Federal Regulations and U.S. Energy Sector Output

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Abstract

A large body of literature finds that the energy sector is important to economic growth and development. The production of energy has negative environmental impacts, however, which has resulted in the sector being highly regulated. While several studies examine the effect of particular regulations on the energy sector, in this study we use the recently developed measure of regulation called RegData to estimate the impact of federal regulations on the energy sector. We employ a panel ARDL model to find an inverted U-shaped relationship between federal regulations and U.S. energy sector output. Federal regulations appear to increase energy sector outputs at low levels and then decline as regulations accumulate.

Keywords: federal regulation, energy sector, panel ARDL, RegData

JEL codes: L51, Q48

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1. Introduction

In the United States, the Federal Register publishes, among other things, regulations. For example, the Federal Register contains federal agency rule and regulations, executive orders, and proclamations. The Code of Federal Registrar (CFR) contains the complete and official text of agency regulations organized into fifty titles covering broad areas of the economy such as the energy sector. These regulations are continuously updated and are rarely removed leading to an accumulation of regulations. The growth of regulations has led scholars to look at the impact of increasing federal regulations on factors such as economic growth (Dawson and Seater, 2013) and entrepreneurship (Goldschlag and Tabarrok, 2018). In this study, we focus on the impact that regulations have on output in the energy sector.

We focus on the energy sector for two reasons. First, the energy sector is an important input to the rest of the economy. To the extent that the accumulation of regulations in a sector are reducing industry output, that should be quantified. In this respect our study is similar to, but more narrowly focused than, Jorgenson and Wilcoxen (1990) who find that environmental regulations reduced the annual growth rate of the U.S. economy by 0.191% from 1973 to 1985. Second, a finding that energy-sector regulations lead to reduced industry output would be consistent with the public-interest theory of regulation (Posner, 1974). The public interest theory of regulation states that regulation is supplied by government in order to protect the public from "inefficiencies and inequities in the operation of the free market" (Posner, 1974: 336). From this perspective, regulations are intentionally designed to increase the cost of the producing energy that generates negative externalities. A reduction in output in this case is consistent with an improvement in economic efficiency. The public-interest theory is contrasted with the special-interest theory of regulation (Stigler, 1971; Peltzman, 1976), which states that special interests often distort regulations in order to positively affect industry. Croucher (2011), for example, argues that energy efficiency standards may be a form of regulatory capture that often require regulators to relinquish some control over price regulation, leading to more automatic and regular price changes without costly rate cases. A finding that energy regulations do not lower or actually increase industry output would be consistent with the special-interest theory of regulation.

In the literature on the effect of regulations on firms and the economy there are essentially two strains of research. The first group is highly aggregated, looking at the effect of regulations on the economy as a whole (Nicoletti and Scarpeta, 2003; Dawson and Seater, 2013). The second group focuses on the effect of specific regulations, such as the Clean Air Act (Greenstone, 2002; Geltman et al., 2016; Hancevic, 2016). Our study lies between these literatures in that we focus on one specific sector of the economy – the energy sector. While this prevents us from utilizing typical causal inference approaches to uncover the causality between regulatory policy and economic activity, it does allow us to capture the aggregate burden of regulation on the energy sector, unlike studies that examine specific policies. We are able to examine the cumulative regulations affecting the energy sector due to the recent creation of RegData, a database that quantifies federal regulations for various industries from 1997 to 2016 based on text analysis and machine learning (Al-Ubaydli and McLaughlin, 2014). Combined with industry-level data from the Bureau of Economic Analysis (BEA), we find that an inverted U-shaped relationship between industry-level regulations and industry output. We interpret this empirical finding to mean that the special-interest effect dominates at low levels of regulatory activity, but that the accumulation of regulations means that as the regulatory burden increases the overall effect is to decrease output.

We proceed as follows. Section 2 describes the data we use in detail, especially RegData, given its newness in the literature. Section 3 discusses our empirical approach, while Section 4 presents our results. Section 5 provides concluding remarks.

2. Data

We gather the data of industrial outputs, real compensation rates and federal restrictions of various energy related industries from 1997 to 2016. The energy related industries are defined based on the North American Industry Classification System (NAICS). NAICS is the standard used by federal statistical agencies in classifying business establishments for collecting, analyzing, and publishing statistical data related to the

U.S. economy. Both the time period covered and use of NAICS is dictated by the time period and structure of our measure of regulations, RegData. The industry outputs, the rate of labor compensation and federal restriction of various energy related industries are therefore gathered based on their NAICS industry codes. We describe in detail what it means to be an energy-related industry and our data on industry output and compensation before describing RegData.

2.1 Defining energy related industries

The North American Industry Classification System (NAICS) defines an industry to its broader sectoral classification. A sector is a collection of similar industries at various levels of aggregation. In this study, we define energy-related industries as Oil and Gas Extraction (NAICS 2111), Coal Mining (NAICS 2121), Support Activities for Mining (NAICS 2131), Electric Power Generation, Transmission and Distribution (NAICS 2211) and Natural Gas Distribution (NAICS 2212). The numbers in parentheses are each industry's four digit NAICS codes.

NAICS defines the mining, quarrying, and oil and gas extraction sector with two-digit code as 21. The Mining sector comprises establishments that extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. The term mining is used in the broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and flotation), and other preparation customarily performed at the mine site, or as a part of mining activity. This sector consists of sub-sectors which are defined by the following three-digit NAICS codes: Oil and Gas Extraction (NAICS 211); Mining except Oil and Gas (NAICS 212), and Support Activities for Mining (NAICS 213). Each three-digit NAICS coded industry may contain more sub-sectors which are labelled with four-digit NAICS code. The NAICS are hierarchical up to six-digit depth.

The Utilities sector comprises establishments engaged in the provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. Within this sector, the specific activities associated with the utility services provided vary by utility: electric power includes generation, transmission, and distribution; natural gas includes distribution; steam supply includes provision and/or distribution; water supply includes treatment and distribution; and sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage treatment facilities. The utilities sector (NAICS 22) consists of a single subsector, Utilities defined as NAICS 221. The subsector consists of these industry groups: Electric Power Generation, Transmission and Distribution (NAICS 2211); Natural Gas Distribution (NAICS 2212), and Water, Sewage and Other Systems (NAICS 2213).

2.2 Industry outputs

The U.S. Input-Output (I-O) Accounts, published by the Bureau of Economic Analysis (BEA), provide supply and use tables. The supply table delivers a detailed elaboration of the total domestic supply of goods and services from both domestic and foreign producers while the use table shows the use of supply across the U.S. economy. These tables provide a detailed "internal workings of the U.S. economy" in terms of the flows of goods and services purchased by each industry (inter-industry transaction), the incomes generated from production in each industry, and the dissemination of sales for each commodity (Young et al., 2015). The Bureau of Labor Statistics (BLS) manages the raw input-output data published by BEA. The BLS I-O matrices include the supply, use and final demand matrices of 205 different sectors from 1997 to 2016. Horowitz and Planting (2009) outline how to generate industry outputs, commodity outputs and final demand based on the supply and use tables provided by the BEA. Based on the approach of Horowitz and Planting (2009), we retrieved and managed the times-series data of industry outputs from 1997 to 2016 for our energy-related industries, measured are in millions of chain-weighted (2009) dollars.

2.3 Real compensation

The U.S. Bureau of Labor Statistics (BLS) website provides hierarchical legacy flat files which contains annual employment and average annual compensation for two-, three-, four-, five-, and six-digit level NAICS industries from 1990 to 2016. We obtained the number of employees and compensation (in millions of dollars) unit from 1997 to 2016 for our energy-related industries. Compensation was deflated using the personal consumption expenditure (PCE) deflator available from the Federal Reserve Bank of St. Louis. We define the real compensation rate as the ratio of deflated compensation to numbers employed by each energy-related industry.

2.4 *Federal regulations*

To quantify the extent of regulations on the energy sector we employ the Industry-Specific Regulatory Constraint Database (RegData) created by Al-Ubaydli and McLaughlin (2014). RegData quantifies federal regulations at the industry-level from 1997 to 2014 based on text analysis and machine learning. Their data has been subsequently updated through 2016, known as RegData 3.0 (McLaughlin and Sherouse, 2017). Recognizing that regulations place limits on the actions of individuals and organizations through language limiting what they can do, Al-Ubaydli and McLaughlin (2014) count the number of 'binding constraints words' in the CFR. Since regulators typically use a relatively standard suite of verbs and adjectives to limit activities or require actions, Al-Ubaydli and McLaughlin (2014) use five strings to quantify binding regulatory constraints: 'shall', 'must', 'may not', 'prohibited', and 'required'. Their use of text analysis and machine learning allows for the creation of an index.

RegData 3.0 quantifies federal regulations by industry and by regulatory agency for all federal regulations from 1997 to 2016 at the two-, three-, four-, five- and six-digit levels of NAICS. Although a relatively new index it has been used in a number of well-published papers (Chambers et al., 2017; Malone and Chambers, 2017; Goldschlag and Tabarrok, 2018; Bailey et al., 2018) as it is the first non-survey measure of regulation to go beyond a simple word or page count. We utilize their annual industry relevant restriction index, which is defined as the industry relevance of a CFR part multiplied by the number of restrictions in that part, summed across all parts of the CFR (McLaughlin and Sherouse, 2017).

2.5 *Trends and descriptive statistics*

Trend diagrams and basic descriptive statistics of the natural logarithm of industrial output ($\mathrm{IND_{it}}$), the real compensation rate ($\mathrm{RCR_{it}}$), and industry relevant restriction index ($\mathrm{IRR_{it}}$) are given in Figure 1 and Table 1. The top panel of Figure 1 shows that output in the oil and gas extraction sector has increased since 2005. The sectors other than oil and gas extraction have declined. The increase in the output of the oil and gas extraction sector can be attributed in part to the increase in shale gas production as the Energy Policy Act of 2005 exempted fluids used in hydraulic fracking from protections under the Clean Water Act and the

Safe Drinking Water Act.[1] The second panel of Figure 1 shows a positive trend in the real compensation rates for all sectors, with the oil and natural gas extraction relatively higher than the others. The third panel of Figure 1 shows that regulations have increased in all energy sectors since 1997, but with sharp increases in the last decade in Natural Gas Distribution and Electric Power Generation, Transmission, and Distribution. During this period a number of federal legislative actions were undertaken, namely, the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and the American Recovery and Reinvestment Act of 2009. These legislative actions targeted our future energy security through greater access of our domestic energy sources along with expanding alternative energy sources. In regards to electricity generation and transmission, the Energy Policy Act of 2005 increased electricity transmission with the authority of the Federal Energy Regulatory Commission to issue federal permits to expand transmission capacity, known as the National Interest Electric Transmission Corridor, primarily in the mid-Atlantic and southwest areas.

[Insert Table 1 here]

[Insert Figure 1 here]

3. Methodology and Results

In this study our goal is to analyze the impact of federal regulations on outputs related to the energy industry ($\mathrm{IND_{it}}$) with the industry relevant restriction index ($\mathrm{IRR_{it}}$) as our measure of federal regulations. Regulations, if enacted in the public interest, should act as a cost of doing business and thus lead to reduced industry output. If enacted for special interests, regulations can act like a barrier to entry and therefore lead to a positive effect on output for existing firms. It is possible, however, that even if individual regulations are not designed in the public interest but to protect special interests, overall regulations are reducing output. This is analogous to an income tax increase designed to pay for road construction having either a positive

[1] In addition, exemptions from the Clean Air Act and the Comprehensive Environmental Response, Compensation, and Liability Act were also a result of the Energy Policy Act of 2005.

or negative cost-benefit analysis depending on the current level of taxation. We therefore hypothesize the following relationship:

$$\mathrm{IND}_{it} = \alpha_0 + \beta_1 \mathrm{RCR}_{it} + \beta_2 \mathrm{IRR}_{it} + \beta_3 \mathrm{IRR}_{it}^2 + \varepsilon_{it} \qquad (1)$$

By setting first order derivatives to zero, i.e. $\frac{\partial \mathrm{IND}_{it}}{\partial \mathrm{IRR}_{it}} = \beta_2 + 2\beta_3 \mathrm{IRR}_{it} = 0$, and solving for the federal restriction yields $\mathrm{IRR}_{it}^* = \frac{-\beta_2}{2\beta_3}$. The IRR_{it}^* is the value of the federal restriction associated with the turning point value of industry output. A negative second order condition verifies industry output yields an inverted U-shaped relationship, where industry output increases with low levels of federal regulations but declines as regulations accumulate.

Though traditional panel methods (fixed effects, random effects, etc.) are suitable for large numbers of observations, N, compared to observations across time, T, such methods come into question when T > N. In such cases, traditional panel methods may produce spurious results as the temporal properties of variables may exhibit nonstationary properties. Given the regression of non-stationary variables produces spurious results, Baltagi (2008) offers two options to address this issue. The first is heterogeneous regressions for each individual to avoid the homogeneity of coefficients obtained with a single regression. The second is the application of time series processes to panels to address nonstationarity and cointegration among the variables.

Several techniques exist to estimate the order of integration of variables in the panel data.[2] The Levin et al. (2002, hereafter LLC) panel unit root test is an extension of the augmented Dickey-Fuller (ADF) test using pooled data and given as:

$$\Delta y_{it} = \phi_{it}\psi_i + \rho y_{it-1} + \sum_{j=1}^{n_j} \varphi_{ij}\, \Delta y_{it-j} + \upsilon_{it} \qquad (2)$$

[2] We only employed first general panel unit root tests for several reasons: (1) these tests have power even with the smaller sample observation across time; (2) the use of first generation unit root methodology for identifying the order of integration of variables is not relevant in the panel ARDL approaches as long as the respective variables are I(1) and I(1) (Pesaran and Smith, 1995 and Pesaran et al. 1999); and (3) the pooled mean group technique considers the homogeneity among the cross-sections, therefore second generation unit root tests may not offer any significant advantages (Al Mamun et al. 2014).

where ϕ_{it} includes individual deterministic components (such as fixed effect, trend, or a mixture of fixed effects and trend); ρ is the homogenous autoregressive coefficient across panels; υ_{it} is assumed to be independently, identically distributed and stationary residuals with zero mean and variance σ_{υ}^{2}; and n represents the lag order. The null hypothesis is that all the variables in the panel have a unit root, $H_0: \rho = 1$, against the alternative that all the variables are stationary, $H_1: \rho < 1$.

Given the LLC panel unit root test can suffer loss of power due to the homogenous autoregressive coefficient across panels (Breitung, 2000). Im et al. (2003, hereafter IPS) allow for heterogeneity in the autoregressive coefficients for all panel units and is obtained as an average of individual ADF statistics. The IPS unit root test is given as:

$$\Delta y_{it} = \phi_{it}\psi_i + \rho_i y_{it-1} + \sum_{j=1}^{n_j} \varphi_{ij}\Delta y_{it-j} + \upsilon_{it} \qquad (3)$$

The null hypothesis of the IPS test is that all variables in the panel have a unit root, $H_o: \rho_i = 1$, against the alternative hypothesis that all the variables are stationary, $H_o: \rho_i < 1$. Note that the larger difference between the size of T and N or the inclusion of an individual deterministic trend can generate biased LLC and IPS tests. Unlike averaging individual test statistics as suggested by IPS, Choi (2001) employs a nonparametric panel unit root test that combine the *p* -value from individual unit root tests in using the Fisher-ADF and Fisher-PP tests.

[Insert Table 2 here]

Table 2 reports the results of the LLC, IPS, along with the Fisher-ADF and Fisher-PP unit root tests. Across the panel unit root tests, the log of industry output, IND, appears integrated of order one, I(1), while the log of the real compensation rate, RCR, is integrated of order one based on the LLC results with the remaining panel unit root tests indicating integrated of order zero, I(0). The log of the industry relevant restriction index, IRR, is integrated of order zero, I(0). Given the orders of integration vary across the variables, we employ the Pesaran and Shin (1999) and Pesaran et al. (1999) panel ARDL methodology to examine the long-run relationship among the variables specified in Equation (1). Pesaran and Shin (1999) and Pesaran et al. (1999) demonstrate that the ARDL approach is not dependent on the endogeneity of the regressors or whether the underlying variables follow a I(0) or I(1) process.

The panel ARDL model allows us to estimate an empirical model that encompasses both the short-run and long-run effects. The ARDL model is given as:

$$\Delta y_{it} = \theta_i ECT_{it-1} + \sum_{j=0}^{q-1} \Delta X_{it-j}\, \beta_{ij} + \sum_{j=1}^{p-1} \lambda_{ij}\, \Delta y_{it-j} + \mu_{it} \tag{3}$$

where y_{it} is the dependent variable defined as the log of industrial outputs of energy related sectors; X_{it-j} is the regressors set; $ECT_{it-1} = y_{it-1} - X_{it-1}\theta$ is error correction term; and μ_{it} is the uncorrelated idiosyncratic errors.[3] Two sets of regressors are contained in X_{it-j} include the log of real compensation rates and log of the industry relevant restriction index along with the squared term of the log of the industry relevant restriction index. The speed of adjustment towards long-run equilibrium is denoted by the coefficient estimate of θ_i, which is expected to be negative. Furthermore, a negative and statistically significant coefficient of the error-correction term also confirms the existence of cointegration. The short-run dynamics are in turn captured by the coefficient estimates of β_{ij} and λ_{ij}.

The panel ARDL model can be estimated using two different estimators: the Mean Group (MG) estimator introduced by Pesaran and Smith (1995) and the Pooled Mean Group (PMG) estimator. The MG approach estimates a separate ARDL model for each group and averages the respective coefficients. Alternatively, the PMG estimator restricts the long-run parameters to be identical over the cross-section units but allows the intercepts, short-run coefficients, speed of adjustment, and error variances to differ across groups for the cross-section units.

[Insert Table 3 here]

We use the PMG version of the panel ARDL model with the results shown in Table 3. The error correction model associated with Equation (1) reveals the error correction term is negative and statistically

[3] The error correcting term is the residuals when y_{it} is regressed on X_{it}.

significant at the 5% level. The statistical significance of the error correction term confirms the presence of a long-run equilibrium relationship between the log of energy sector outputs to the log of real compensation rates and log of industry relevant restriction along with the square of the log of industry relevant restrictions. The speed of adjustment toward long-run equilibrium is roughly 14.1% per year. In terms of the short-run estimates, only the real compensation rate is statistically significant at the 10 % level. The short-run impact of federal restrictions are statistically insignificant in the short-run, although the signs are consistent with an inverted U-shape relationship.

With respect to the long-run estimates, both industry relevant restrictions and the real compensation rate are statistically significant at the 5% level. Specifically, there appears to be a quadratic relationship between industry relevant restrictions and energy sector output. The results are consistent with federal regulations acting initially acting as a barrier to entry at lower levels leading to higher output, but eventually reducing output when the amount of restrictions in an industry accumulate. A 1% increase in the log of industry relevant restrictions increases industry output by 16.735%. The square of the log of industry relevant restriction index is negative and statistically significant. The coefficient of -0.851 on the square term implies that industry-relevant restrictions increases industry output until the log of the industry relevant restriction index reaches 9.833. Electric Power Generation, Transmission, and Distribution sector is currently above that range with Coal Mining close behind.

4. Concluding Remarks

We find an inverted U-shaped relationship between federal regulations and industry output in the energy sector. This finding is consistent with regulations acting as a barrier to entry at low levels, but in the long-run the accumulation of regulations leads to reduced output. While our approach cannot provide causal evidence of the special-interest view of regulation, the results are not at all consistent with the public interest view of regulation. The measure of federal regulations we employ is industry relevant restrictions from Al-Ubaydli and McLaughlin (2017). Our empirical results suggest that federal regulations turn from having a positive impact on industry output to negative when the industry relevant restriction index reaches 9.833.

Our study contributes to the literature in at least three ways. First, most studies of regulation on the energy sector are based on micro-level studies. Ours is the first, to our knowledge, to examine at the aggregate level the effect of regulations on the energy sector. Second, our study tests whether regulations in the energy sector are consistent with the public interest or special interest view of regulation. While we can only say our results are consistent with the special interest view of regulation, we can rule out the public interest view of regulation as regulations on the energy sector are positively associated with industry output for most of the output range, only turning negative at very high levels. Third, our empirical estimates show that the Electric Power Generation, Transmission, and Distribution energy sector is at the point where accumulated regulations are leading to lower industry output.

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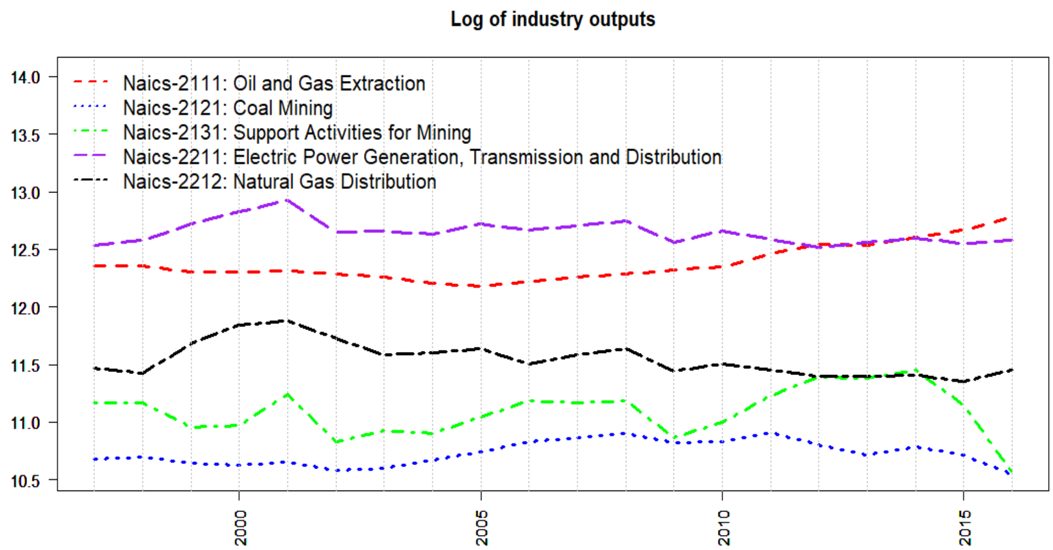
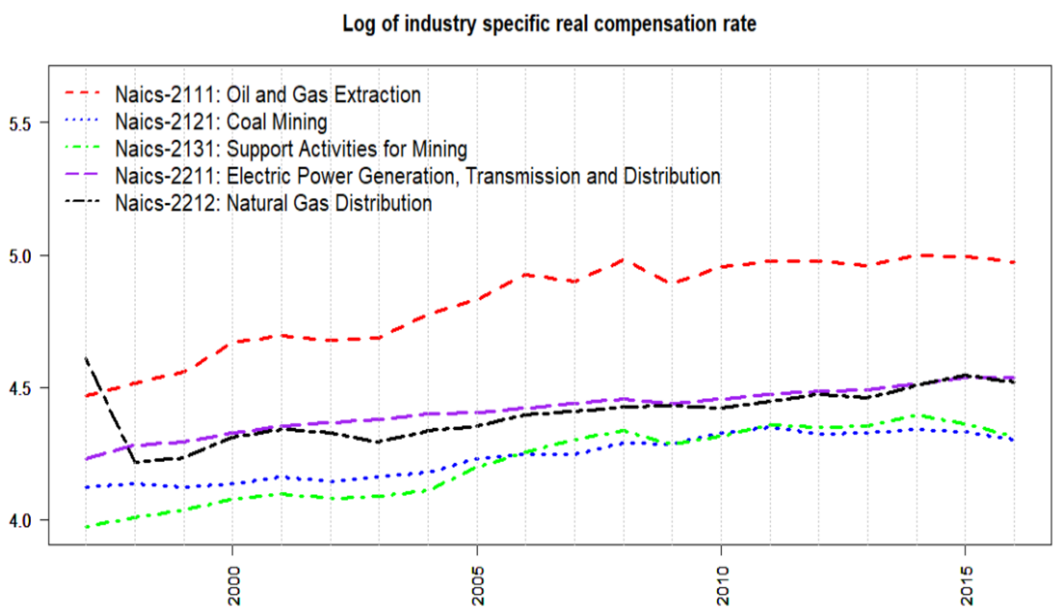
Figure 1. Trend Diagrams





**Figrue 1. Trend Diagrams
(continued)**

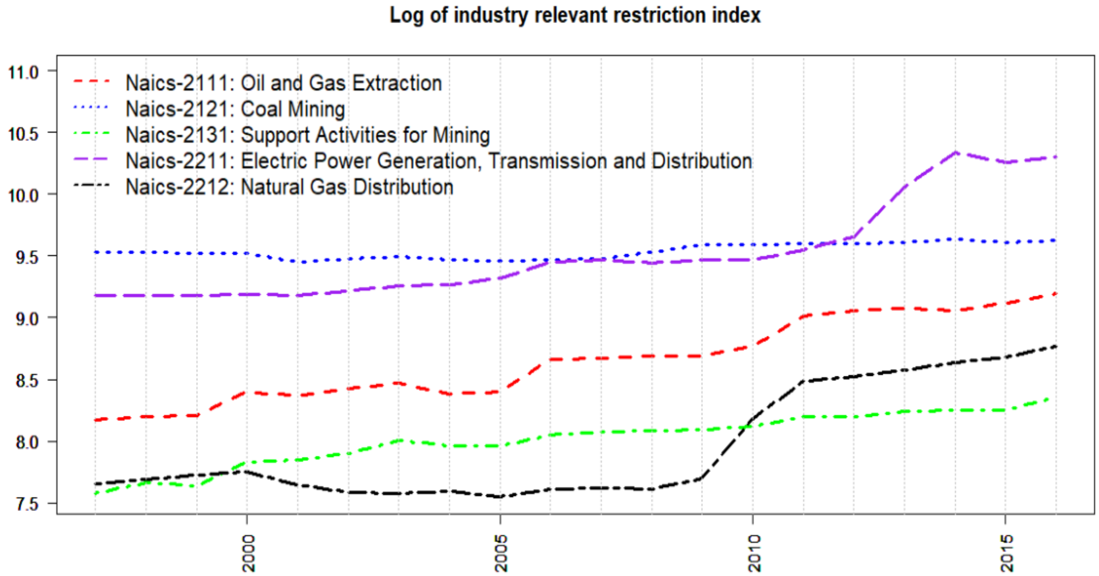


Table 1. Descriptive Statistics

Descriptive Statistics	Mean	Median	Max	Min	SD	JB
IND						
Oil and Gas Extraction	12.38	12.32	12.78	12.18	0.16	3.47 (0.18)
Coal Mining	10.73	10.72	10.91	10.55	0.11	1.00 (0.61)
Support Activities for Mining	11.09	11.16	11.46	10.57	0.22	0.57 (0.75)
Electric Power Generation, Transmission and Distribution	12.65	12.64	12.93	12.52	0.10	4.17 (0.12)
Natural Gas Distribution	11.55	11.51	11.88	11.35	0.15	2.03 (0.36)
RCR						
Oil and Gas Extraction	4.82	4.90	5.00	4.47	0.18	2.24 (0.33)
Coal Mining	4.24	4.25	4.35	4.12	0.08	2.22 (0.33)
Support Activities for Mining	4.21	4.27	4.40	3.97	0.14	2.13 (0.34)
Electric Power Generation, Transmission and Distribution	4.41	4.43	4.53	4.23	0.09	1.00 (0.61)
Natural Gas Distribution	4.40	4.41	4.61	4.22	0.10	0.24 (0.89)
IRR						
Oil and Gas Extraction	8.65	8.66	9.20	8.17	0.34	1.56 (0.46)
Coal Mining	9.54	9.53	9.63	9.45	0.06	1.85 (0.40)
Support Activities for Mining	8.01	8.07	8.36	7.57	0.22	1.25 (0.54)
Electric Power Generation, Transmission and Distribution	9.52	9.44	10.33	9.18	0.40	4.31 (0.12)
Natural Gas Distribution	7.96	7.69	8.77	7.55	0.46	3.15 (0.21)

Notes: All variables are in natural logarithms. SD is the standard deviation. JB represents the Jarque-Bera test for normality with probability values in parentheses.

Table 2. Panel Unit Root Tests

Variables	LLC	IPS	Fisher-ADF	Fisher-PP
IND	1.46 (0.93)	0.69 (0.76)	8.65 (0.57)	5.67 (0.84)
ΔIND	-4.71 (0.00)[a]	-3.18 (0.00)[a]	28.78 (0.00)[a]	32.49 (0.00)[a]
RCR	-0.95 (0.17)	-1.88 (0.03)[b]	28.50 (0.00)[a]	26.38 (0.00)[a]
ΔRCR	-7.44 (0.00)[a]	-----	-----	-----
IRR	-4.86 (0.00)[a]	-2.94 (0.00)[a]	35.37 (0.00)[a]	37.80 (0.00)[a]
ΔIRR	-----	-----	-----	-----

Notes: Unit root tests include both an intercept and trend. Probability values are in parentheses with significance levels: a(1%) and b(5%). Null hypothesis is a unit root. Lag length determined by minimizing Akaike information criterion (AIC). Δ is the first difference operator.

Table 3. Panel ARDL Results

Pooled Mean Group ARDL Model:
Dependent Variable: ΔIND

<u>Short-Run Estimates:</u>	
Constant	-8.606 (0.04)^{b}
ECT	-0.141 (0.04)^{b}
ΔRCR	1.725 (0.06)^{c}
ΔIRR	0.614 (0.90)
ΔIRR^2	-0.077 (0.79)
<u>Long-Run Estimates:</u>	
RCR	-1.838 (0.04)^{b}
IRR	16.735 (0.02)^{b}
IRR^2	-0.851 (0.02)^{b}

Notes: the Model is an ARDL (1,1,1,1). Pesaran cross-sectional dependence test (normal) under the null hypothesis of cross-sectional independence is 0.0402 with a probability value of 0.97, failing to reject the null hypothesis of cross-sectional independence. Probability values are in parentheses. Significance levels: b (5%) and c (10%).