, and wages, of women in manufacturing. Due to lower wages (i.e., lower production costs), overall manufacturing employment increases. This sectoral reallocation of labour (from mining to manufacturing) is similar in flavour to the crowding out of manufacturing predicted by Dutch disease models (Corden and Neary, 1982). However, lower wages imply lower population: some workers emigrate to other locations. As a result there is an absolute, and relative, decrease in female manufacturing employment. This is the crowding out of women in the manufacturing sector. In Section 4 we evaluate empirically these predictions.

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.[19] 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.

[18] A sufficient condition for mine closures to increase women's relative wage ($\frac{w_F}{w_M}$) is $\eta_F > \epsilon_F^c + \epsilon_F^p$, where ϵ_F^p and ϵ_F^c are the own and cross wage elasticity of female labour demand, and η_F is the elasticity of female labour supply.

[19] 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.

Demographic and employment data We use information from the UK Census on population and employment status for years 1981-2011.[20] The raw data is disaggregated at ward level. Given the continuous changes in wards' boundaries, we aggregate the data at the 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.[21]

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.[22] 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 information 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.[23] 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.[24] 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.[25] 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

[20] 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.

[21] Results are robust to alternative sample definitions.

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

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

[24] Table B.2 in the Appendix presents additional information on baseline industrial composition mining and non-mining districts..

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

not for women.

Ancillary data We collect data on the EU 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 division 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.[26]

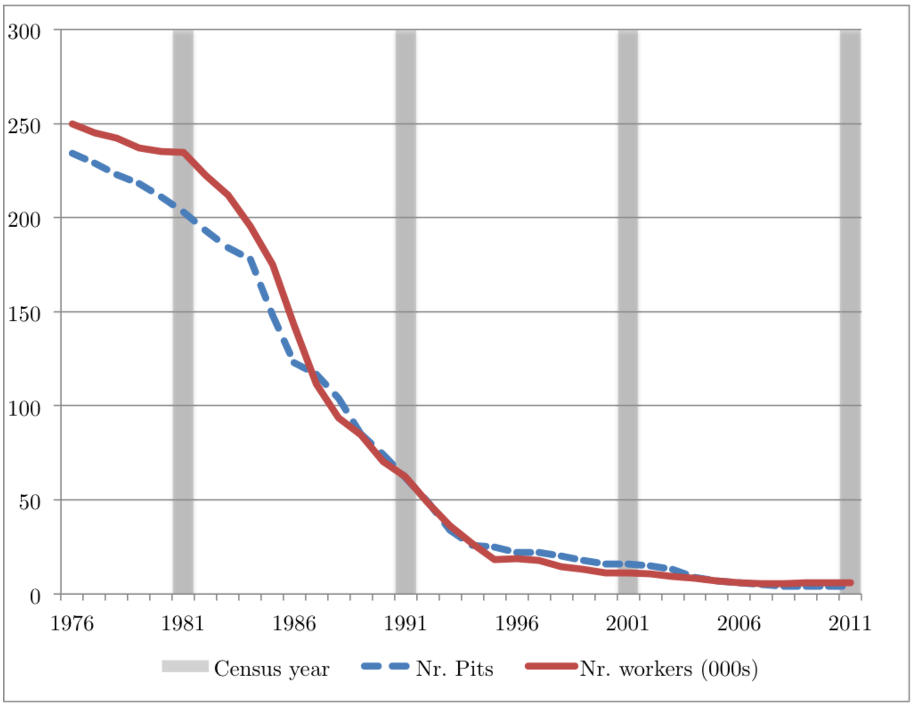
Table 1: Main employment indicators for average district, by gender, 1981 and 2011

	1981			2011		
	Total (1)	Women (2)	Men (3)	Total (4)	Women (5)	Men (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.

[26]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. For those years, we impute the regional values using a linear interpolation.. As a robustnes check, we also impute regional values using the predicted values from a regression that includes total population, unemployment rate, and gender ratio. The results are similar using either imputation method.

Figure 2: Coal mines and miners: 1976-2011



3.2 Empirical strategy

Our aim is to estimate the effect of mine closures on local employment outcomes by gender. 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 the mid 1980s, there was a dramatic acceleration in mine closures and loss of mining jobs. We treat this event as a significant, negative shock, to local labour 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 the mid 1980s and the 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 neighbouring, mine-less, districts. We restrict the sample to districts with any part of its territory within 30 miles of a mine active in 1981.[27] Figure 3 displays a map with the location of mines in 1981,

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

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 sectors employed relatively more women, and has a slightly larger population. However, both types of districts 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)
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		

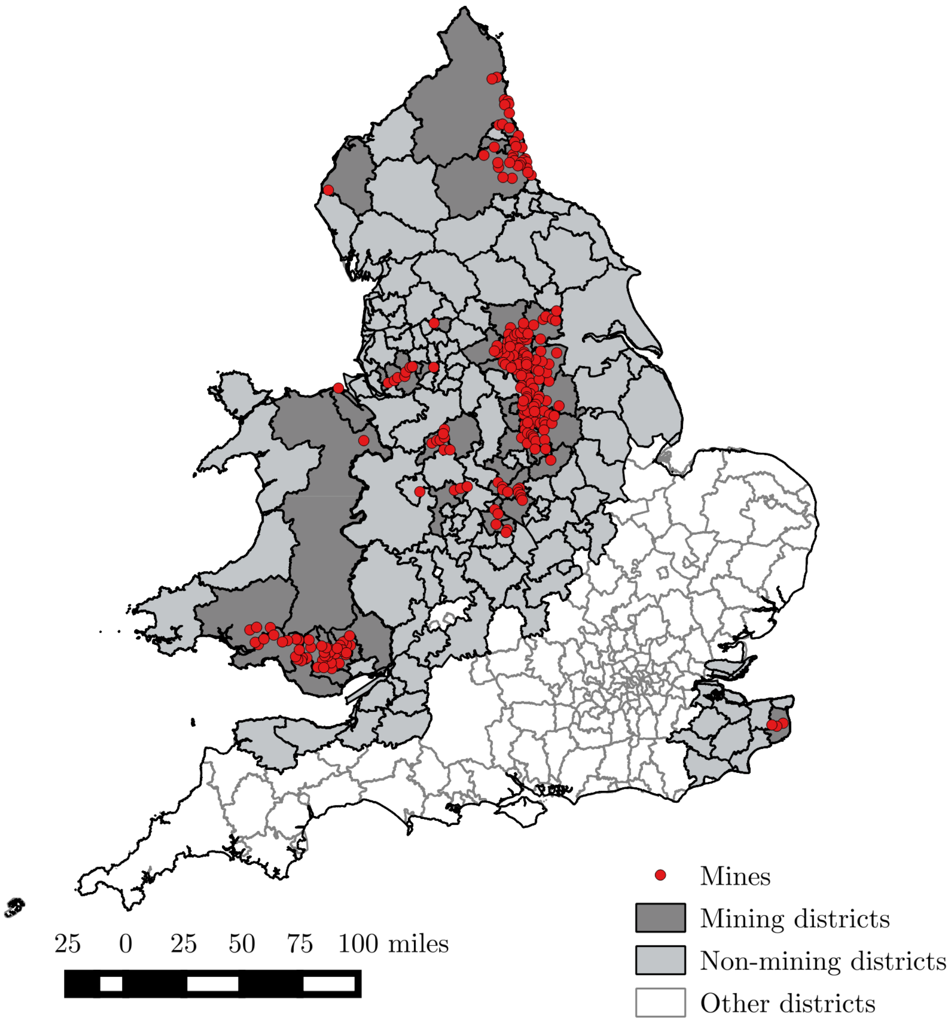
Note: Column 5 displays the p-value of a mean comparison test of columns 1 and 3.

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.[28] Formally, we estimate the following regression model:

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

[28]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 F).

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



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 clusters the errors by county to account for possible serial and spatial correlation.[29]

Based on the discussion in Section 2.2 our main outcome is the share of female manufacturing workers.[30] This variable captures the relative use of female labour, and thus can be used to measure the extent of the substitution of male for female workers in the tradable sector.[31] Importantly, since it is a relative measure of input use, it avoids the confounding effects of changes in population size that can be picked up, for instance, when using total number of female workers. That said, we use the baseline specification (5) to examine other outcomes suggested by the analytical framework, such a population size, participation rates, number of workers, and wages.

The validity of our identification strategy relies on the assumption that, in the absence of mine closures, the outcomes in both mining and non-mining districts would have followed the same trend. We explore the validity of this assumption in several ways. First, we use annual data from the UK New Earnings Survey (NES) to compare the evolution of our main outcome (i.e., share of female manufacturing workers) in mining counties (treated group) relative to non-mining countries (control group) and a synthethic control group. This latter group is a weighted average of the share of females in manufacturing in regions without a single active coal mine in 1975 that mimics the development of the female share in manufacturing in the treated regions before 1984.[32]

The results, displayed on Figure 4, suggest that between the 1970s and early 1980s this outcome remained reasonably stable by fluctuating around 26 and 29 percent. We interpret this as evidence supportive of the validity of our identification assumption. We also observe

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

[30]This variable is equal to (manufacturing female workers)/(total manufacturing workers). and it is proportional to the female-to-male ratio in manufacturing, $\frac{L_F^b}{L_M^b}$. To see this, note that the share of female manufacturing workers is equal to $\frac{\phi}{\phi+1}$, where $\phi = \frac{L_F^b}{L_M^b}$.

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

[32]We use the period 1975 to 1984 (10 years) to calibrate the counterfactual based on two variables: size of manufacturing sector and females in manufacturing. Counterfactual regions are only considered those which do not have a single active mine in 1975. Regions with at least one active mine in 1975 are considered as treated from 1984 onwards. The weights determined in the pre-treatment period determine the development of the synthetic counterfactual. The procedure is based in abadie2010synthetic and implemented in STATA using the *synth* command.

that after 1984, when mine closures started, a negative trend appears in treated regions, relative to the persistent evolution in both counterfactuals. This is prima facie evidence of the crowding out effect discussed above, that we explore more formally in the next section. There seems, however, to be a lag between the closure of mines and distinguishable employment changes: the share of female manufacturing workers accelerate after 1994, when the industry was privatized and most mines finally closed.[33]

Second, we examine these findings more rigorously by estimating a modified version of equation (5). In particular, we replace *mine closures* with a set of year dummies interacted with an indicator of being a mining county.[34] This specification effectively examines differences in trends, year by year, relative to mid 1970s. The estimated coefficients, displayed in Figure A.2 in the Appendix confirm the findings we observe in Figure 4. We replicate this exercise using wages and present the results in Figure 5. We also find evidence of similarity of trends before mid 1980s and a divergence afterwards.

Finally, we use data from the Census 1971 to examine pre-trends of other outcomes, such as participation rates, unemployment rates, and sectoral employment. There are, however, two important limitations. This dataset does not disaggregate employment by gender, so we cannot examine our main outcome. More importantly, the district boundaries in 1971 are not comparable to 1981.[35] These changes in district boundaries can confound observed changes in population outcomes. With these caveats in mind, we estimate a standard D-i-D regression using data from years 1971 and 1981.[36] To reduce the potential bias due to boundary changes, we include the log of population size as an additional control. Table B.1 in the Appendix presents our results. We observe that between 1971-1981 mining districts experienced a reduction in number of workers in primary sectors. This is consistent with the decline of mining employment that started in 1950s (see Figure 1).[37] We do not, however, observe any significant change in pre-trends in participation or unemployment rates, nor in the number of manufacturing or

[33] A possible explanation of this lag is that laid-off miners did not immediately searched for new non-mining jobs, As documented by Beatty and Fothergill (1996), many miners went through a period of "hidden" unemployment during which they lived off welfare benefits. Gradually, some of them, reinserted into the labour force. This slow adjustment of labour markets can explain the lack of changes in non-mining employment in the first years after mine closures.

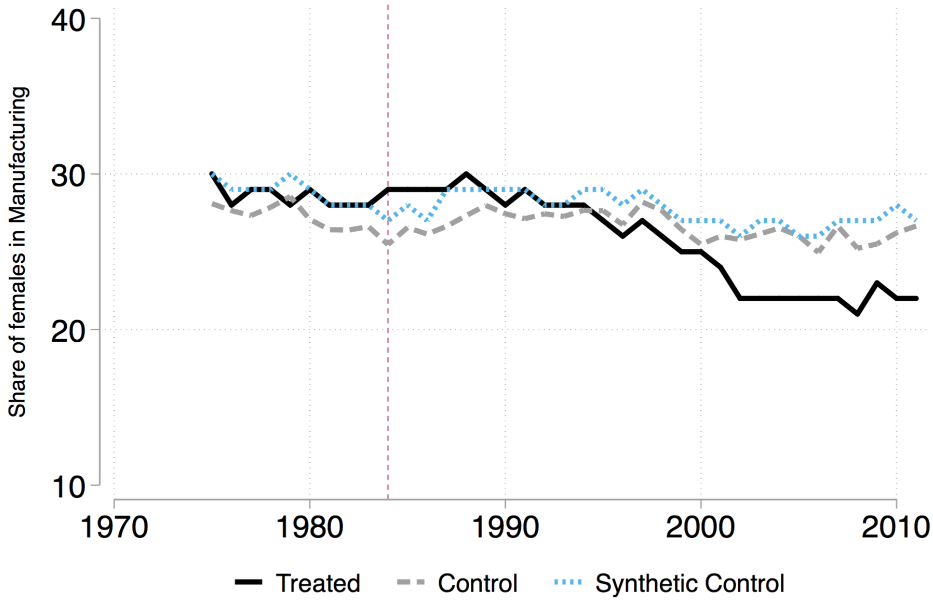
[34] The UK NES sample includes years 1975-2011. We use years 1975-1977 as the omitted category.

[35] There were significant changes in number and boundaries of districts mid 1970s following the 1972 Local Government Act.

[36] In particular, we estimate regression (5) replacing *mine closures* with an interaction of year 1981 and an indicator of being a mining district.

[37] Note that we exploit the acceleration in loss of mining jobs associated with mine closures.

Figure 4: Share of female manufacturing workers



Notes: The solid line is the share of females in manufacturing in the treated regions, i.e. regions with at least one active coal mine in 1975. The dashed line is the average share of females in the control region, i.e. regions without active coal mines in 1975. The dotted line is a synthetic counterfactual, i.e. a weighted average of the share of females in manufacturing in regions without a single active coal mine in 1975 that mimics the development of the female share in manufacturing and the size of the manufacturing sector in the treated regions before 1984. The vertical dotted line indicates 1984. See Figure A.5 in the Appendix for more detailed results of the analysis in which the treated region is disaggregated into 8 mining regions.

service workers.

Taken together, these results are reassuring of the validity of the empirical strategy. There are, however, additional concerns such as presence of time-varying confounders and endogenous timing of mine closures. We explore the importance of these issues in the empirical analysis.

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 and the overall effects on population and employment. Column 1 in Table 3 shows that each mine closure reduced the number of male workers in primary sectors by almost 1,000 workers. This is consistent with the average size of coal mines. In contrast, the number of female workers decreased by less than 20.[38] This is prima facie evidence that mine closures disproportionally affected the demand for male workers.

The effects on population and employment are, however, much broader (see columns 2-6 in Table 3). We observe a reduction in population, number of workers, participation and employment rates for both men and women.[39] These effects of mine closures on men are as expected: they are consistent with workers leaving mining areas or the labour force after a negative demand shock. It is less obvious why women, who were not directly laid off by mines, would be affected. We argue that this phenomenon is consistent with women and men being imperfect substitutes in non-primary sectors. In that case, the initial shock on male employment would be transmitted to women through changes in local labour markets In what follows, we explore in detail this negative spillover.

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

	Primary workers (1)	Population (log) (2)	Workers (log) (3)	Employment rate (4)	Participation rate (5)	Unemployment rate (6)
A. Men						
No of mines closed since 1981	-1.045***	-0.006**	-0.009***	-0.225***	-0.207***	-0.003
	(0.066)	(0.002)	(0.003)	(0.074)	(0.061)	(0.075)
B. Women						
No of mines closed since 1981	-0.017	-0.004*	-0.006*	-0.178**	-0.181**	-0.011
	(0.015)	(0.002)	(0.003)	(0.079)	(0.073)	(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.

[38] 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 F. 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 labour reallocation within the primary sector.

[39] 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., 2005; Michaels, 2011; Marchand, 2012; Jacobsen and Parker, 2014; Fleming and Measham, 2014).

4.2 Crowding out effects by industry and gender

As discussed in Section 2.2, mine closures can induce a reallocation of labour from primary to non-primary tradable sectors. However, the strong male-bias of the resource shock also creates a 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, tradable, sectors.[40] The effect on non-tradable sectors is, however, ambiguous, as there are two opposing forces: a reduction in wages, which increases employment, but also drop in the local demand for services, which decreases it.

Table 4 explores these crowding out effects. First, we find evidence of labour moving from the primary to the manufacturing sector (column 1). This negative relation between mining and manufacturing employment contrasts to studies that find a positive relation (Allcott and Keniston, 2013).[41]

Second, we find evidence consistent with the crowding out of women in non-primary, tradable, sectors. Mine closures have gender-specific effects on manufacturing employment (panel A): they *increase* the number of male workers, but *decrease* the number of female workers (columns 2 and 3). This translates into a reduction of around 0.78 percentage points in the share of female manufacturing workers for every mine closed (column 4). This result is robust to using annual data from the UK New Earnings Survey (column 5).[42] We find similar effects in the gender composition of service employment (panel B), although there is no significant reduction in the absolute number of female workers.

This crowding out of women is the main finding of this paper. We show how resource shocks can affect a local economy not only by reallocating labour across industries, but also reallocating jobs between men and women. As we find in the UK case, this reallocation of labour can attenuate the negative shock on male employment, but also create negative spillovers on women. This effect has been generally overlooked in the academic and policy debate but it is

[40] In Section 5.5 we also examine possible differentiated effects by type of job.

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

[42] The magnitude of the effect on the share of female workers is, however, much smaller. This is likely due to the level of aggregation: the census data is aggregated at district level (n=174), while the UK NES is aggregated at county level (n=38). Thus, results using UK NES data are attenuated because the "treated" counties contain both mining and non-mining districts. The advantage of this dataset is that we can use it to look at wages and also disaggregate manufacturing into sub-sectors. The results are presented in Table B.3 and suggest that the the effect is slightly stronger in light manufacturing, as opposed to heavy manufacturing or chemicals.

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

	ln(no. of workers)			% female workers	
	Total	Women	Men	Census	UK NES
	(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	0.004	-0.002	0.010**	-0.278***	-0.082**
	(0.004)	(0.004)	(0.005)	(0.064)	(0.035)

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. 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. For column 1-4 the number of observations is 696 and number of districts is 174. For column 5, the number of observations is 1,406 and the number of counties is 38.

likely to be present when other male-dominated activities are subject to shocks.

Our results suggest that the effects are economically relevant. In 1981, before the start of the mine-closure process, around 22.6% of women were working in manufactures (6,000 women per district, on average). The shares were very similar in mining and non-mining districts (23.5% and 21.5%, respectively). Note that over the analyzed period, a mining district would experience a closure of 2.4 mines, which represents an average of more that 2,200 workers per district (3.2% of the average district number of workers in 1981).

Using our estimates, we find that an average district would have displaced more than 209 women from manufacturing jobs out of almost 6,000 (a loss of 3.5% of female manufacturing jobs), while males would have gained 725 jobs (an increase of 5.5% of male manufacturing jobs). These effects are larger if we think in terms of the magnitude of the shock: for every 10 men displaced from mining jobs, 3.3 men get manufacturing jobs and 1 woman losses its factory job. Effects in the service sector are smaller, as expected from the point estimates in Table 4: women lost around 67 jobs (not significant) while males gained 429 jobs.

4.3 Exploring the mechanism

Our analytical framework suggests that the crowding out effects (both across industries and gender) are driven by reduction in local wages and imperfect substitutability of female and male workers. We explore empirically this mechanism in two ways.[43]

First, we examine heterogeneous effects of mine closures on industries with different ratios of female-to-male workers. The key idea is that in industries with lower share of female workers women and men might be less substitutable, and thus the crowding out effects may be weaker. We focus on different service sub-sector, such as construction and transportation, retail and catering, and other services (which include government, healthcare and education).[44] In 1981, the construction and transportation sector, similar to mining, were male dominated: around 88% of workers were men. In contrast, the rest of services were more balance: the share of women in retail and catering, and other services were 30% and 50% respectively.

Table B.5 in the Appendix displays the results. We observe that in construction and transportation there was no significant change in the share of female workers. However, in the rest of service industries there was a significant reduction. This change in the intensity of female workers is driven by an increase in the number of male workers. Although there is no reduction in the number of female workers, these results suggest that in mining areas the growth of service employment was slightly more male-biased, i.e., they hired relatively fewer women than before.

Second, we estimate the effect of mine closures on local wages. To do so, we use data from the UK New Earnings Survey and estimate the baseline regression (5) using the log of hourly wage as the outcome variable.[45] Our empirical specification includes country-by-year fixed effects and county-specific trends to control for confounding factors, such as changes in local prices and governmental policies.

Table 5 displays the results of these wage regressions splitting the sample by industry of

[43]We also estimate the elasticity of substitution (σ) between female and male workers using a similar approach as Acemoglu et al. (2004) and De Giorgi et al. (2015). We aggregate the UK NES data at county-year level and instrument the relative labor supply with number of mines closed since 1975. The results, shown in Table B.4, are similar to De Giorgi et al. (2015) and cannot rule out imperfect substitutability.

[44]Due to data availability, we cannot do this exercise for the manufacturing sector using Census data. We can, however, use the UK NES data to separate between three types of manufacturing industries: light, heavy and chemical. Results are available in Table B.3 in the Appendix.

[45]In particular, we estimate the following wage regression for each sub-sample:

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

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.).

occupation and gender. Consistent with the crowding out effects previously documented. we find that mine closures reduce wages (for both men and women) in manufacturing. We also observe a reduction in wages of service workers, although it is only significant for men's wages in retail, catering, and other services. As mentioned above, these industries might be ones in which women and men are more substitutable.

Table 5: Effect on wages

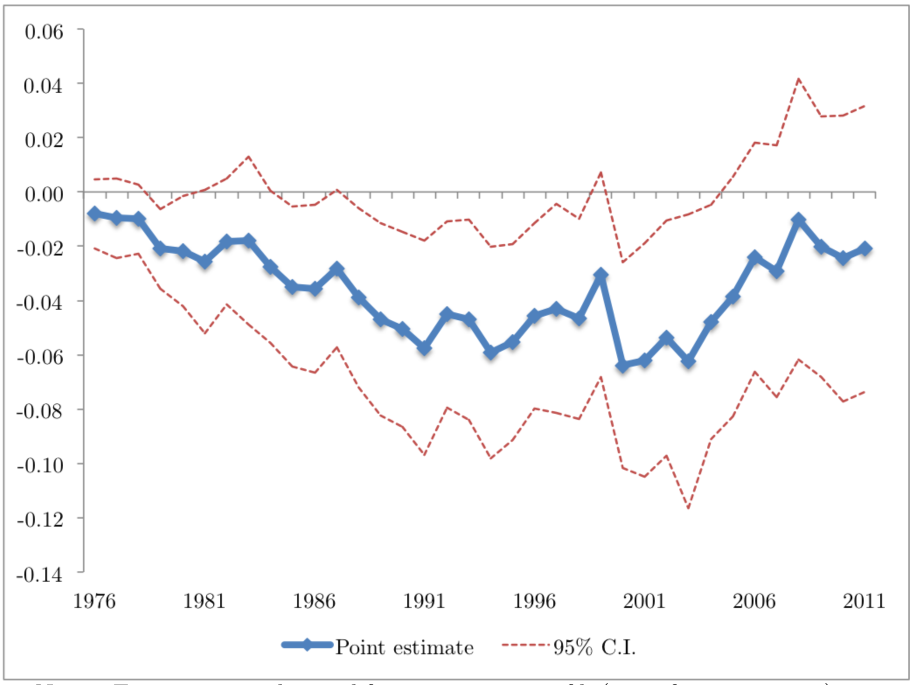
	Dep. variable = Ln(wage)					
	Manufacturing workers		Service workers			
			Construction and transportation		Retail, catering and other services	
	Women	Men	Women	Men	Women	Men
	(1)	(2)	(3)	(4)	(5)	(6)
No. of mines closed since 1975	-0.0014*	-0.0016**	-0.0000	-0.0002	-0.0004	-0.0017**
	(0.0008)	(0.0007)	0.0012	0.0006	0.0005	0.0008
No. Obs.	205,686	575,333	54,871	261,980	562,978	467,695

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.

We exploit the richness of the UK NES data to further examine the effecs on manufacturing wages. Figure 5 depicts the differences in manufacturing wages between mining and non-mining counties for years 1975 to 2011.[46] There are two important observations. First, consistent with the previous results, there is a significant reduction 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).

[46]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



Notes: Estimates are obtained from a regression of ln(manufacturing wage) on a set of year dummies interacted with an indicator of being a mining county. The omitted category is years 1975-1977.

5 Ancillary results

In this section, we examine possible threats to our identification, such as geographical spillovers and endogenous timing, and check the robustness of our results to alternative specifications, We also explore additional issues such as the persistence of the effects, effect on other demographic outcomes, and whether our results are picking up other biases, such as the type of job (manual vs. non-manual).

5.1 Geographical spillovers

Our baseline specification implicitly assumes that the effects on local labor markets decline with distance. That assumption allows us to use neighbouring districts (within 30 miles of a mining district) as control group. it is possible, however, that areas in the vicinity of mining districts would have alse been affected by mine closures. For instance, displaced workers emigrating from mining districts could have affected population size and labor markets in neighbouring areas. These geographical spillovers are interesting by themselves, but also raise concerns regarding the validity of our identification strategy: our control group could be affected by mining closures and thus would not be a good counterfactual.

We examine this issue in two ways. First, we evaluate the role of distance on the effects of mine closures. To do so, we estimate the baseline regression (5) using the number of mines 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.[47]

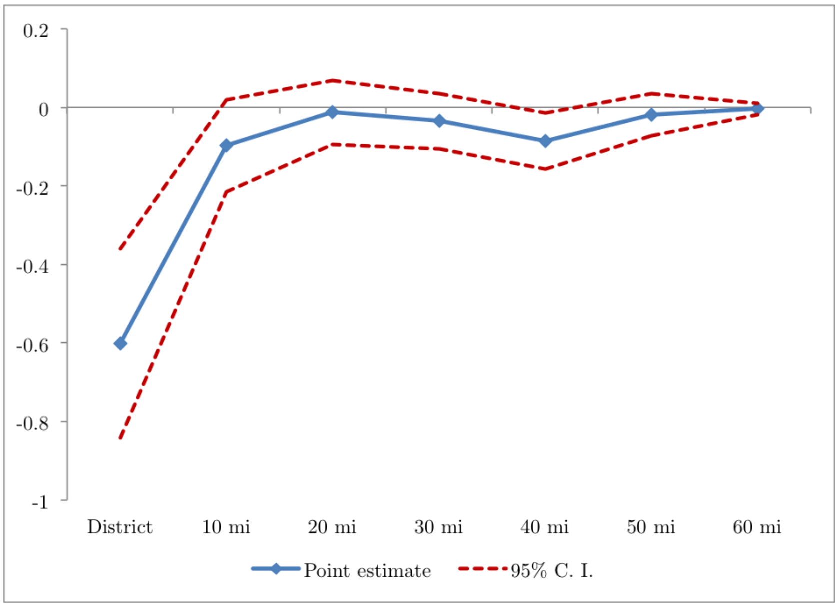
Figure 6 displays the estimated effect of mine closures on share of female manufacturing workers. We observe that the magnitude of the effect decreases rapidly, and monotonically, with distance. The effect of mine closures in a district is negative and significant, while the effect on neighbouring areas is much smaller and statistically insignificant. We observe a similar pattern on the effect of population size: there is significant reduction only in mining districts, and a negliglible effect on areas farther away (see Figure A.4 in the Appendix).[48]

Second, we replicate our main results excluding non-mining neighbouring districts from our

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

[48] Table B.6 in the Appendix presents full regression estimates on role of distance for other outcome variables. Figure A.3 in the Appendix displays the estimates using the share of female service workers as the outcome variable. Results are less precise but show a similar pattern.

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 B.6 for further details.

sample. This reduces our sample by around 38.5%, as we exclude 67 out of 174 districts. The results, in Table 6, are very similar in magnitude and significance to the ones we obtained using our baseline sample. We still observe an increase in the absolute number of workers in manufacturing jobs in mining districts, that is driven by male workers and despite the decrease in women working in the sector. As a consequence, the share of female workers decreases. Similarly, the pattern of Table 4 is repeated for the service sector: a drop in the share of females, driven by a increase in the number of male workers.

Together, these findings provide suggestive evidence that geographical spillovers may not be quantitatively important, and reduce concerns that they drive our results.

5.2 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 an indicator of mining district interacted with year dummies as main

Table 6: Effect of mine closures on employment excluding neighbouring districts

	ln(no. of workers)			% female workers
	Total	Women	Men	
	(1)	(2)	(3)	(4)
A. Manufacturing				
No. of mines closed since 1981	0.011*	-0.014**	0.023***	-0.777***
	(0.006)	(0.006)	(0.008)	(0.135)
B. Services				
No. of mines closed since 1981	0.007	-0.002	0.010*	-0.297***
	(0.005)	(0.004)	(0.005)	(0.066)

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 but excludes neighbouring districts. Services include construction and transportation, retail, catering and other services. The share of females in column 4 is calculated using the information from the UK Census. The number of observations is 428 and number of districts is 107.

regressor, 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 7) 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 labour 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).

5.3 Endogenous timing

Our identification strategy compares mining to non-mining districts and exploits changes over time in mine closures. A relevant concern is that the timing of mine closures was endogenous. Existing studies suggest that the timing of mine closures was driven, in part, by mine profitability: the less productive and profitable mines closed first (Glyn and Machin, 1997). Howevever,

Table 7: Persistence of effects of mine closures

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

other factors, such as size of the manufacturing sector or strength of local unions could have also played a role (Glyn, 1988). If these factors are unaccounted in our regressions and are correlated to our outcomes, they can bias our results.

While we cannot rule out this possibility, two pieces of evidence suggest that endogenous timing of mine closures is not driving our results. First, the results in Table 7 are obtained using a standard D-i-D approach comparing districts in 1981 to years 2001-2011. By this latter period, all mines were effectively closed. This specification does not exploit timing in mining closures (other than the before and after comparison) but produces similar results as our baseline specification.

Second, we implement an instrumental variable approach exploting variation in international coal prices. In particular, we use as instrument for number of mines closed ithe interaction (price of coal × number of active mines in 1981). The idea behind this IV strategy is that the price of coal is a determinant of mine profitability. Columns 7 and 8 in Table 8 present the results using the baseline sample, and restricting the sample to mining districts only. In both cases, our results are similar to our baseline regressions.

5.4 Robustness checks

Table 8 presents additional robustness checks. We focus on our main outcome, i.e, the share of female manufacturing workers.[49] In columns 1- 3 we change the sample definition. Column 1 uses all districts in England and Wales. In column 2, we exclude districts from the control group which had some active mines in the past but did not have any active mines in 1981. These districts experienced previous mines closures and thus may contaminate our results. Column 3 uses a narrower sample by keeping only districts which had at least one active mine in 1981. This last column exploits only the timing of mine closure among mining districts.

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 in mining areas. We address this concern in two ways (columns 4 and 5). 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.

Finally, we estimate the baseline regression correcting the standard errors for spatial and serial correlation using the procedure described by Conley (2008) (column 6).[50]

5.5 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.[51] According to whether manual and non-manual workers are imperfect substitutes or not, we could also expect heterogeneous effects by type of job, such as a crowding out of non-manual workers. We examine this possibility in this section. To do so, Table 9 replicates Table 4 distinguishing between manual and non-manual

[49] See Table B.7 in Appendix for robustness checks using other outcomes.

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

[51] See Table B.8 in the Appendix.

Table 8: Robustness checks

	Share of female manufacturing workers							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
No. of mines closed since 1981	-0.977***	-0.777***	-0.436***	-0.741***	-0.612***	-0.782***	-0.789***	-0.471***
	(0.176)	(0.14)	(0.104)	(0.142)	(0.120)	(0.148)	(0.159)	(0.125)
Robustness check:	All districts	No former mining districts	Only mining districts	EU & UK regional funds	Non-param. trends	Conley S.E.	IV	IV - Only mining
First stage F-test							1,722	1,273
Observations	1,356	680	212	696	696	696	696	212
R-squared	0.293	0.517	0.699	0.530	0.740	0.097	0.521	0.699
No. districts	339	170	53	174	174	174	174	53

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 30 miles of a mine. Column 4 includes the log of UK and EU regional funds as proxy for regeneration policies. Column 5 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 6 estimates the baseline regression with standard errors corrected for spatial and serial correlation using the procedure described by Conley (2008). In column 7 and 8, we instrument the number of closed mines with the price of coal interacted with the number of active mines on the district in 1981. Column 7 uses baseline sample, while column 8 restricts sample to mining districts only.

workers, instead of women and men.[52]

In contrast to the baseline results, we find no evidence of a sizeable crowding out effect of non-manual workers. 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 and 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.[53]

Table 9: 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 mines closed since 1981	0.014*	0.011*	-0.001
	(0.007)	(0.006)	(0.001)
B. Services			
No. of mines closed since 1981	-0.002	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.

5.6 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 10 we explore this issue by using age as a proxy for experience.

[52] 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.

[53] We also check that our baseline results are not driven by changes in number of manual and non-manual workers. See Table B.10 in the Appendix.

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.[54] 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. That is, older, and probably more experienced, women are less likely to lose their manufacturing jobs. In terms of the services sector we find that the increase of employment among males that we saw in Table 4 is stronger among older men, as the coefficients are increasing in magnitude with age-group.

Table 10: 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.

5.7 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 11).

[54] Mine closures reduce number of male primary workers of all ages in a similar proportion, see Table B.9 in the Appendix.

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. (2005).[55] 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.[56] 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. We explore this channel by using a proxy of fertility, namely children per women in child-bearing age.[57] 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 labour opportunities, we find that mines closures are associated with an increase in share of single, unmarried, individuals.

Table 11: 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.

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

[56] 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.

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

6 Conclusion

This paper highlights the importance of considering heterogeneous effects by gender when assessing the impact of extractive industries on local labour markets. This heterogeneity arises because extractive industries are heavily male-dominated. Thus, shocks to their labour 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 labour from mining to manufacturing.

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 labour displacement on individuals may be different. Finally, data availability prevents us to examine other relevant possible effects such as changes in productivity and to be able to explore the gender-specific welfare effects of mining closures, derived from changes in intra-household bargaining power, human capital accumulation, or other relevant channels that have been shown to matter in other contexts (e.g. crime, substance abuse, health, etc.). However, we make progress in the understanding of how women are affected by mining boom and busts, by highlighting that the net welfare effects need to account for interactions in labour markets. In particular, the substitutability of men and women in non-primary sectors implies that even though women may not directly work in mining, their employment opportunities are still affected by mining cycles.

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ONLINE APPENDIX - NOT FOR PUBLICATION

A Additional figures and tables

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

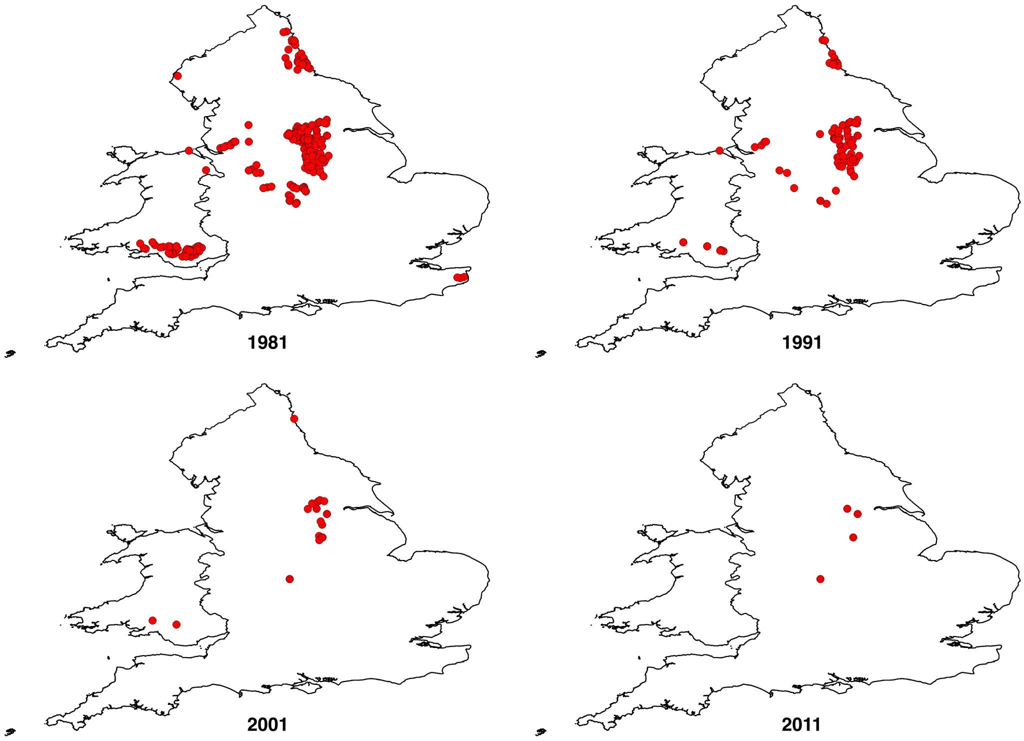
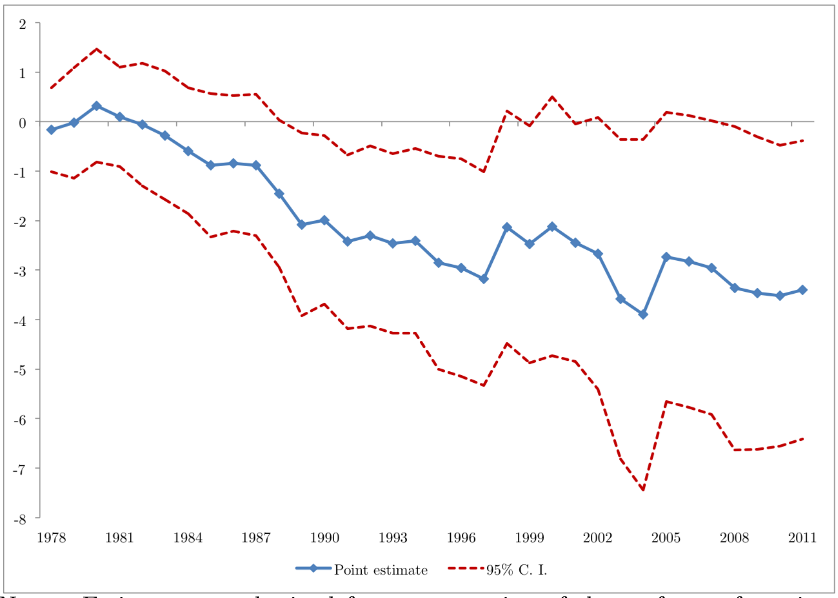
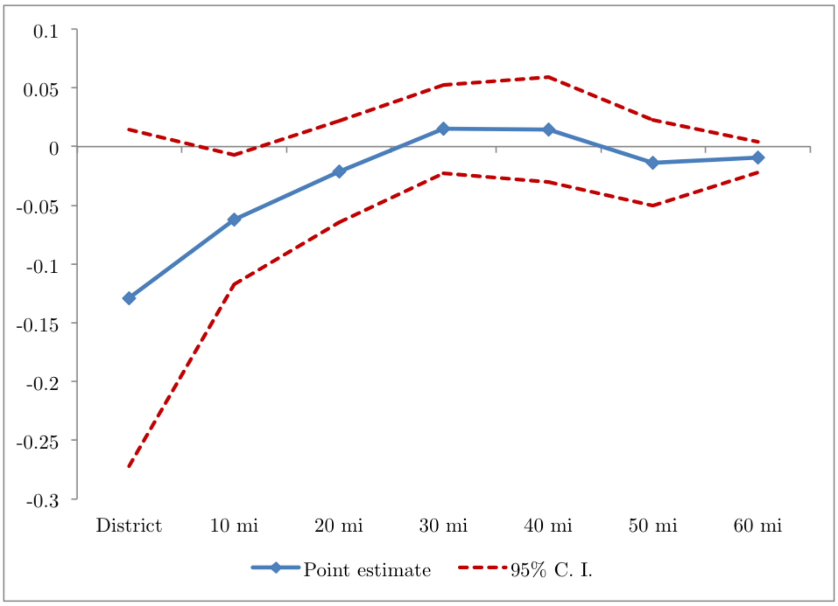


Figure A.2: Difference in share of female non-primary workers between mining and non-mining counties



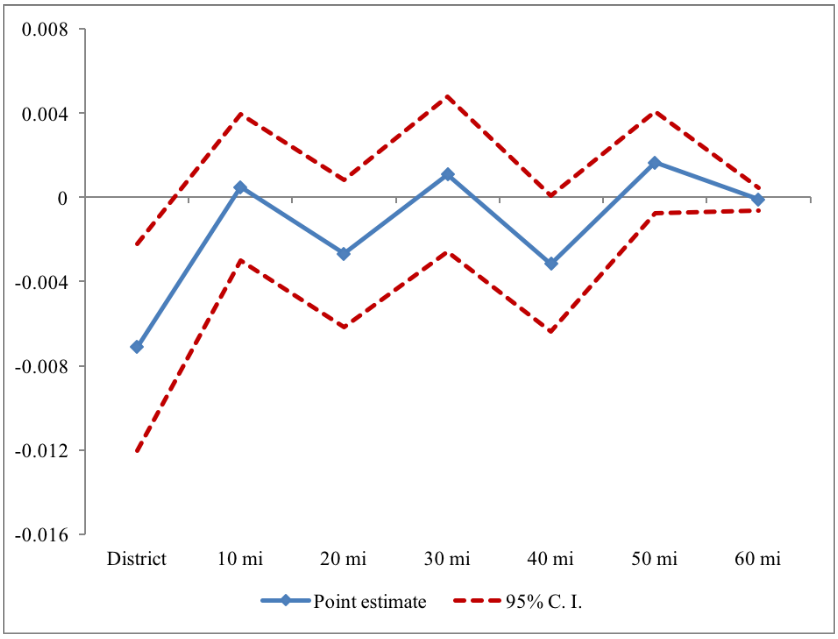
Notes: Estimates are obtained from a regression of share of manufacturing and service workers on a set of year dummies interacted with an indicator of being a mining county. The omitted category is years 1975-1977.

Figure A.3: Effect of mine closures on share of female service workers, by distance



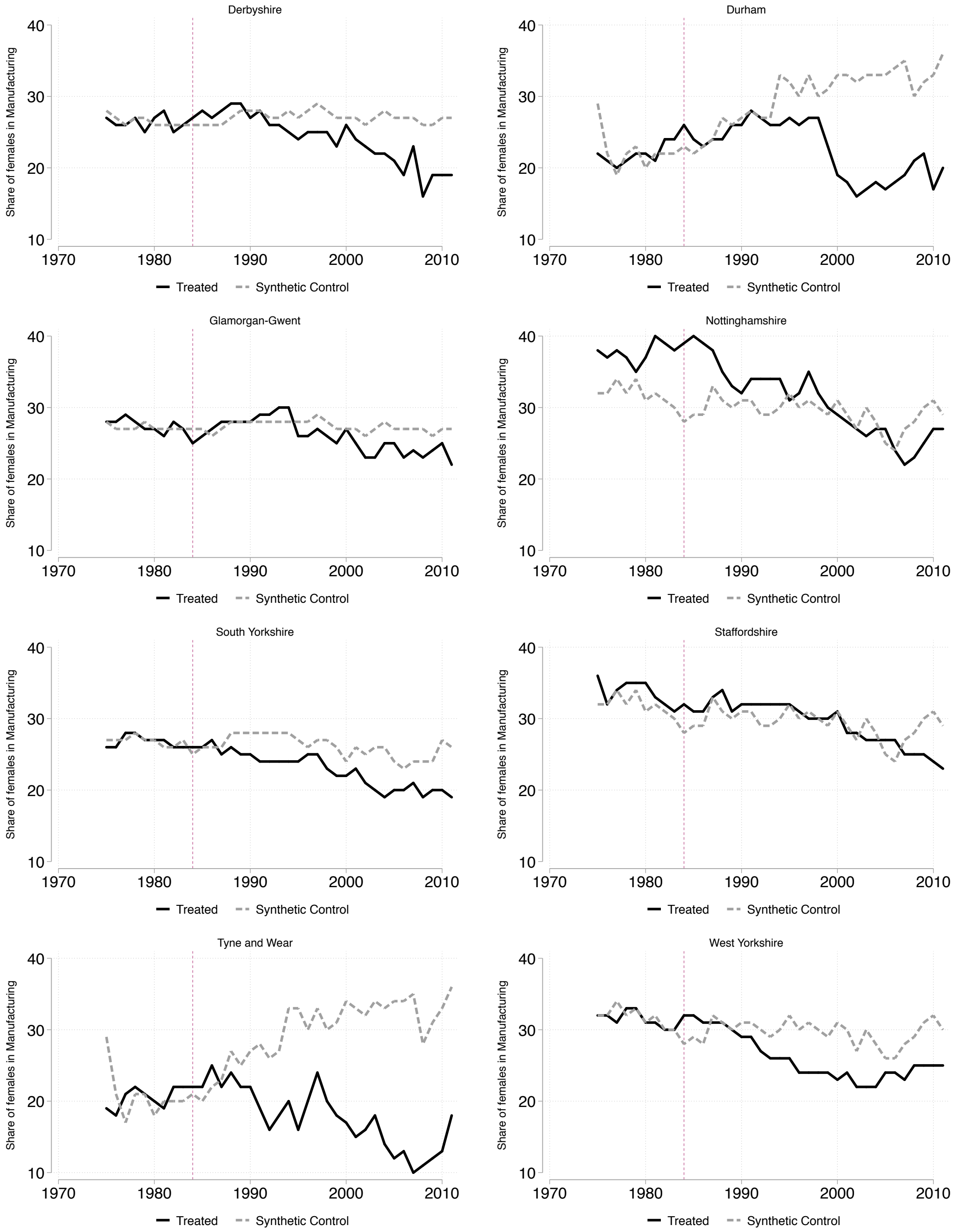
Notes: Estimates are obtained from a regression of share of female service workers on number of mines closed since 1981 at different distance brackets.

Figure A.4: Effect of mine closures on ln(adult population), by distance



Notes: Estimates are obtained from a regression of ln(adult population) on number of mines closed since 1981 at different distance brackets.

Figure A.5: Share of Females in Manufacturing: Synthetic Controls



B Additional tables

Table B.1: Differences in pre-trends, years 1971-1981

	Particip. rate	Unemploy. rate	ln(no. workers)		
			Primary	Manufact.	Services
	(1)	(2)	(3)	(4)	(5)
Mining district x year 1981	-0.091	0.359	-0.449***	-0.020	0.019
	(0.227)	(0.488)	(0.101)	(0.027)	(0.014)
Observations	348	348	348	348	348
R-squared	0.120	0.780	0.396	0.768	0.969

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 ln(population), district and year fixed effects. Sample of districts is similar to baseline regression.

Table B.2: Composition of manufacturing and service sub-sectors in 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)
Employment Share					
Mining	0.05	0.04	0.01	0.01	0.00
Agriculture	0.07	0.04	0.05	0.03	0.06
Chemical Manuf.	0.02	0.02	0.02	0.02	0.82
Light Manuf.	0.11	0.05	0.14	0.04	0.09
Heavy and Other Manuf.	0.15	0.05	0.16	0.06	0.55
Const. & Transport	0.12	0.02	0.12	0.03	0.36
Public Services	0.23	0.04	0.25	0.04	0.10
Other Services	0.27	0.03	0.23	0.04	0.01
Number of districts	21.0		29.0		

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

Table B.3: Effect of mine closures on manufacturing sub-sectors

	% female workers in manufacturing			
		Sub-sectors		
	Total	Heavy	Chemical	Light
	(1)	(2)	(3)	(4)
No. of mines closed since 1975	-0.202*	-0.2*	-0.26	-0.29***
	(0.075)	(0.09)	(0.19)	(0.06)
Observations	1,406	1,406	1,406	1,406
R-squared	0.07	0.02	0.03	0.11

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.

Table B.4: Estimates of $-1/\sigma$

	$\ln(\text{wage}_{male}/\text{wage}_{female})$			
	OLS		IV	
	not weighted	weighted	not weighted	weighted
	(1)	(2)	(3)	(4)
ln(male/female)	0.02	-0.01	-0.71**	-0.84*
	(0.030)	(0.035)	(0.26)	(0.430)
Implied σ	∞	∞	1.4	1.19
Observations	1,850	1,850	1,850	1,850
R-squared	0.80	0.85	0.43	0.46

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 include county and year fixed effects. The sample consists of individuals in Columns 1 and 2 are estimated using OLS. Columns 3 and 4 are estimated using 2SLS with the number of coal mines closed since 1975 as an instrument. The first stage F-test in columns 3 and 4 are 86 and 138 respectively. Columns 2 and 4 report weighted regressions by number of workers by county-year cell. Sample include only manufacturing and service workers (excluding government, health and education and research workers).

Table B.5: Effect of mine closures on employment in service sub-sectors

	ln(no. of workers)			% female workers	
	Total	Women	Men	Census	UK NES
	(1)	(2)	(3)	(4)	(5)
A. Construction and transportation					
No. of mines closed	0.011*	0.010	0.011*	-0.013	0.015
since 1981	(0.007)	(0.008)	(0.007)	(0.062)	(0.054)
B. Retail and Catering					
No. of mines closed	0.005	-0.001	0.012**	-0.310***	-0.160***
since 1981	(0.004)	(0.004)	(0.005)	(0.055)	(0.049)
C. Other services					
No. of mines closed	0.002	-0.003	0.007	-0.238***	-0.130***
since 1981	(0.004)	(0.004)	(0.005)	(0.066)	(0.044)

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 C report estimates using outcomes for different service sub-sectors. 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. For column 1-4 the number of observations is 696 and number of districts is 174. For column 5 the number of observations is 1,406 and the number of counties is 38.

Table B.6: 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.

Table B.7: Robustness checks using other outcomes

Robustness check / Outcome	All districts (1)	Only mining districts (2)	EU & UK regional funds (3)	Non-param. trends (4)	Conley S.E. (5)
ln(population)	-0.012***	-0.002	-0.004	-0.001	-0.005**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Participation rate	-0.370***	-0.089	-0.186**	-0.051	-0.217***
	(0.077)	(0.076)	(0.071)	(0.066)	(0.080)
ln(no. manuf. workers)	0.015	0.015*	0.013*	0.012*	0.011**
	(0.010)	(0.007)	(0.007)	(0.007)	(0.005)
ln(no. manuf. workers - female)	-0.017**	0.002	-0.011	-0.006	-0.015**
	(0.008)	(0.009)	(0.007)	(0.007)	(0.006)
ln(no. manuf. workers - male)	0.029**	0.022***	0.024***	0.021***	0.022***
	(0.011)	(0.007)	(0.008)	(0.007)	(0.006)
ln(no. service workers)	0.002	0.001	0.006	0.007*	0.004
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
ln(no. service workers - female)	-0.004	-0.004	0.000	0.003	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ln(no. service workers - male)	0.008*	0.006	0.011**	0.011**	0.010**
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
female share of service workers	-0.306***	-0.269***	-0.270***	-0.211***	-0.278***
	(0.067)	(0.078)	(0.065)	(0.052)	(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%. Table replicates robustness checks shown in Table 8 using other outcomes. Each estimate is obtained in a different regression. See notes of Table 8 for further details.

Table B.8: 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	-1.045***	-0.017	-0.973***	-0.099***
closed since 1981	(0.066)	(0.015)	(0.064)	(0.016)
Panel B				
No. mine workers	-1.078***	-0.017	-0.995***	-0.112***
laid-off since 1981	(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 B.9: 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 B.10: Substitution effects in non-primary sectors, controlling by manual and non-manual employment

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

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:

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

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^b_F. However, male manufacturing workers, L^b_M, should increase since $L^b = L^b_M + L^b_F$ is increasing (prediction 2).

D Extension with a service sector

We extend the basic model presented in Section 2.2 by adding a service sector. Let us denote this sector with letter c. Similar to manufacturing, the service sector employs male and female workers, and both are imperfect substitutes in the production process. The main difference is that the service sector produces a non-tradable good whose demand depends of size of the local market. To keep the model analytically tractable, we assume that demand for the non-tradable good is inelastic: every individual demands 1 unit of the good. Thus, total demand is always equal to the population size N. With these assumptions, the aggregate labor demand of the service sector is $L^c = L^c_M(w_M, w_F, N) + L^b_F(w_M, w_F, N)$, where L^c_M and L^c_F refer to demand for male and female workers. Similar to the baseline model , we assume that all labor demands are downward sloping.

Note that, N is an increasing function of wages. Thus, in contrast to manufacturing, changes in wages have two opposite effects in the service sector. Consider a decrease in wages. A direct effect is a reduction in costs of production and thus an increase in L^c. There is also an indirect effect: the reduction in wages decrease market size and thus also the demand for the service good and labor, L^c. This feature will make the predictions on sectoral employment less clear than in the baseline model. However, the main prediction of crowding out of female employment in the tradable sector still remains.

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

$$N_M(w_M) = L^a_M(w_M, A_a) + L^b_M(w_M, w_F, A_b) + L^c_M(w_M, w_F, N) \quad (9)$$

$$N_F(w_F) = L^b_F(w_M, w_F, A_b) + L^c_F(w_M, w_F, N). \quad (10)$$

Similar to the baseline model, let us define the following terms:

$$A \equiv \frac{\partial L^a_M}{\partial A_a}, B \equiv \frac{\partial L^b_M}{\partial w_F}, C \equiv \frac{dN_M}{dw_M}, D \equiv -\frac{\partial L^a_M}{\partial w_M},$$

$$E \equiv -\frac{\partial L^b_M}{\partial w_M}, F \equiv \frac{dN_F}{dw_F}, G \equiv -\frac{\partial L^b_F}{\partial w_F}, H \equiv \frac{\partial L^b_F}{\partial w_M},$$

$$I \equiv \frac{\partial L^c_M}{\partial w_F} + \frac{\partial L^c_M}{\partial N}\frac{\partial N_F}{\partial w_F}, J \equiv -(\frac{\partial L^c_M}{\partial w_M} + \frac{\partial L^c_M}{\partial N}\frac{\partial N_M}{\partial w_M}), K \equiv -(\frac{\partial L^c_F}{\partial w_F} + \frac{\partial L^c_F}{\partial N}\frac{\partial N_F}{\partial w_F}), L \equiv \frac{\partial L^c_F}{\partial w_M} + \frac{\partial L^c_F}{\partial N}\frac{\partial N_M}{\partial w_M},$$

Note that the assumptions of upward sloping labor supplies, downward sloping labor demands, and substitutability of men and women in manufacturing and services imply that all these terms are unambiguously positive, and that $E > H$, $G > B$, $J > L$ and $K > I$.

We examine the effect of a mine closures by taking derivatives of the equilibrium conditions with respect to A_a. Using the above definitions, we can write these derivatives as follows:

$$A + (B + I)\frac{dw_F}{dA_a} = \frac{dw_M}{dA_a}\left[C + D + E + J\right] \tag{11}$$

$$\frac{dw_M}{dA_a} = \frac{(F + G + K)}{H + L}\frac{dw_F}{dA_a}. \tag{12}$$

Solving the system we obtain that:

$$\frac{dw_M}{dA_a} = \frac{(F + G + K)}{H + L}\frac{A}{B + I}\frac{1}{(\pi^* - 1)},$$

where $\pi^* \equiv \frac{(F+G+K)(C+D+E+J)}{(H+L)(B+I)}$. Note that $E > H$, $G > B$, $J > L$ and $K > I$ are sufficient conditions for $\pi^* > 1$. $\pi^* > 1$ implies that $\frac{dw_M}{dA_a} > 0$. This result, together with equation (12), implies also that $\frac{dw_F}{dA_a} > 0$.

Similar to the baseline model, this extension also predicts that mine closures would reduce wages of both men and women (prediction 3), and, due to the reduction of wages, also decrease population (N_F, N_M) (prediction 1).

The effect on total manufacturing employment (L^b) is unambiguosly positive (prediction 2). This happens because of the reduction in wages. The effect on service employment (L^c) is, however, ambiguous. It could increase due to cheaper labor, but could decrease due to the reduction in local demand. The net effect depends of the elasticities of demand and supply which we cannot estimate in our case. For the same reason, we cannot obtain predictions of the effect on service employment by gender (L^C_F, L^c_M) nor on the share of female employment for this sector.

We can, however, identify three possible cases based on the effect on female service employment (no change, increase or decrease). These three cases are empirically testable and for each we can obtain predictions regarding the crowding out of women.

Case 1: no change in L^c_F Since there is reduction in female population (N_F), this case implies a reduction in female manufacturing employment (L^b_F). Since total manufacturing employment increase, this result implies an increase in male manufacturing employment (L^b_F). Together, these results imply a reduction in the share of female manufacturing workers $\frac{L^b_F}{L^b}$).

Case 2: increase in L_F^c Since there is reduction in female population (N_F), this case implies a larger reduction in female manufacturing employment (L_F^b). Similar to the case 1, this implies increase in L_F^b and reduction in $\frac{L_F^b}{L^b}$.

Case 3: decrease in L_F^c In this case the effect on L_F^b and, by extension, on $\frac{L_F^b}{L^b}$ is ambiguous. It could increase, decrease, or remain unchanged. However, if the decrease in L_F^c is small enough so it does not explain all the reduction in female population, then L_F^b and $\frac{L_F^b}{L^b}$ would decrease.

In Section 4, we show that mine closures did not significantly changed L_F^c. Thus, our results supports case 1. In that case, the model predicts a crowding out of female workers in manufacturing and reduction in $\frac{L_F^b}{L^b}$ (prediction 2).

E 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 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 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. Alternatively, we model the allocation of funds according to district specific characteristics such as the total population, the unemployment rate and time-invariant characteristics for the period 1991 to 2001. We use the predictions of this model to infer the allocation of funds for the missing years. Our results do not change. 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 E.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).

F Main results using number of miners laid-off

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

	No. primary workers '000s (1)	ln(pop.) (2)	ln(no. 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 F.2: Effect of mine closures on employment in non-primary sectors

	ln(no. of workers)			% female workers
	Total	Women	Men	
	(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 F.3: Robustness checks

	share of female manufacturing workers				
	(1)	(2)	(3)	(4)	(5)
No. of mine workers	-0.982***	-0.482***	-0.755***	-0.558***	-0.795***
laid-off since 1981	(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 F.4: Effect of mine closures on manual and non-manual employment

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

Table F.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 F.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.