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Employment Booms and Busts Stemming from Nonrenewable Resource Extraction

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ABSTRACT

A non-renewable resource extraction model is embedded within a lake model of industry-specific employment, where flows to (from) employment from (to) unemployment depend on the attachment (separation) rate. The attachment and separation rates vary with resource extraction, and the results, driven by the rate of extraction and the remaining resource stock, indicate that changes in the stationary employment level can be positive, negative, or zero. There is a range where the separation rate is decreasing (increasing) and the attachment rate is increasing (decreasing), and the change in employment is determined by the combined effect of these changes. Using data on coal production and employment in the US as a guide, simple calculations provide a range of years beyond 2013 when it is expected that peak employment will be reached in the Marcellus Shale, and the results suggest that employment gains will likely continue for at least a decade.

Keywords: Marcellus Shale, Shale Gas, Nonrenewable Resource, Employment, Lake Model
JEL Classifications: Q32, Q33, Q47

1. INTRODUCTION

The economics of non-renewable resource extraction can be traced back to Gray's (1914) model of a price-taking firm faced with an increasing marginal cost of extraction. Most research on non-renewable resource extraction, however, begins with Hotelling's (1931) classic model of a firm deciding how to use its resource stock to maximize profits, where profits depend on a rising resource price and a constant unit-cost of extraction. Various versions of Hotelling's model have since been developed and analyzed under different theoretical and empirical assumptions.[1] In most versions, the price and extraction paths of the resource are easily derived and demonstrate two basic outcomes. First, as the price of the resource grows, firms will have an incentive to save some of the resource for future periods. This is known as profit-based conservation. Second, in equilibrium, the discounted resource rent will be equal across time which leads to the derivation of Hotelling's rule: The net price of the natural resource will grow at the market rate of interest.

The basic Hotelling model also predicts that the resource will eventually be depleted, but model extensions have shown that the nature of depletion and Hotelling's rule can depend on, for example, the market structure (Stiglitz, 1976; Dasgupta and Heal, 1979); tax instruments imposed on the extracting firm (Burness, 1976; Heaps, 1985); aspects of demand and reserve uncertainty (Pindyck, 1980); quality variations in the resource deposit (Hartwick and Olewiler, 1998); the price and availability of substitutes (Herfindahl, 1967); the existence of backstop technologies (Nordhaus et al., 1973; Hartwick and Olewiler, 1998); discovery and exploration costs (Pindyck, 1978; Hartwick, 1991; Cairns, 1990); and changes in extraction costs (Herfindahl, 1974).[2] Despite these various extensions, there is an important sometimes overlooked theoretical consideration of non-renewable resource extraction: How does employment in the extractive industry

1 According to Google Scholar, Hotelling (1931) has since been cited over 4000 times, whereas Gray (1914) has been cited slightly more than 300 times.

2 For excellent overviews of these and many other extensions of Gray (1914) and Hotelling (1931), see the following texts: The Economics of Natural Resource Use (Hartwick and Olewiler, 1988); Economic Theory of Natural Resources (Herfindahl and Kneese, 1974); Economic Theory and Exhaustible Resources (Dasgupta and Heal, 1979); and Resource Economics (Conrad, 2010).

change as the resource is depleted?[3] This question is particularly important in light of the (Shale) natural gas boom in the US of the late 20th century and throughout the 21st century.[4]

Before focusing closely upon employment issues associated with the shale gas boom, and the Marcellus Shale region in particular, it should be noted that the large increase in shale gas production in the US has impacted many energy markets and raised numerous environmental considerations. Sovacool (2014) provides a wide ranging review of many of the environmental issues while Kim and Lee (2015) focus upon how shale gas developments are impacting the US Regional Greenhouse Gas Initiative. The US Environmental Protection Agency recently completed a comprehensive review of the impacts of hydraulic fracturing ("fracking") upon drinking water. Their draft assessment concludes that fracking has "not lead to widespread, systemic impacts on drinking water resources," but identifies specific instances where fracking has impacted drinking water (Environmental Protection Agency, 2015).

Investigations of the impact of the shale gas boom on other energy markets includes its impact on oil prices (Obadi et al., 2013) and electricity production (Yuan and Zhang, 2014). In terms of employment impacts, the direct impact of the shale gas boom upon employment in the oil and natural gas industry has been substantial. In particular, the Marcellus Shale gas boom has transformed the state of Pennsylvania's oil and natural gas industry. From 2007 to 2012, Pennsylvania rose from the 10th to 6th largest state in terms of oil and gas industry employment, and was second only to Texas in the increase in oil and gas employment over this period (BLS, 2014).

Going from direct counts of related industry employment to estimates of the overall employment impact from shale gas drilling, however, is challenging for reasons including the potential for "resource curse" related job displacement in non-oil and gas sectors and the difficulty of accurately estimating employment linkages across both geographic regions and industries. Using national data Corden and Neary (1982) use the term "resource curse" to characterize findings that resource abundant nations grow more slowly than resource scarce countries, findings extended by Sachs and Warner (2001). More recent work by Menegaki (2013) analyzes a set of European nations and finds that while more oil production has a negative impact upon per capita real gross domestic product (GDP) growth, greater natural gas production has a positive impact upon per capital real GDP growth. At the county level within the US, results are mixed with some studies finding that counties more dependent upon natural resources grow more slowly (James and Aadland, 2011) while others find a positive employment impact from oil and natural gas resources (Weber, 2012; 2014; Brown, 2014).

Early estimates of the employment impact from shale gas development came from studies utilizing input-output models. Considine et al. (2009) estimate that Marcellus shale gas extraction created nearly 30,000 jobs in Pennsylvania in 2008, and follow-up studies raised the employment estimate to over 44,000 jobs in 2009 and 139,000 in 2010 (Considine et al., 2010; 2011). Similar methodologies generated estimated employment gains for Arkansas from Fayetteville shale gas extraction of approximately 9500 jobs over 2008-2012 (Center for Business and Economic Research at the University of Arkansas, 2008; 2012). These estimation methodologies were reviewed by Kinnaman (2011) who noted they may well be overstating the employment gains from shale gas development due to a variety of assumptions embedded in the input-output models. Econometrically based estimates of the employment effects from shale gas development have been varied, but largely positive. Analyzing county-level panel data from Colorado, Texas, and Wyoming, Weber (2012) finds moderate positive changes in employment, wage and salary income, and median household income. Each $1 million spent on natural gas production, for example, would generate roughly 2.35 local jobs.

Using county-level panel data from Pennsylvania, Perides et al. (2015) also find modest statistically significant employment effects from Marcellus Shale gas extraction over the 2004-2011 extraction period. Evaluated at the average number of wells in a Marcellus Shale Pennsylvania county (10.8 wells), they estimate an average employment effect of 71-181 total county jobs or 6.5-16.8 jobs per well. These employment estimates are larger than those of DeLeire et al. (2014) whose Pennsylvania county-level analysis finds a mean impact upon county total employment of 4.2 jobs per Marcellus shale well in the county. They estimate that by 2012, Marcellus Shale drilling accounted for on average only 2% of job growth (not total jobs) in Pennsylvania counties with Marcellus shale drilling. Similarly modest employment effects are found by Mauro et al. (2013) and Kelsey et al. (2011; 2012). Jaenicke et al. (2015) utilize Pennsylvania state tax data to more precisely estimate the jobs for residents within the county where Marcellus shale gas drilling occurs. They find a statistically significant positive impact on county employment only for counties with 90 or more wells drilled in a single year. Aggregating their results to the state level, they estimate total employment gains of 18,000-20,000 for Pennsylvania from Marcellus shale drilling, but only 7300-9600 of those jobs went to residents of the county in which the drilling occurred. Lastly, in contrast to the previous research Munasib and Rickman (2015) utilize a synthetic control methodology and fail to find any significant impact upon total employment through 2011 for any of their tested aggregations of Pennsylvania Marcellus shale gas counties.

While most of the empirical studies show a positive relationship between natural gas extraction and job creation, there is clearly a lack of consensus about how many jobs are created. Moreover, the Marcellus Shale related empirical research to date also has been focused upon job creation during this early phase of resource extraction for this formation. Over time jobs can also be lost, however, and this is especially the case as the stock of the natural resource is depleted. Rather than directly contribute to the empirical literature, we develop a simple

3 A notable but indirectly related exception is the seminal research of Corden and Neary (1982).

4 This is also a relevant question for the extraction of any non-renewable resource.

"lake" model of employment that helps to explain the empirical variations in employment gains and also captures the possibility of employment declines.[5] The lake model thus captures flows from employment in the extractive sector to the unemployed pool, and flows from the unemployed pool to the extractive sector, where the separation and attachment rates depend on remaining stock of the non-renewable resource available for extraction.

The remainder of the paper is organized as follows: Section 2 presents the resource extraction and lake model; Section 3 presents the stationary employment level and subsequent employment changes based on resource extraction; Section 4 first reviews the historical employment and extraction patterns for coal in the Appalachian Basin using the model's analytic perspective, and then constructs potential scenarios for peak employment related to Marcellus shale gas extraction given the findings for coal; and, Section 5 concludes.

2. MODEL

The stock of the natural gas, X_t evolves according to the following law of motion,

$$X_{t+1} = f(X_t, Q_t) \tag{1}$$

Where, X_t is the initial stock of natural gas, and Q_t is the total amount of natural gas extracted in period *t*. We assume a fixed initial stock such that $X_0 = A$, and also that,

$$\frac{\partial f(X_t, Q_t)}{\partial Q_t} < 0, \tag{2}$$

Which implies extraction of natural gas today reduces the stock available for extraction tomorrow.

Employment in period *t* + 1 in sector *i* takes the following form,

$$E_{it+1} = [1 - \delta_i(X_t)]E_{it} + \beta_i(X_t)[N_{it} - E_{it}] \tag{3}$$

Where, $\delta_i(X_t)$ is the separation rate from employment in sector *i*; $\beta_i(X_t)$ is the attachment rate or the rate at which the unemployed find a job in sector *i*; and N_{it} is the size of the labor force qualified for jobs in sector *i* in period *t*. N_{it} is further defined as the sum of the existing labor force in sector *i*, N_i, and also those employees who were separated from their jobs in sector i in period *t*, $\delta_i(X_t) E_{it}$ Equation (3) is augmented in the following way,

$$E_{it} = [1-\delta_i(X_t)]E_{it} + \beta_i(X_t)[N_i + \delta_i(X_t)E_{it} - E_{it}] \tag{4}$$

Because the stock of natural gas is either fixed or diminishing, depending on extraction rates, we make the following assumptions about the separation rate,

$$\frac{\partial \delta_i(X_t)}{\partial X_t} = \delta_i' \Rightarrow \begin{cases} \dfrac{\partial \delta_i(X_t)}{\partial X_t} < 0, \text{for } A > X_t > X_T > 0 \\ \dfrac{\partial \delta_i(X_t)}{\partial X_t} = 0, \text{for } A > X_t = X_T > 0 \\ \dfrac{\partial \delta_i(X_t)}{\partial X_t} > 0, \text{for } A > X_T > X_t > 0, \end{cases} \tag{5}$$

Where, X_T is a critical threshold value of the natural gas stock where the likelihood of losing a job in sector *i* starts to increase. We also make the following assumptions about the attachment rate,

$$\frac{\partial B_i(X_t)}{\partial X_t} = \beta_i' \Rightarrow \begin{cases} \dfrac{\partial B_i(X_t)}{\partial X_t} > 0, \text{for } A > X_t > X_T > 0 \\ \dfrac{\partial B_i(X_t)}{\partial X_t} = 0, \text{for } A > X_t = X_T > 0 \\ \dfrac{\partial B_i(X_t)}{\partial X_t} < 0, \text{for } A > X_T > X_t > 0, \end{cases} \tag{6}$$

Which implies that the likelihood of finding a job in sector *i* increases as natural gas is extracted, but only up to the threshold value of the natural gas stock. Once the threshold is reached, the likelihood of attachment decreases.

3. CHANGES IN STATIONARY EMPLOYMENT

Given (4), (5), and (6), it is straightforward to determine the potential effects of natural gas extraction/depletion on equilibrium employment in sector *i*. Imposing the typical stationary employment condition that $E_{it+1} = E_{it} = E_i \; \forall \; t$, yields the following stationary employment rate,

$$E_i = \frac{N_i \beta_i(X_t)}{\delta_i(X_t) + \beta_i(X_t) - \delta_i(X_t)\beta_i(X_t)} \tag{7}$$

To determine the net effect of resource extraction and depletion on employment in sector i, differentiate (7) with respect to X_t to find the following,

$$\frac{\partial E_i}{\partial X_t} = E_i' = \frac{N_i[\delta_i(X_t)\beta_i' - \delta_i'[\beta_i(X_t) - \beta_i(X_t)^2]]}{\delta_i(X_t) + \beta_i(X_t) - \delta_i(X_t)\beta_i(X_t)]^2} \tag{8}$$

By signing the numerator of expression (8), it is easy to see that the net effect on employment of resource extraction and depletion can be positive, negative, or zero depending on the relative changes in the separation and attachment rates as extraction increases (i.e. as the resource is depleted). Figure 1 illustrates a relatively simple way to view this relationship.

As seen in Figure 1, as extraction approaches the threshold level, employment in sector is increasing, and as extraction is

5 See Chapter 6 in Ljungqvist and Sargent (2004) for more on basic lake models of employment/unemployment.

pushed beyond the threshold level, employment in sector begins to decline.

The above analysis assumes that the inflection point and hence the threshold level of non-renewable reserves are the same across the separation and attachment rate functions, but it is possible that the inflection points occur at different threshold levels. The turning point of the stationary employment function will be determined by the net effects of attachment and separation. Suppose, as depicted below in Figure 2, the threshold value for the inflection point of the separation rate function is smaller than it is for the attachment rate. Over the range (X_T^δ, X_T^β) , employment could be increasing or decreasing. Although there is diminished hiring as a result of $\beta_i' < 0$, there is less separation as a result of $\delta_i' < 0$, and one effect could dominate the other. If instead the range were reversed to (X_T^δ, X_T^β) , then it would be the case that $\beta_i' < 0$ while $\delta_i' < 0$ with hiring gains and increased separation.

4. APPALACHIAN BASIN: HISTORICAL AND PROJECTED DEPLETION PATHS FOR COAL AND SHALE GAS

The large multi-state Appalachian coal basin region has been one of the world's largest historical sources of coal, and extraction of the resource has been underway for more than 200 years. As such, the pattern of coal employment and remaining recoverable reserves across US. states in the basin can be compared against the stylized predictions of this paper's model. Figures 3 and 4 contain indexes of coal mining employment by Appalachian basin state from 1969 to 2013. Coal mining employment data for 1969-2000 is from the bureau of economic analysis (BEA) data files (BEA, 2015), and the 2000 onward data is from the (BLS, 2015). Each of the seven states reach peak coal mining employment within the 5 years from 1976 to 1981. The declines in employment from peak have been substantial for each of the states. West Virginia and Alabama have had the smallest relative declines, but their current employment is only about 1-3rd of peak employment. The other states' current employment levels are only 1-5th or less of their peak employment levels.

Of course many factors beyond simply the remaining stock of recoverable reserves has impacted the employment patterns and the timing of peak employment across these states. These factors include the severity of the early 1980s recession in the US, the collapse of oil prices in 1984-85, and the passage of environmental regulations restricting sulphur emissions from coal-fired power plants. While these market forces compressed the time range for peak employment across the states, the depletion of these reserves had been ongoing for many decades and declining employment would have begun somewhat later even in the absence of these adverse Appalachian coal demand shocks. Relevant to the insights from our model, we next examine the remaining recoverable coal reserves at the time of peak employment by state shown in Table 1.

Figure 1: Relationship between employment and non-renewable resource depletion

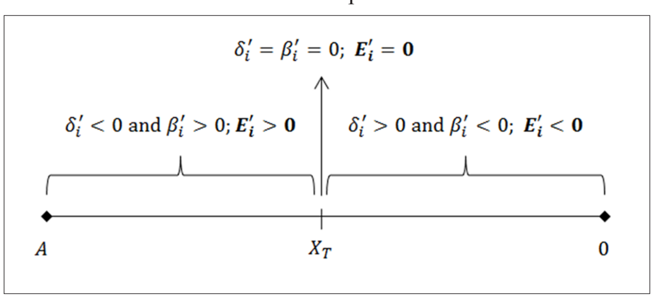

Figure 2: Peak employment and different threshold remaining reserve values

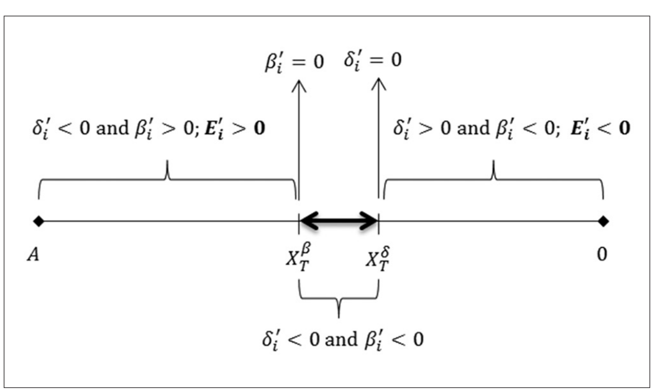

Figure 3: State coal mining employment indices (1969=100), North and Central Appalachia states

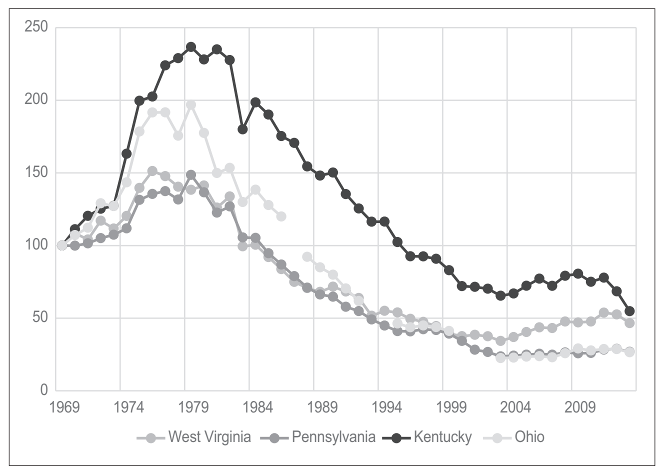

Figure 4: State coal mining employment indices (1969=100), Southern Appalachian states

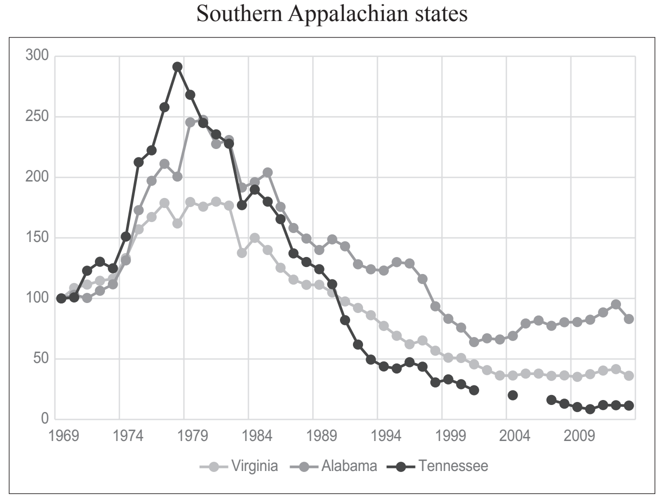

Table 1: Remaining recoverable appalachian coal reserves at peak employment

State	Peak employment year	Original reserves (billions tons)	Cumulative production through peak employment year	% original reserves remaining
Alabama	1980	4.6	1.33	71
Kentucky	1979	11.7	3.16	73
Ohio	1979	15.2	2.93	81
Pennsylvania	1979	22.6	9.83	57
Tennessee	1978	1.14	0.53	54
Virginia	1981	3.4	1.52	55
West Virginia	1976	30.6	8.54	72

The peak employment year data in Table 1 is as reported in Figures 3 and 4. The estimates for the original recoverable reserves are from Milicini and Dennen (2009), and the cumulative production through peak employment year estimates are from Milicini (1997). The estimated percentage of original reserves remaining relates to the range of and in Figure 2 or X_T in Figure 1. For Appalachian coal reserves, peak employment by state is associated with between one-quarter and one-half of the originally recoverable reserves having been extracted.

Unlike the coal reserves, extraction of the Marcellus formation shale gas is in its early years. Marcellus shale original recoverable reserves are estimated as 210 trillion cubic feet, which is the sum of: (1) Approximately 7 trillion cubic feet in production through 2013 from Pennsylvania and West Virginia Marcellus shale gas (Energy Information Administration [EIA], 2015a), (2) 62 trillion cubic feet of proved recoverable reserves (EIA, 2015b), and (3) 141 Trillion cubic feet of unproved technologically recoverable reserves (EIA, 2012). While it is impossible to know with any certainty the future extraction path for this resource, it is somewhat informative to consider when peak employment might occur under a variety of assumed threshold percentages of remaining recoverable reserves and average annual rates of extraction. Based on the remaining coal reserves at peak employment, Table 2 presents a few scenarios for prospective peak Marcellus Shale employment dates measured in years from 2013.

With these assumptions, if production is maintained at the 2013 level of 3600 billion cubic feet per year (BCF/year) and peak employment occurs once 80% of original recoverable reserves remain, then the peak employment date will be 11.67 years from 2013 or about 2025. If instead employment does not peak until 40% of original reserves remain while production remains at 3600 BCF/year, then the peak employment date will be 35 years or around 2048. While gas production from the Marcellus shale continues to rise, the explosive growth phase is likely over, suggesting that the assumed annual extraction rates that are 25% (4500 BCF/year) or 50% (5400 BCF/year) higher may be plausible upper bounds on production. If so, then peak employment would be 8-28 years beyond 2013 if X_T lies in the 40-80% range. Table 2 highlights the large uncertainty surrounding the employment path for Marcellus shale gas development, but it seems likely that the peak employment date is at least a decade into the future.

Table 2: Years from 2013 to reach prospective peak marcellus shale gas employment

Average annual production (bcf)	Remaining original reserves at peak employment (%)				
	80	70	60	50	40
2,700	15.56	23.33	31.11	38.89	46.67
3,600	11.67	17.50	23.33	29.17	35.00
4,500	9.33	14.00	18.67	23.33	28.00
5,400	7.78	11.67	15.56	19.44	23.33
6,300	6.67	10.00	13.33	16.67	20.00
7,200	5.83	8.75	11.67	14.58	17.50

5. CONCLUSION

The simple model presented above captures sector-specific employment gains and losses associated with the extraction or depletion of a non-renewable resource. Although the model was motivated with a discussion of and applied to coal production and shale gas extraction in the US, the model is applicable to the extraction of any non-renewable resource. Empirical deviations in shale gas employment gains (losses) stemming from resource extraction are easily explained by considering the rate of extraction and the remaining size of the resource stock as each relates to increased (decreased) labor demand. To a certain extent, a relatively large stock reduces the need to fire employees, for example, and also allows for an expansion in sector-specific employment from the existing unemployed pool. Then as the resource is depleted, however, the need for firms to maintain a relatively large workforce falls while there is a decreased need to hire workers from the unemployed pool. As noted above, these inflection points in attachment and separation can be different, thereby leading to increased uncertainty in both the time path of employment gains (losses) and the employment peak.

Although the primary theoretical results are driven purely by assumptions about the attachment and separation rates as each relates to the remaining stock of the resource, it is straightforward to consider complicated yet realistic extensions similar to the development of the basic Hotelling model. Additional caveats include, but are not limited to, the lack of ancillary employment gains (losses) in other sectors; extraction costs; the lack of labor force differentiation; the role of prices in determining the feasibility of extraction; and uncertainty about the threshold resource stock.

Using data on coal production and employment in the US as a guide, simple calculations based on the results of the theoretical model offer a range of years beyond 2013 when peak employment is expected in the Marcellus Shale. Based on an arguably strong assumption that employment depends wholly on the remaining resource stock, the results suggest that employment gains will perhaps continue for at least a decade.

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