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Inter-Regional Coal Mine Competition in the US: Evidence from Rail Restrictions†

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There has been much discussion recently in the U.S. press about the fate of coal mining and its employees, specifically in the Appalachian region. This analysis looks at how Appalachian coal mining responds to changes in coal production from the Western US, whose mines are generally on federal land. Specifically we look at how an unexpected reduction in the ability to move coal from Wyoming to Eastern power plants in 2005-06 impacted the rate of opening and closure of mines in Appalachia. The findings reveal that restrictions in coal from federal lands leads to a reduction in the rate of Appalachian coal mine closure but no impact on the rate of coal mine openings. The results imply inter-regional coal mine substitution possibilities and shed light on the tradeoffs inherent in policies to encourage production in one region.

JEL codes: L71, Q35.

Keywords: Coal switching, Railroads, Supply Shock

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Introduction

In January 2016, the Department of Interior (DOI) announced that it was ordering a moratorium on new coal leases from federal lands with the DOI considers changes to the federal coal leasing policy. The moratorium was rescinded in March of 2017, however these actions have highlighted the inter-regional competition between Appalachian and Western coal mines. While coal mining on federal lands accounts for around 40% of all coal produced in the U.S., a large majority of the coal production from federal lands comes from mines in Western states. Specifically, the Powder River Basin (PRB) in Wyoming accounts for most of the coal produced from federal lands. Conversely, very few of the coal mines from the Appalachian coal basin in West Virginia, Virginia, and Kentucky are located on federal lands. PRB mine's tend to be the low-cost producers in the coal mining industry given the thick seams and proximity to the surface of the coal mined while Appalachian mines are higher cost given their thinner seams and being further from the surface.

How changes in polices that might favor one region's coal mining over another will affect coal mine activity is an open question (Gillingham et al 2016). Given the political interest in helping coal mining counties in Appalachia particularly, it is important to understand the tradeoffs from boosting one region's coal mining incentives. Mining jobs account for a significant portion of the workforce in parts of Appalachia: for instance, comparing 2011 and 2016, Houser et al (2017) find mining job losses in West Virginia account for 1.64% of the total workforce. To attempt an answer, we looked for another instance in the past where one region's coal was unexpectedly restricted.

In May of 2005 there was a derailment on the main rail line out of the PRB which caused the two main rail companies to declare *force majeure* on their delivery commitments (Department of Energy, 2007)The *force majeure* was lifted in November 2005, but deliveries were generally back to pre-derailment levels by spring 2006. Many utilities were provided a fraction of their contracted amount of coal from the PRB during this period. As such, the years 2005 and 2006 will be our treatment period and how we will draw inference on the nature of inter-regional coal mining competition. This treatment is somewhat analogous to 2016 when the federal coal leasing moratorium was imposed. In both cases, the market suddenly had less coal than expected available for the near future.

Our main outcome variable is the rate at which mines close. Intuitively it makes sense that the response to a temporary restriction in PRB coal would be for Appalachian mines to stay open longer rather than open new mines. Permitting and investment in a new mine do not happen instantaneously so it is simpler to keep a functioning mine open. It is unclear, though, how Appalachian mines may respond: Appalachian and PRB coal are not perfect substitutes for each other, and the distances shipped to power plants vary significantly between these coal types. Substitutability between federal and non-federal coal determines in part how policies that differentially affect mining regions may work (Gillingham et al (2016), Gerarden et al (2016), Haggerty et al (2016)).

We find Appalachian mines tend to close 8% - 10% less frequently during the years the PRB rail restrictions was in effect. We do not find new mine openings to be statistically significantly affected by the PRB rail restrictions, nor do we find any statistically significant impact on the intensive margin, coal production, for Appalachian mines. We believe our results capture a short-run effect of policies like a coal leasing moratorium: assuming they are forward looking, a moratorium initially acts as a supply shock as mines and utilities have to suddenly deal with lower than expected future supply of federal coal. As the moratorium runs its course, other adjustments – changes in leasing strategy by mines, switching away from coal by the utilities - are possible and it is less likely our estimates can reflect these. It should be noted the short-run impacts in the energy sector can have long-term implications due to path dependence as illustrated in Meng (2016).

To be fair, the state of the coal market in 2005 is different than present times in other ways. In 2005, natural gas prices were significantly higher than they are now, such that electricity generation from natural gas was not competitive with electricity generation from coal (Linn et al 2014, Fell and Kaffine, 2018, Coglianese et al, 2017). Additionally, renewable technologies were in their infancy compared to their current state (Houser et al 2017).Overall electricity consumption has also fallen (Linn and McCormack 2017), which directly impacts coal production since most of the consumers of coal in the US are electric utilities. To counter these coal demand reductions, many states have taken to encouraging their plants to burn coal from instate mines (Eyer and Kahn, 2017).

We first describe the rail restrictions, then discuss the data we use as well as the methodology. Results follow, together with a few falsification and robustness tests. We conclude with implications for policy, limitations of the current study and suggestions for future work.

The PRB Rail Restrictions

The Powder River Basin is the largest coal producing region in the world, located in the western part of the US across Wyoming and Montana (Figure 1). As is common throughout the US, this coal is transported using rail. The main rail line – known as the Joint line – connecting the PRB to the broader freight network is the most heavily trafficked freight line in the world (Department of Energy, 2007). Figure 2 shows annual freight tonnage by rail, road and water in 2002 – we clearly see shipments out of the PRB accounting for the largest share. Two major US railroads – Burlington Northern Santa Fe and Union Pacific – jointly own this line, which connects Caballo Junction to Shawnee Junction both in Wyoming. Figure 3 shows more closely the railroad ownership around the PRB: the joint line is the line running north to south.

In May 2005, three major derailments took place on this line which severely damaged track and equipment. These derailments meant a temporary stoppage of coal deliveries, with the railroads embargoing new customers on the Joint line. Record volumes of coal shipments resulted in large quantities of coal dust. The railroads were unable to keep up with the dust being generated, and this dust degraded the roadbed on which the tracks were laid ultimately creating an instability which is suspected to have led to the derailments.

Exacerbating the problem, nearly all coal shipments from the PRB are through rail – for Wyoming coal 95% of all deliveries for electric power were through rail in 2006 (EIA Coal Distribution Report, 2006).As Figure 3 makes clear, Union Pacific does not have alternate lines leading out of the PRB, and so was forced to declare *force majeure* for six months from June 2005 to November 2005. Repairs then had to be halted until spring of 2006 due to bad weather. It is therefore these two years – 2005 and 2006 – that form the time period during which we examine the effect of the PRB closure.During the force majeure, coal shipments reduced to around 85% of normal capacity (Department of Energy, 2007).

Estimating the impact of the PRB restrictions from the Mine Health Safety Administration Address and Employment Data

The first metric we will look at is whether Appalachian mines opened up as a result of the PRB restrictions. Figure 4 shows the propensity of new mines to open in Appalachia from 1990 to 2010. The data come from the Mine Health Safety Administration Address and Employment Data. The rate at which new Appalachian mines open is fairly consistent, with probabilities of between 28% and 35%. Importantly, the rate does not change drastically during 2005 or 2006. We can conclude that the restrictions in PRB coal did not lead to an increase in the opening of new mines in Appalachia. Figure 4 also shows the rate of openings for the Interior and Western coal basins. Openings are slightly higher in the Interior region during the treatment period but not statistically different than each other years.

Next, let's see whether Appalachian coal mines closed at the same rate in 2005 and 2006 as they had been closing in other years. Figure 5 shows the propensity for mines to close from 1990 to 2010.[1] Here we see that the treatment period has a slowdown in the rate of mine closure for mines in the Appalachian region. The rate falls from about 30% to a little over 20% during the time when production from the PRB was constrained by the rail firm's ability to deliver coal. Once the PRB production was back to normal in 2007 the rate of mine closure increases again in Appalachia.

Table 1 shows Appalachian mines tend to close the quickest. Here we distinguish mine closures by coal basin. Appalachian coal mines make up the bulk of the observations, but are the fastest to close and are in operation for an average of 3 years. Coal mines on federal lands – that is, those in the western part of the US – are relatively fewer in number, but tend to last three times as long and are the least likely to close.

Appalachian mines are also more likely to close at any given point in time. Figure 6shows survival probabilities for Appalachian and non-Appalachian mines with 95% confidence intervals. These curves show the probability of a mine continuing to survive into the future, conditional on surviving until the present. As expected, they slope downward, indicating the longer a mine is in operation, the higher the probability it will exhaust its reserves and close. Importantly, the slope is larger for Appalachian mines, indicating Appalachian mines face a statistically significantly lower chance of survival into the future conditional on being alive until the present at every point in time.

More formally, to identify the effect of the temporary PRB restriction, we estimate a Cox proportional hazard model, given below, and a linear probability model as well.

$$Probability\ [Close_{it}|Time\ Since\ Open, X_{it}] = h_0(t)\exp(\beta X_{it}) \qquad (1)$$

Here, i indexes mines and t indexes year. Mine closure ($Close_{it}$) is defined as follows: it is an indicator variable that equals one if the mine is observed in the current year but not in the following year, and zero if it is also observed in the following year. Itis also set equal to zero if the year is 2012 (the last year we have data on) and the mine is recorded as being active. We additionally set this variable as missing if the mine is recorded as closed by MSHA or permanently abandoned. The probability of closure is predicted with a number of variables (X).

The variable of interest in this analysis is STOPPAGE, which is a dummy variable equal to 1 in the years 2004 and 2005 and zero otherwise, interacted with an APPALACHIAN dummy. This variable will reveal

[1] As a mine is considered closed if it is observed in the present year but not in the following, we rescaled the axis so that 1990 represents the percentage of mines observed in 1989 but not observed in 1990.

the impact of the restriction in moving coal out of the PRB on Appalachian coal mines relative to other coal mines in the US over the same time period.

The three coal basin dummies in the analysis are: APPALACHIAN, INTERIOR, and WESTERN. Each basin dummy variable is coded to one if the mine is in that basin and zero otherwise.Given the discussion above, we expect APPALACHIAN to have a positive effect on mine closures.

A number of control variables related to the mine are included. SEAM HEIGHT is the height of the coal seam, in inches, that the mine is currently extracting from. A larger seam height is expected to reduce the probability of closure as it is cheaper to mine from taller seams. TOTAL INJURIES is the number of injuries at the mine during the year and should increase the probability of closure. TOTAL PRODUCTION and TOTAL HOURS are the amount of coal in tons and hours worked at the mine during the year, respectively. Either variable can affect mine closings positively or negatively: increased production can reduce the likelihood of mine closings as it means a rich seam has been found, or could reflect the mine is close to exhaustion. EMPLOYEES is the average number of employees working in a mine during the year, and expectations over the sign of the effect are similar to that of TOTAL PRODUCTION or TOTAL HOURS. The final mine level control is a mine type variable. The three types are: SURFACE, UNDERGROUND, and MILLS. The NATURAL GAS PRICE in the given year is also used as a control, as natural gas is a substitute fuel for electricity generation.

These mining basins contain significantly different mines which involve significantly different techniques for mining, as Table 2 makes clear. Table 2 shows summary statistics for the control variables by coal basin. Appalachian mines tend to locate underground, have less productive coal seams, lower injury counts, and involve lower levels of production while hiring fewer people than either mines in the Interior or in the Western basin. All these differences are both economically and statistically significant.For instance, comparing Appalachian to Western mines, the production to employee ratio is more than five times higher amongst Western minesalthough the number of employees per mine is only three times higher. Last, the distances to be shipped from either basin imply significantly different transportation costs (Figure 1); for all these reasons, the switch from Western to Appalachian coal is not a straightforward choice.

The PRB restrictions and the Survival Probability of Appalachian Mines

Estimates from the regression of equation (1) are shown in Table 3. The first four columns show estimates of mine closures, while the next four show estimates of mine openings. Columns (1) and (2) show estimates from a linear regression model; columns (3) and (4) show estimates of the Cox proportional hazards model shown in equation (1).

Our main focus is on the interaction term STOPPAGE X APPALACHIAN: this shows the effect of the PRB restrictions for Appalachian mines. We can see clearly Appalachian mine closings are negatively affected during the years the PRB closure is in effect, and the effect is robust to the inclusion of control variables. The linear model suggests estimates of around a 6% reduction in the probability of an Appalachian mine closing down while the survival models suggest between an 8% to 10% reduction in the probability of an

Appalachian mine closing.[2]As expected, in years when the PRB closure is not in effect, Appalachian are much more likely to close with the survival models suggesting an estimate of 21%.

All the control variables show statistically significant effects but only hours worked, number of employees and mine type appear to have economically strong effects as well. An increase in the number of hours worked lowers the probability of a mine closing by 15%, while an increase in the number of employees raises the probability by 17%. Surface mines are 4% more likely to close than underground mines.

We examine mine openings in columns (5) to (8). Here, we use the variable INTERRUPT, which equals one in the years 2005 and 2006 and zero otherwise. Since we are looking at mine openings, we use the years in which the PRB closure was operative; similar to before, we focus on the interaction of INTERRUPT and APPALACHIAN. Column (5) shows estimates from a linear regression, while column (6) shows estimates from a logit model. Columns (7) and (8) show estimates from a Poisson regression using total mine openings at the county level as the outcome variable.[3]From these estimates we can rule out the possibility that more Appalachian mines opened up in response to the PRB restrictions.

Looking at the intensive margin, we find insignificant effects on Appalachian mines in response to the PRB closure. Table 4 shows estimates of the impact of the PRB closure on the intensive margin. Attempts to separate out Kentucky coal mines from other Appalachian mines, due to Kentucky be the Western most state in the region, did not reveal any heterogeneity among Appalachian mines for intensive margin outcomes. As the intensive margin outcomes are continuous variables, we use mine fixed effects to examine within-mine changes over time. In addition, we cluster standard errors at the level of the county where the mine is located, as correlation within a county is quite likely amongst multiple mines.[4]

Placebo and Falsification Tests

To ensure we are indeed identifying the effect of the PRB closure on Appalachian mines, we conduct several placebo and falsification tests.

Using mine closings as the outcome, we first define the treatment to operate in other years – in 2007/2008 and in 1997/1998. The interaction term STOPPAGE X APPALACHIAN appears statistically insignificant. In these specifications, the coefficient on APPALACHIAN remains positive and statistically significant, consistent with our finding that Appalachian coal mines are on average more likely to close. The point estimate suggests around a 25% increase in the probability of an Appalachian mine closing, much the same as that in our main regression shown in Table 3. Columns (1) to (4) in Appendix Table 1 show these results.

Our specification could simply be generating reduced closures by design, if there was something special other than the PRB closure operating in 2005 and 2006. We therefore redefine the treatment to affect

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[2] Note the null hypothesis in the survival models is that the coefficient equals one i.e. the variable does not alter the baseline probability of a mine continuing operations.

[3] Here we exclude the years 1989 and 1990 as these years will entirely contain new mines by definition.

[4] There are an average of 31 mines per county in the Appalachian basin. There were some mines recorded as changing counties over time; these are dropped in the results reported in Table 4 as the panel defined by the mine identification variable will not be nested within a cluster. 493 mines accounting for 2,831 observations were dropped following this rule. Clustering errors by county does not change the main results in Table 3.

only the interior or western coal basins, keeping the year of treatment that same as before – 2004 and 2005. Here our focus is on STOPPAGE X INTERIOR and STOPPAGE X WESTERN. We find Interior mine closures in fact rise by between 14% to 16% while closures for Western mines are not statistically affected. Columns (5) to (8) in Appendix Table 1 show these results.

Conclusion

In this paper, we use a natural experiment in the form of an unexpected Western coal supply restriction to evaluate the substitutability of different regions coal. We find evidence of cross-regional substitution between coal basins. Specifically, following from a restriction on federal coal supply, Appalachian minesare less likely to close down.

Our results suggest Appalachian coal communities likely did better as a result of the Obama administrations' moratorium on new coal leases on federal land. While allowing these communities short term resource increases without any lock-in to longer term investment. The removal of the moratorium under the Trump administration could then potentially undo some of these benefits.

Nevertheless, our results also indicate the adoption of supply side policies may not necessarily lead to the outcomes originally envisioned. The motivation behind the moratorium stems from controversial and possibly inefficient leasing practices. That Appalachian coal can serve as a substitute for Western coal would mean that a moratorium may simply shift production from one place to another without affecting total coal production or emissions;[5] at the same time, the federal government loses out on royalty payments from mines operating on federal land.

We provide only an estimate of the effects of a short-term restriction in moving Western coal: we do not examine the policies like a federal coal leasing moratorium directly, and the present world is substantially different from that in 2005. To the extent possible, we have attempted to control for these differences, but clearly a detailed look at a moratorium or other policies that impacts one regions' coal mines itself would be informative.

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[5] Appalachian coal is more polluting, after all, than western coal. Given the difference in size and magnitude of production, the environmental effect is probably small.

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Figures

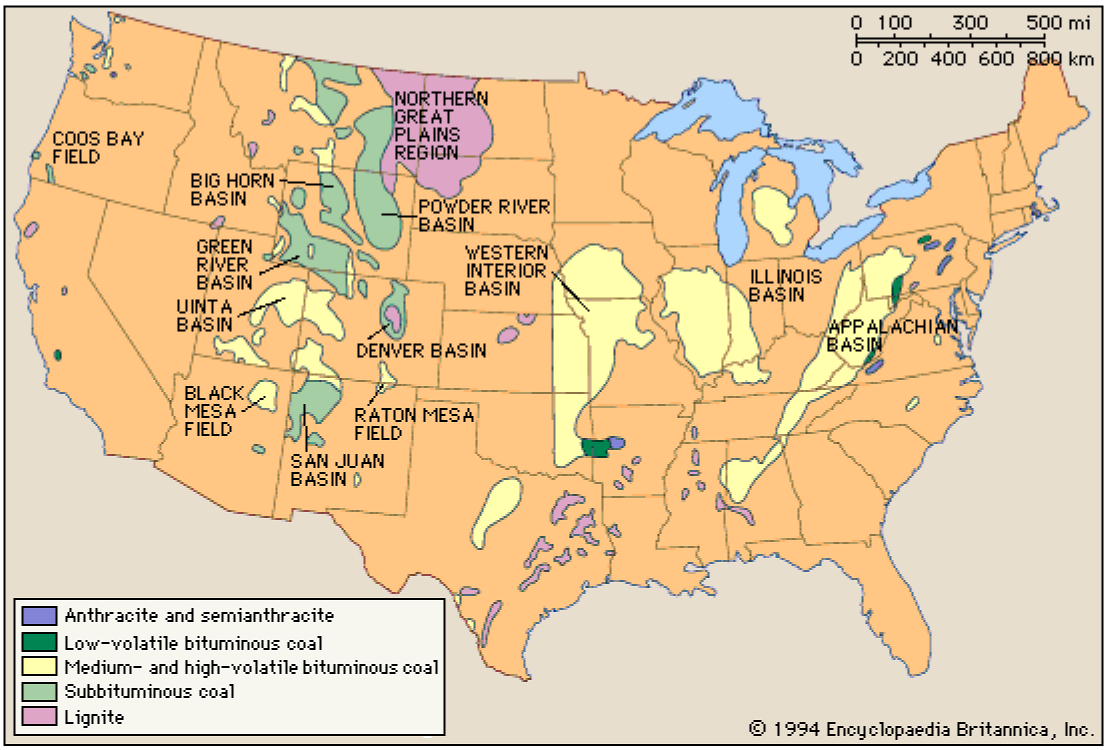
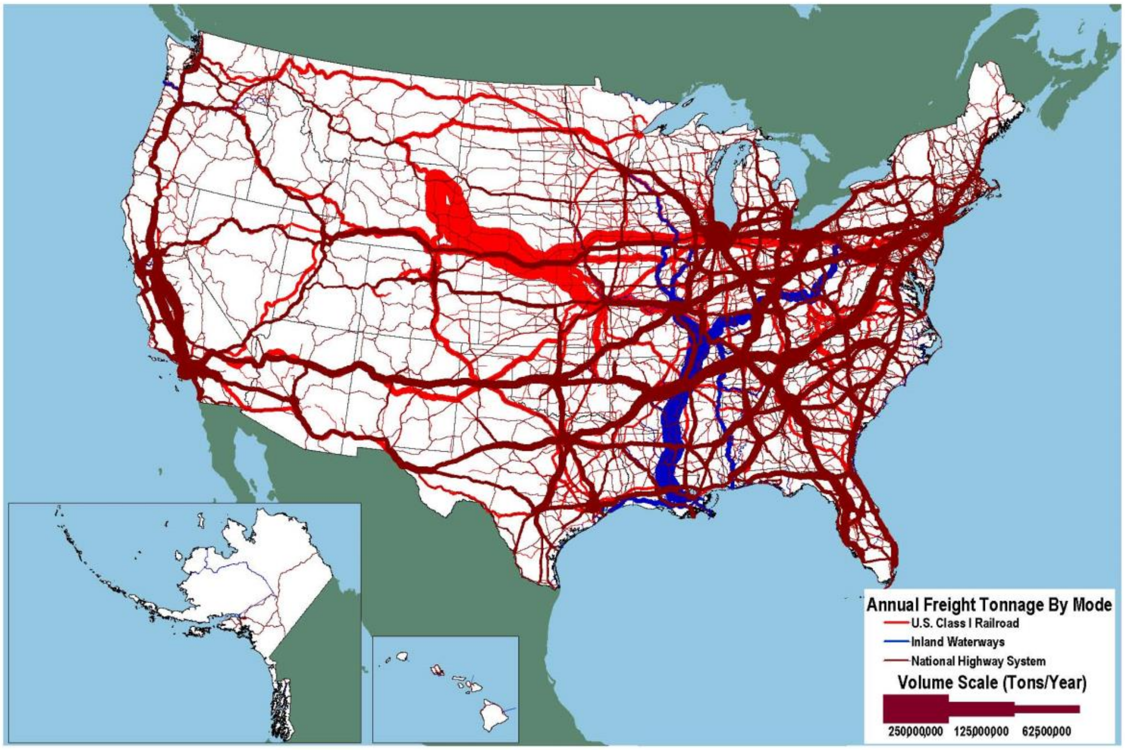


Figure 1: Coal Basins in the US

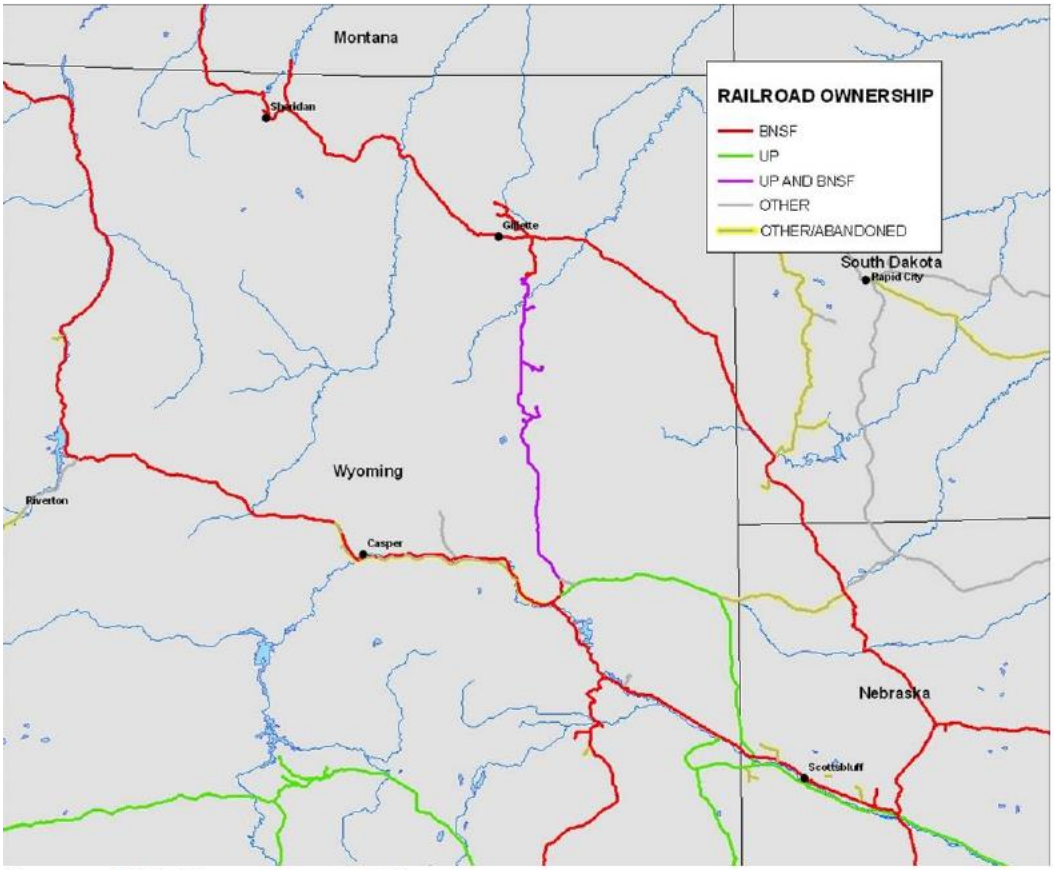
<u>Figure 2: Freight Shipments in the US</u>

Tonnage on Highways, Railroads and Inland Waterways: 2002



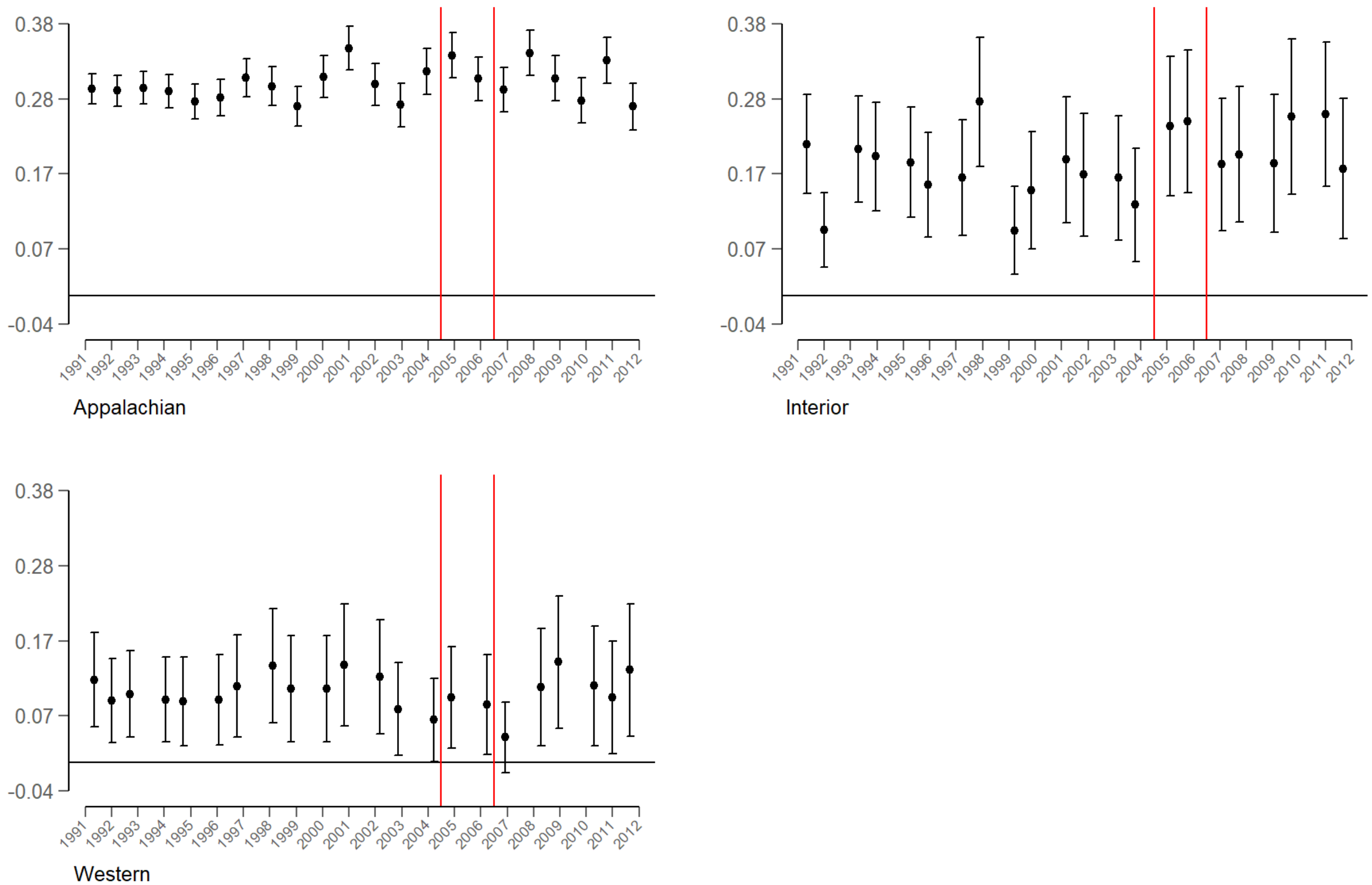
Sources: Highways: U.S. Department of Transportation, Federal Highway Administration, Freight Analysis Framework, Version 2.2, 2007. Rail: Based on Surface Transportation Board, Annual Carload Waybill Sample and rail freight flow assignments done by Oak Ridge National Laboratory. Inland Waterways: U.S. Army Corps of Engineers (USACE), Annual Vessel Operating Activity and Lock Performance Monitoring System data, as processed for USACE by the Tennessee Valley Authority; and USACE, Institute for Water Resources, Waterborne Foreign Trade Data, Water flow asssignments done by Oak Ridge National Laboratory.

Figure 3: Rail Ownership in the PRB



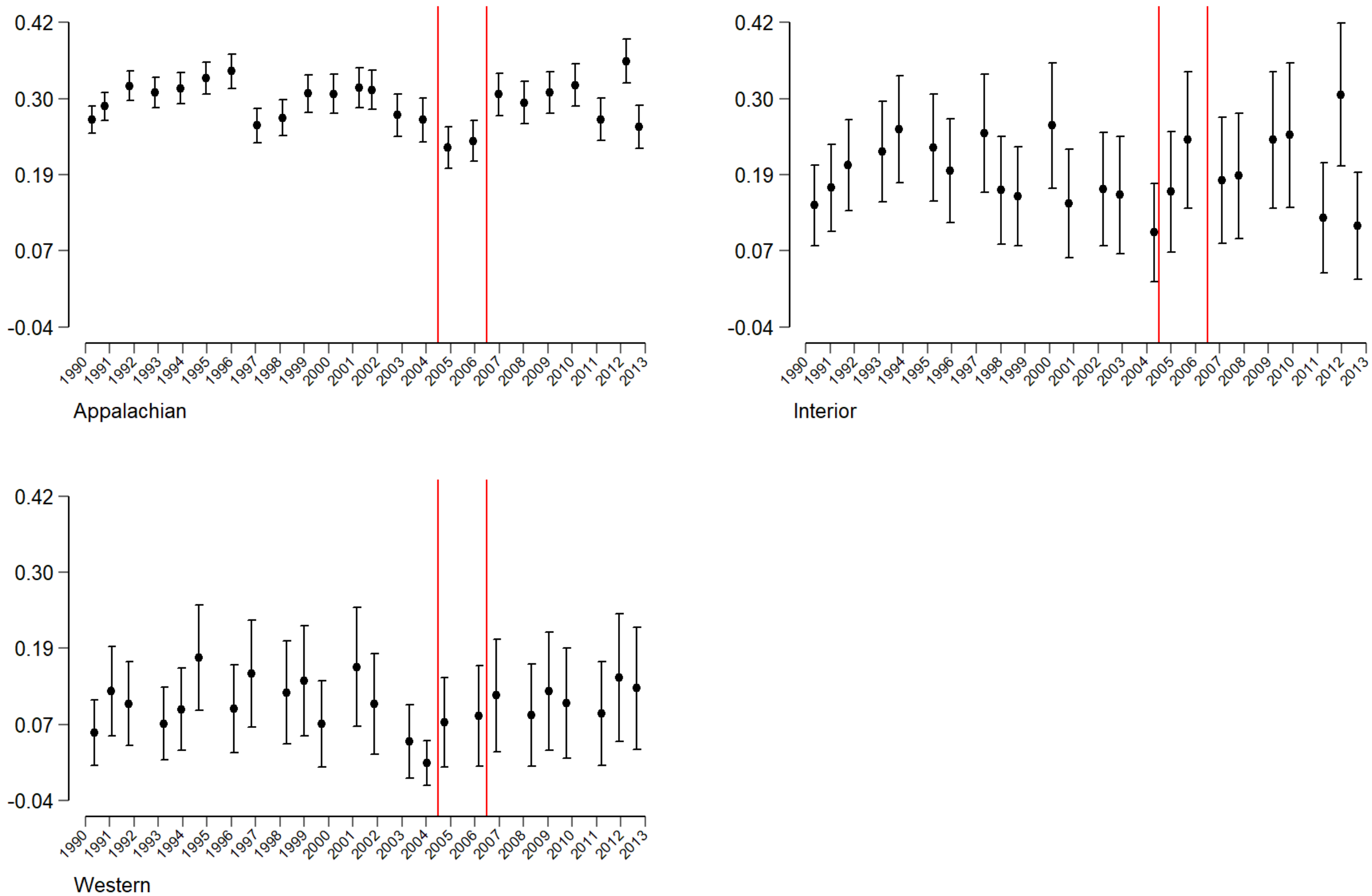
Source: U.S. Department of Energy.

Figure 4: New Appalachian Coal Mines do not appear to be more likely to open when the supply of PRB coal is restricted



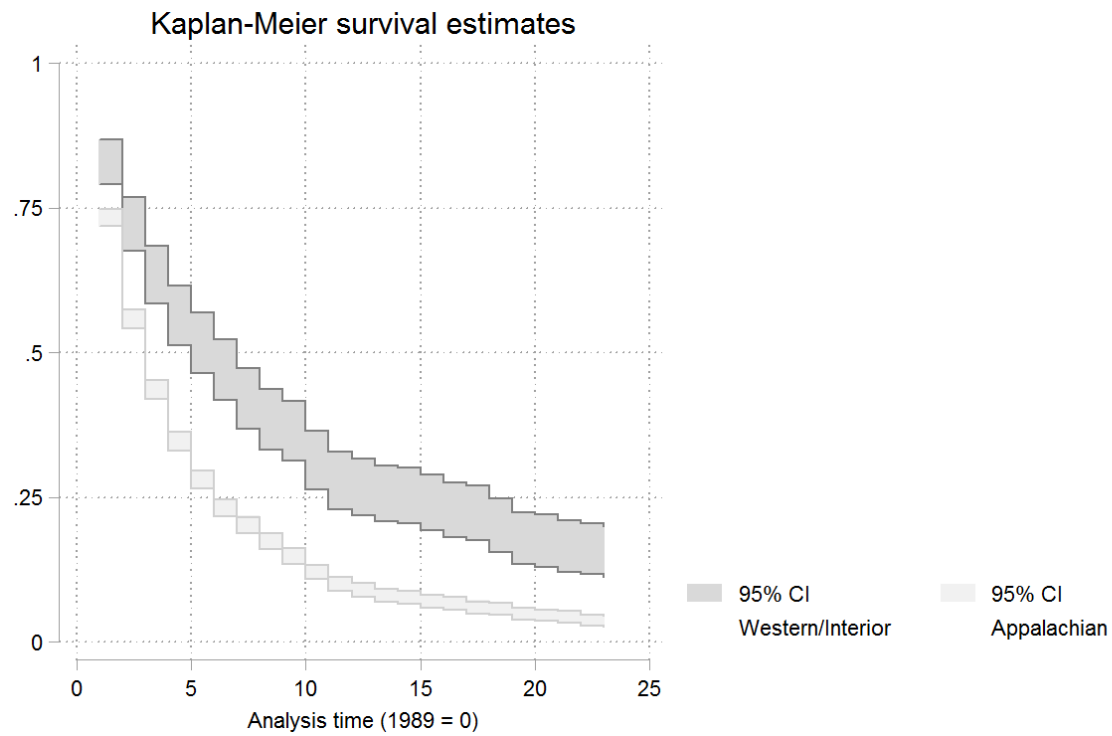
Source: Mine Safety and Health Administration; Figure shows the propensity for new mines to open by year for each coal region, with 95% confidence intervals. Mine openings are defined by an indicator variable that equals one if the mine is observed in the current year and also observed in the following year, and zero if it is observed in the past year. The two vertical red lines indicate the period of time when the supply of PRB coal met was unexpectedlyrestricted. The black horizontal line indicates a value of zero on the y-axis. Table 1 gives details on which states are included in each region.

Figure 5: Appalachian Coal Mines are less likely to close when PRB coal supply is unexpectedly restricted



Source: Mine Safety and Health Administration. This figure shows the propensity for existing mines to close by year for each coal region, with 95% confidence intervals. Mine closings are defined by an indicator variable that equals one if the mine is not observed in the following year and zero if it is observed in the current year. The vertical red lines indicate the years in which the supply of PRB coal was unexpectedly restricted. The black horizontal line indicates a value of zero on the y-axis. Table 1 gives details on which states are included in each region.

Figure 6: Appalachian Coal Mines are less likely to survive into the future



This figure shows mine survival probabilities by coal region, specifically the instantaneous probability that a mine will continue operations conditional on the probability it has survived until the present. As time moves forward, the probability a mine survives decreases as its reserves of coal are depleted. Mines in the Western or Interior region are statistically significantly more likely to survive till next year than Appalachian mines. Table 1 gives details on which states are included in each region.

Table 1: Descriptive Statistics regarding Mine Closures, by Region

Panel A: Overall

Total Observations	16641
Total Mines	4077
Total Mines that Shut Down	3237

Panel B: By Coal Region

Region	*States*	*# Mines*	*# Observations*	*# Mines Closed‡*	*# Years Observed (Mean)*	*Mine Closing Rate**
Appalachian	Alabama, Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia	3711	13961	2965	3.76	79%
Interior	Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Mississippi, Missouri, Oklahoma and Texas	235	1442	184	6.13	78%
Western	Arizona, California, Colorado, Montana, New Mexico, North Dakota, Utah and Wyoming	128	1209	85	9.44	66%

‡Mine closings are defined by an indicator variable that equals one if the mine is not observed in the following year and zero if it is observed in the current year.

*Mine closing rate is the total number of mine closings in each region divided by the total number of mines observed in that region.

Table 2: Summary Statistics showing each Coal Basin differs significantly from each other

	Appalachian		Interior		Western		Difference	
	Observations	Mean	Observations	Mean	Observations	Mean		
	(1)	(2)	(3)	(4)	(5)	(6)	(2) – (4)	(2) – (6)
Seam Height (Hundred Inches)	26,728	0.45	2,148	0.55	1,741	2.73	-0.10***	-2.28***
Injury Count	26,843	4.70	2,151	9.56	1,743	6.55	-4.86***	-1.85***
Total Production (Million Tons)	26,843	0.36	2,151	1.41	1,743	6.70	-1.05***	-6.34***
Total Hours (100 thousands)	26,843	1.13	2,151	2.84	1,743	3.82	-1.71***	-2.69***
Average Number of Employees (Hundreds)	26,843	0.52	2,151	1.28	1,743	1.86	-0.76***	-1.34***
Price of Natural Gas (Hundreds)	24,666	4.77	2,016	3.95	1,646	4.15	0.82***	0.62***
Mine Type	Observations	Percentage	Observations	Percentage	Observations	Percentage		
Underground	26,843	56%	2,151	29%	1,743	37%	26%***	18%***
Surface	26,843	30%	2,151	65%	1,743	57%	-35%***	-28%***
Mills	26,843	14%	2,151	6%	1,743	5%	8%***	9%***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. For a definition of which states are included in which coal basin, see Table 1. Sample is restricted to those mines that are in the data for at least two years if they enter in the first year in the sample, and that are not recorded as having closed in the first year (i.e. 1989).

Table 3: PRB Closure reduces the likelihood of Appalachian Mines Closing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mine Closings				Mine Openings			
Estimation Method	Linear		Survival		Linear	Logit	Poisson	
Method of Handling Ties			Breslow					
STOPPAGE	-0.011	-0.006	0.972	0.988				
	(0.021)	(0.021)	(0.028)	(0.033)				
APPALACHIAN	0.150***	0.081***	1.782***	1.212***	0.086***	0.082	3.423***	3.263***
	(0.010)	(0.013)	(0.110)	(0.072)	(0.009)	(0.066)	(0.679)	(0.642)
STOPPAGE X APPALACHIAN	-0.060**	-0.063***	0.917**	0.896***				
	(0.024)	(0.023)	(0.033)	(0.034)				
INTERRUPT					0.015	0.160	0.117	0.277
					(0.027)	(0.209)	(0.184)	(0.214)
INTERRUPT X APPALACHIAN					-0.014	-0.209	-0.692***	-0.002
					(0.029)	(0.216)	(0.228)	(0.342)
SEAM HEIGHT		-0.019***		0.980***	-0.018***	-0.128***		-0.017
		(0.006)		(0.006)	(0.002)	(0.030)		(0.039)
TOTAL INJURIES		-0.001		0.990***	-0.001***	-0.124***		0.004***
		(0.000)		(0.002)	(0.000)	(0.008)		(0.001)
TOTAL PRODUCTION		0.006***		1.013***	0.006***	0.186***		0.086***
		(0.002)		(0.004)	(0.001)	(0.031)		(0.016)
TOTAL HOURS		-0.150***		0.853***	-0.136***	-2.033***		-0.026
		(0.016)		(0.014)	(0.008)	(0.089)		(0.175)
EMPLOYEES		0.224***		1.170***	0.199***	1.061***		-0.484
		(0.030)		(0.030)	(0.020)	(0.197)		(0.463)
Mine Type (Base = Underground)								
SURFACE		0.123***		1.043***	0.122***	0.749***		-0.560***
		(0.008)		(0.010)	(0.006)	(0.037)		(0.115)

MILLS		0.051***		0.983*	0.049***	0.181***		-0.339***
		(0.013)		(0.010)	(0.008)	(0.047)		(0.083)
NATURAL GAS PRICE		0.002*		0.996**	0.007***	0.064***		-0.166**
		(0.001)		(0.002)	(0.001)	(0.008)		(0.082)
Constant	0.157***	0.237***			0.192***	-0.271***	3.357***	4.613***
	(0.009)	(0.015)			(0.011)	(0.081)	(0.469)	(0.567)
Observations	29,319	26,919	16,641	16,412	26,136	26,136	26,517	26,136
R-squared	0.013	0.102			0.099			

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Columns (1) to (6) show regressions at the mine level; (7) and (8) are at the countylevel. Standard errors clustered by mine for columns (1) to (6); and at the county level for columns (7) and (8).

Table 4: Changes Along the Intensive Margin

	(1) Total Production	(2) Total Hours	(3) Total Injuries	(4) Seam Height	(5) Average Number of Employees
INTERRUPT	1.395	0.020	0.488	-0.039	-0.021
	(1.042)	(0.047)	(0.563)	(0.054)	(0.023)
INTERRUPT X APPALACHIAN	-1.082	0.001	-0.495	0.039	0.013
	(0.845)	(0.044)	(0.712)	(0.052)	(0.022)
TOTAL HOURS	-0.161		0.601	0.006	0.411***
	(0.241)		(1.726)	(0.018)	(0.007)
TOTAL INJURIES	-0.025	4.0E-04		-0.009	8.40E-04
	(0.020)	(0.001)		(0.040)	(0.001)
SEAM HEIGHT	-0.260	0.002	-0.034		0.003
	(0.265)	(0.005)	(0.167)		(0.004)
EMPLOYEES	2.965*	2.238***	6.068	0.052	
	(1.716)	(0.038)	(3.876)	(0.047)	
TOTAL PRODUCTION		-0.004	-0.792***	-0.022***	0.013***
		(0.004)	(0.133)	(0.002)	(0.002)
Mine Type (Base = Underground)					
SURFACE	0.432	-0.050	-2.579	-0.048	0.012
	(0.453)	(0.073)	(1.615)	(0.049)	(0.037)
MILLS	0.066	-0.044	0.489	-0.049	0.016
	(0.230)	(0.064)	(1.120)	(0.044)	(0.031)
NATURAL GAS PRICE	-0.083	0.015***	-0.345***	-0.005	-0.007***
	(0.059)	(0.005)	(0.100)	(0.006)	(0.002)
Constant	-0.567	-0.103**	3.864***	0.708***	0.094***
	(0.757)	(0.052)	(1.109)	(0.028)	(0.019)
Mine Fixed Effects	Y	Y	Y	Y	Y
Observations	13,627	13,627	13,627	13,627	13,627
R-squared	0.380	0.952	0.103	0.006	0.954
Number of Mines	3,528	3,528	3,528	3,528	3,528

Standard errors clustered at the county where the mine is located; *** p<0.01, ** p<0.05, * p<0.1. Sample is restricted to those mines that are not recorded as changing counties over time.

Appendix Table 1: Placebo and Falsification Tests, Cox Proportional Hazard Model Estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Method of Handling Ties	Breslow	Efron	Breslow	Efron	Breslow	Efron	Breslow	Efron
Placebo defined in:	2007/08		1997/98					
PLACEBO STOPPAGE	1.034	1.040	0.988	0.980				
	(0.030)	(0.033)	(0.034)	(0.038)				
PLACEBO STOPPAGE X APPALACHIAN	1.018	1.019	1.001	1.004				
	(0.030)	(0.032)	(0.035)	(0.040)				
APPALACHIAN	1.197***	1.214***	1.194***	1.208***				
	(0.071)	(0.081)	(0.070)	(0.081)				
INTERIOR					0.912	0.898		
					(0.063)	(0.073)		
STOPPAGE					0.893***	0.879***	0.903***	0.891***
					(0.020)	(0.022)	(0.019)	(0.021)
STOPPAGE X INTERIOR					1.125***	1.142***		
					(0.045)	(0.050)		
WESTERN							0.697***	0.692***
							(0.072)	(0.078)
STOPPAGE X WESTERN							1.071	1.068
							(0.057)	(0.062)
SEAM HEIGHT	0.981***	0.977***	0.980***	0.977***	0.979***	0.974***	0.981***	0.977***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
TOTAL INJURIES	0.990***	0.988***	0.990***	0.988***	0.990***	0.988***	0.990***	0.988***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
TOTAL PRODUCTION	1.014***	1.017***	1.013***	1.017***	1.013***	1.016***	1.014***	1.017***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
TOTAL HOURS	0.852***	0.831***	0.854***	0.833***	0.853***	0.832***	0.851***	0.831***
	(0.015)	(0.016)	(0.015)	(0.016)	(0.014)	(0.016)	(0.014)	(0.016)
EMPLOYEES	1.169***	1.193***	1.167***	1.191***	1.168***	1.190***	1.174***	1.197***
	(0.030)	(0.033)	(0.030)	(0.033)	(0.030)	(0.034)	(0.030)	(0.033)

NATURAL GAS PRICE	0.989***	0.987***	0.992***	0.990***	0.996**	0.995**	0.996**	0.995**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Mine Type (Base = Underground)								
SURFACE	1.043***	1.052***	1.044***	1.054***	1.041***	1.050***	1.042***	1.051***
	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)	(0.009)	(0.011)
MILLS	0.982*	0.978*	0.983*	0.979*	0.982*	0.978*	0.983*	0.979*
	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)
Observations	16,412	16,412	16,412	16,412	16,412	16,412	16,412	16,412

Robust standard errors in parentheses, clustered by mine. *** p<0.01, ** p<0.05, * p<0.1.