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# Environmental Regulation and Interest Group Pressure on Petroleum Refinery Capacity Growth in the United States: A Regional Analysis

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**ABSTRACT**

Between 1986 and 2006 U. S. refinery capacity increased by twelve percent. Over the same time period, U.S. demand for refined petroleum products increased by 29 percent. Many have suggested that this lack of investment, and thus higher petroleum product prices, can be attributed to increased environmental regulation and increased influence from environmental pressure groups. This paper investigates empirically this potential influence on investment in refinery capacity additions/subtractions between 1988 and 2006. While there appears to be some evidence to support the notion that the environmental influence has depressed such investment, this impact appears to be relatively small in magnitude.

Subject Category: Energy Economics

Keywords: interest groups, environmental regulation, refinery capacity

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## 1. INTRODUCTION

The increase in gasoline and other energy product prices since 2000, both in the United States and in rest of the world, is well-documented. Indeed, according to the US Department of Energy's Energy Information Administration, between 2000 and 2007, the average retail price paid for unleaded gasoline has increased over 55 percent on an inflation adjusted basis.[1] The hypotheses advanced for this dramatic increase are many and varied; from increased world demand for crude oil, particularly in China and India, to natural disasters such as hurricanes that can disrupt deliveries and damage production capacity, to the dramatic reduction in the value of the dollar.

In addition, concerns over domestic refinery capacity have also received attention. While it is frequently reported that since 1976 no new refineries have been constructed in the United States, it is less frequently noted that the number of refineries has decreased. According to the US Department of Energy, from 1986 to 2006, the number of operable refineries fell from 216 to 149. Over the same time period, US demand for petroleum products increased by 29 percent. While there have been increases to refinery capacity of 12 percent between 1986 and 2006, it seems clear that domestic capacity has not kept pace with demand. Indeed, according to a recent Washington Post article, Senator James Inhofe stated that "…Americans are paying more at the pump because we do not have the domestic capacity to refine the fuels consumers demand."[2] This article goes on to say that tight supply is pressuring wholesale petroleum product prices upwards and that a spate of mergers over the last 10-to-15 years have resulted in limited interest in creating new refining capacity.

Moreover, Dahl et al. (2007) suggest that environmental regulations have impeded the construction of additional refineries, due to an extensive environmental permitting process that tends to deter such investment. Also, broader environmental concerns have been cited as preventing the re-opening of a refinery in Santa Fe, New Mexico.[3]

This paper empirically investigates the impact of environmental regulatory enforcement and environmental pressure groups on the US petroleum industry's capital investments in refinery capacity additions/subtractions, during the period from 1988 to 2006.

The literature linking environmental regulation to capital investment decisions is limited and inconsistent. Gray (1997), for instance, found that states with more stringent environmental regulations and more aggressive environmental enforcement practices have fewer manufacturing plants. The implication, then, is that industry is hesitant to invest new capital in areas with tougher regulations and enforcement. This would then imply that additional capital expenditures would occur in areas with more lax environmental regulation and enforcement. By contrast, in a study specific to the US oil refining industry, Berman and Bui (2001)

[1] This data is available at the US Department of Energy's web pages: http://www.eia.doe.gov/.
[2] See www.washingtonpost.com/wpdyn/content/article/2007/06/17/AR2007061700230.html?tid=informbox retrieved May 30, 2008.
[3] See http://www.econbrowser.com/archives/2005/09/the_question_ab.html, retrieved May 31, 2008.

found higher refinery productivity was observed in regions with more stringent environmental regulation, suggesting that tougher regulations prompt increased investment in newer, cleaner, and perhaps more efficient, refinery capital. Hence, one might expect additional capital expenditures in areas with tougher regulations and enforcement. However, the relationship between refinery productivity and refinery capacity is unclear.

With respect to broader environmental concerns and capital investment, the literature appears to be more limited. These broader concerns are largely manifested through interest group pressures designed largely to influence policy. There are a number of studies demonstrating that increased membership in environmental interest groups (the most common empirical proxy for the strength and efficacy of such groups to impact policy) have influenced the structure and enforcement of environmental regulations. Decker (2003), for instance, found that increased state-level Sierra Club membership delayed environmental permit issuance by states for new construction and modification of polluting manufacturing facilities.

Also, there is literature that has demonstrated that interest group pressure has, either directly or indirectly, impacted firm pollution releases. Maxwell et al. (2000) found some evidence that membership in environmental interest groups resulted in reductions in state-wide toxic chemical releases by industries between 1988 and 1992.[4] However the pollution reductions found by Maxwell et al. (2000) could have been the result of expenditures on clean technologies, or output reductions. Hence, the link between interest group influence and industry capacity is still an open question.

The specific link between interest groups and capital investment has been addressed in previous studies, though at a much broader level than what our research covers. Olson (1982) argued that in more stable economies, special interest groups tend to develop, grow and, through intense lobbying and other rent-seeking activities, succeed in re-distributing society's resources in ways favorable to their stated objectives. Using country-level data, Knack and Keefer (1997) and Coates and Heckelman (2003) empirically examined the relationship between both economic growth and capital investment and interest group activity. They found, *ceteris paribus*, that increased interest group activity does indeed act as a drag on broad economic growth as well as investment. The industry specific sources of this drag, however, were not addressed in this literature.

The principal question is, then, to what degree does environmental group membership impact oil refinery capacity growth. While our results provide some evidence to support the notion that the environmental movement has depressed such capacity, the impact appears to be relatively small in magnitude. The remainder of this paper is organized as follows: In section 2, the basic empirical model, empirical hypotheses, and data sources are discussed. In section 3, a few estimation issues are addressed. The econometric results are presented in section 4, and section 5 concludes.

[4] Most of these toxic chemicals were not subject to any specific environmental regulation so such reductions are often considered voluntary pollution reductions. Hence, the impact of environmental groups of industry behaviour is interpreted as largely separate from formal regulatory pressure.

## 2. MODEL AND DATA

Following Chen (2003), in this paper we use as a proxy for oil refinery capital investment, the year over year growth (decline) in oil refinery operable capacity, $\ln(CAP_t/CAP_{t-1})$, calculated from capacity data reported by the US Department of Energy's Energy Information Administration (EIA).[5] In addition to the above mentioned environmental variables (formally defined below), following the existing investment literature, we include additional independent variables in our investment equation. While we present the more detailed specification in the next section, the general model statement is:

$$\begin{aligned}\ln(CAP_t / CAP_{t-1}) = f\,(&UTIL, MARGIN, NUM, CAP / NUM, \\ &TRI / CAP, MEMBERSHIP)\end{aligned} \tag{1}$$

Our data, discussed further below, is regional in nature, covering the five PADD regions as delineated by the EIA, over the period 1988 to 2006.[6] As advanced by Eisner (1960, 1978) and Diamond (1962), we include measures of demand and profitability as proxied by two variables, UTIL and MARGIN. UTIL comes from the EIA and measures the percent of operable capacity being employed. It is calculated by dividing the amount of crude and other unfinished oils input into refinery units by the operable refining capacity. Utilization rates reflect various factors, such as the relative strength of market demand, routine maintenance on the industrial system, and the amount of entry and capacity expansion that has occurred over time. We include UTIL largely as a proxy for market demand. As Eisner (1978) indicates, if production constraints are sufficiently tight for a period of time due to elevated market demand, oil companies may be prompted to increase productivity capacity. Hence, we would expect higher capacity utilization rates to increase capacity growth.

MARGIN is a variable included to capture industry profitability. We calculated this series, again using price data from the EIA, as the difference between the wholesale price of gasoline minus the composite refiners' acquisition cost of crude, adjusted for inflation using the Bureau of Labor Statistics' all urban consumer price index.[7] This price-margin measure proxies for refinery profitability. As hypothesized by Eisner (1978), sustained price margins signal the return on investment, thus prompting capacity adjustments.

In addition, we include a measure of average refinery capacity by region, CAP/NUM, where NUM is the number of operating refineries in a given region in a given year. As suggested by Jovanovic (1982) and Chen (2003), the "size" effect on capacity additions largely reflects productive efficiency. Larger facilities may capture scale economies and thus are more efficient in production. Hence, the need

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[5] Operable capacity, measured in barrels per day, is the amount of capacity that, at the beginning of the period, is either in operation or not in operation but will be in operation within 30 to 90 days.

[6] PADDs (or Petroleum Administration for Defense District) regions were originally set up during World War II to facilitate internal oil allocation and distribution. The delineations are listed in Table A1 in Appendix A of this paper.

[7] This inflation measure was obtained on line at http://www.bls.gov/cpi/home.htm, on May 14th, 2008.

to expand capacity, *ceteris paribus*, would decrease with average refinery size. Therefore, we would expect less growth in capacity in those regions with generally larger facilities. We also include NUM as a regressor as well, hypothesizing that more refineries in a region will likely hinder additional capital investment. From a company perspective, if managers have multiple refineries in a region, they may choose to shift production between units to meet demand rather than build new capacity. Also, as the number of refineries in a region increases, merger activity is more likely to result in the reduction of capacity. In a region with more refineries, regulators would be less likely to require the divestment of refineries as a merger condition, and the newly merged firm would be more likely to shut down refineries. Finally, aspects of federal government energy policies such as the mandatory oil import quotas which were enforced from 1959 through 1973 and crude oil price controls which existed from 1971 through the end of 1980, effectively subsidized small and independent refineries and taxed large refineries and refineries owned by vertically integrated oil companies. The end of these subsidies and taxes undermined the economic viability of many small refineries.[8] Other factors constant, the resulting shutdowns would have had a larger impact on capacity in regions with a larger number of refineries.[9]

Empirical implantation of the environmental variables discussed above is accomplished as follows. To capture regulatory pressure, we collected data on toxic chemical releases by the petroleum refining industry, TRI, by PADD region. These data represent self-reported pollutant releases of a large set of toxic chemicals into all environmental media (air, water, underground injection) as required by the Emergency Planning and Community Right-to-Know Act (EPCRA), enacted in 1986.[10] We use this as a proxy for environmental regulation and enforcement since direct measures of regulatory enforcement, such as inspections and enforcement actions, are difficult to obtain over time by state and industry. However, recent published work has demonstrated a significant link between environmental enforcement behaviour undertaken by states and TRI chemical releases. For instance, Decker (2005, 2006) finds that state-conducted inspections for environmental compliance are positively related to TRI releases per unit of output

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[8] For additional historical background on these issues, see Bohi and Russel (1978), Mitchell (1978), and Vieter (1984).

[9] There may be a competitive perspective to consider here as well. A higher number of refineries in a region may represent little room for additional supply, again suggesting slower capacity additions.

[10] EPCRA was enacted as a regulatory response to political pressure brought to bear on US lawmakers in response to several environmental disasters that occurred in the late 1970s and early 1980s. The primary purpose of EPCRA is to inform communities and citizens of chemical hazards in their local areas. Sections 311 and 312 of EPCRA require businesses to report to state and local governments the locations and quantities of chemicals both stored on-site and transferred off-site in order to help communities prepare to respond to chemical spills and similar emergencies should they occur. EPCRA Section 313 requires both the EPA and the states to annually collect data on releases and transfers of toxic chemicals from industrial facilities, and make the data available to the public. This dataset is referred to as Toxics Release Inventory (TRI). Since 1987, the EPA has annually compiled this TRI data and has made it available through several data access tools (see http://www.epa.gov/triexplorer/chemical.htm). Currently, there are some 650 chemicals whose releases are required to be reported. However, since chemicals are added (listed) and removed (de-listed), and since our analysis has a time-series component to it, we collected data on a set of chemicals consistently reported on an annual basis since 1988. See the above web page for details on these chemicals.

over a large set of manufacturing industries, including petroleum refining. With respect to our analysis then, we would expect more inspections in those regions with higher TRI per unit capacity (TRI/CAP). Hence, if, as suggested above, regulatory pressure hinders investment in new refinery capacity, TRI/CAP should have a negative impact on capacity.

Finally, to investigate the impact that environmental pressure groups have on capacity additions, we collected data on Sierra Club membership (MEMBERSHIP) over time by state.[11] Again, if environmental pressure groups adversely impact refinery capacity expansion, we would expect to observe a negative coefficient for this variable.[12]

As indicated above, our dataset covers five PADD regions from 1988 through 2006. There are some clear limitations to such regional aggregation. Some variation that may be evident in a more geographically delineated dataset is clearly lost. Such aggregation may obscure the impact on capital decision making of firm and plant-level characteristics since all refineries in a region are treated as similar to one another, even though there may be specific characteristics such as age, technology, and management structure, that might influence capital investment decisions. That said, the use of PADD data facilitates the analysis. First, the data is readily available from the EIA and is relatively consistent over time (unlike more localized data where significant data disclosure issues arise and vary from year to year). Second, environmental regulation and enforcement is designed to target polluters in general, rather than specific companies.

**Table 1: Summary Statistics**

| | PADD 1 | | PADD 2 | | PADD 3 | | PADD 4 | | PADD 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | mean | st. dev. | mean | st. dev. | mean | st. dev. | mean | st. dev. | mean | st. dev. |
| CAP[a] | 1,602.9 | 105.7 | 3,453.8 | 115.9 | 7,416.2 | 435.5 | 544.6 | 29.2 | 3,042.1 | 112.3 |
| UTIL[a] | 88.74 | 3.58 | 93.57 | 2.85 | 90.87 | 4.67 | 90.45 | 4.25 | 89.18 | 1.97 |
| MARGIN[a] | 17.07 | 3.28 | 14.39 | 3.05 | 11.82 | 3.28 | 17.02 | 2.58 | 20.03 | 4.13 |
| NUM[a] | 18.68 | 3.25 | 32.00 | 5.67 | 63.16 | 7.85 | 16.37 | 1.16 | 42.32 | 5.04 |
| CAP/NUM[a] | 88.85 | 19.14 | 111.56 | 21.81 | 119.56 | 19.52 | 33.41 | 2.67 | 72.96 | 10.03 |
| TRI/CAP[b] | 2.76 | 1.04 | 2.81 | 1.59 | 3.54 | 1.20 | 2.98 | 2.11 | 1.28 | 0.38 |
| MEMBERSHIP[c] | 205.82 | 38.46 | 118.35 | 22.97 | 36.56 | 4.80 | 24.87 | 6.33 | 240.13 | 25.02 |

[a]US Department of Energy, Energy Information Administration (www.eia.doe.gov)
[b]US Environmental Protection Agency (www.epa.gov), 1,000 lbs. per unit capacity
[c]Sierra Club, 1,000s

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11 The authors are grateful to Ms. Camellia Watkins of the Sierra Club for graciously supplying this data. While it would be beneficial to include other environmental group membership data in this measure, we encountered substantial difficulty in obtaining such data by state over time from other groups. That said, the Sierra Club is one of the largest environmental interest groups in the United States. It is thus reasonable to assume that membership in this organization represents a significant degree of environmental activism in a given location.

12 Clearly, a major concern is the degree to which environmental regulatory enforcement (proxied by TRI/CAP) and MEMBERSHIP are potentially related. Indeed, one might be concerned with either multicollinearity (i.e. the degree to which TRI/CAP and MEMBERSHIP are correlated), or endogeneity (i.e. the degree to which regulatory enforcement may be influenced by environmental pressure groups). While these are legitimate concerns, as it turns out, there appears to be little evidence of either collinearity or endogeneity given our specific econometric specification. We address both of these issues in detail below.

Moreover, the petroleum refining industry has historically been a EPA-designated "priority industry", whereby particular attention is paid to polluting activities in this sector. This targeting again suggests a broader analysis may be reasonable. Finally, environmental interest groups, like the Sierra Club, are likely to cast a large net in terms of the pressure it places on polluters to control pollutant releases and adopt environmentally sustainable practices. Hence, refinery operations within a particular region will likely be influenced in similar ways by environmental pressure groups. For these reasons, we believe the regional analysis provided here does offer some credible insight in refinery investment behaviour as it relates to environmental regulation and influence.[13] Summary statistics by PADD are reported in Table 1.

## 3. Econometric Issues

Before defining the specific econometric model, a few statistical issues need to be addressed. First, it is worth investigating whether or not the independent variables are highly correlated, suggesting possible multi-collinearity. For instance, it is possible that there is a correlation between price-cost margins and capacity utilization in that greater potential profit might stimulate utilization rates. This could result in an upward bias in the standard errors of our estimated coefficients. Table 2 shows the correlation matrix between the independent variables in the model.[14]

**Table 2: Correlation Matrix**

| | NUM | CAP/NUM | UTIL | MARGIN | TRI/CAP | MEMBERSHIP/ MAN |
|---|---|---|---|---|---|---|
| NUM | 1.00 | 0.24 | -0.07 | -0.35 | -0.24 | 0.21 |
| CAP/NUM | | 1.00 | 0.32 | -0.31 | -0.21 | -0.15 |
| UTIL | | | 1.00 | -0.31 | -0.13 | -0.38 |
| MARGIN | | | | 1.00 | **0.68** | -0.31 |
| TRI/CAP | | | | | 1.00 | **-0.55** |
| MEMBERSHIP/MAN | | | | | | 1.00 |

With a correlation of -0.31, the results suggest relatively little collinearity between MARGIN and UTIL. However, with a correlation coefficient of 0.68, the data does suggest some statistical correlation between TRI/CAP and MARGIN. Moreover, there may be a potential collinear relationship between TRI/CAP and MEMBERSHIP, where the correlation coefficient is -0.55 percent. These potential issues are addressed below.

This correlation between TRI/CAP and MEMBERSHIP also suggests a second potential issue. It is possible that TRI/CAP, our environmental regulatory enforcement variable, is endogenous with respect to MEMBERSHIP. It is reasonable to suspect that environmental interest groups could exert influence over

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[13] That said, we did attempt to construct a state-level dataset. However, again, constructing a consistent refinery capacity dataset over time proved quite difficult.

[14] Note that the Sierra Club membership variable, MEMBERSHIP, is divided by the total number of manufacturing jobs in each PADD (the manufacturing employment data (MAN) came from the US Bureau of Economic Analysis' (BEA) Regional Economic Information Service (RIES), which can be found online at http://www.bea.gov/regional/spi/). The data for this study was retrieved on May 1, 2008. We address below why we normalize MEMBERSHIP by MAN, however, similar results are obtained when we normalize by total population as well.

environmental regulation and enforcement. Hence, increased Sierra Club membership could subsequently induce increased regulatory scrutiny and thus, perhaps lower pollution releases. To mitigate this concern further, in our specific model specification defined below, we adopt a common practice and lag TRI/CAP relative to the membership variable in the estimation. While this does not necessarily eliminate a potential endogeneity problem, the likelihood that current membership functionally determined historical pollutant releases is highly unlikely.

Our econometric analysis utilizes a fixed effects regression framework. The full model estimated is:

$$\begin{aligned} \ln(CAP_{i,t} / CAP_{i,t-1}) = \alpha + b_1 \ln(NUM_{i,t-1}) + b_2 \ln(CAP_{i,t-1} / NUM_{i,t-1}) \\ + b_3(avg(\ln(UTIL_i))) + b_4(avg(\ln(MARGIN_i))) \\ + b_5 \ln(TRI_{i,t-2} / CAP_{i,t-2}) + b_6 \ln(LQ_{i,t-1}) \\ + \sum_{i=2}^{N} \gamma_i PADD_i + \varepsilon_{i,t}. \end{aligned} \tag{2}$$

The independent variables are lagged largely because added capacity in period t takes time to plan and construct. Thus, the amount of the capital addition is likely predicated by previously available information.[15] The lagged UTIL and MARGIN variables in equation (2) are three-year moving averages reflecting the fact that capacity adjustments based upon perceived changes in demand and/or profitability likely require evidence that such changes in demand and margins are to some degree sustained, not temporary or cyclical.[16]

The final variable in equation (2), LQ, is a location quotient which measures the regional intensity that Sierra Club membership has relative to the regional intensity of manufacturing employment. This variable is intended to capture the impact of environmental groups relative to competing interests. Specifically, the LQs are constructed for each PADD i, as follows:

$$\mathrm{LQ}_{\mathrm{i,t}} = \frac{\mathrm{MEMBERSHIP}_{\mathrm{i,t}} / \mathrm{MAN}_{\mathrm{i,t}}}{\mathrm{MEMBERSHIP}_{\mathrm{US,t}} / \mathrm{MAN}_{\mathrm{US,t}}}. \tag{3}$$

The numerator in equation (3) represents the share of Sierra Club members to manufacturing employment in PADD i, and the denominator is the same ratio for the US as a whole. The LQ is designed to capture regional variation in environmental regulation. Interest group pressure can influence national policy and thus have impacts on industries across regions. However, the LQ construct employed here highlights the potential *regional* influence that a higher concentration of such group members might have on more localized decision-making. Normalizing with respect to manufacturing employment was done to capture

[15] Note the two-year lag on TRI/CAP relative to the one-year lag on the membership variable (LQ – discussed below) to mitigate endogeneity concerns as previously discussed.

[16] Longer averages and different lag structures were investigated. However, including longer moving averages was costly in terms of degrees of freedom and alternative lag structures (such as polynomial distributed lags) offered little additional insights.

potential competing interests. It is reasonable to presume that manufacturing sectors of an economy likely desire reduced environmental regulation. MAN is designed to capture this influence.[17]

We estimate our equation using a one-way fixed effects model, as there may be time-invariant regional characteristics, such as transportation and pipeline infrastructure, coastal access that facilitates imported crude oil, etc., that might impact capacity growth. We, however, do not include dummy variables for each time period, for a couple of reasons. First, our dataset is rather small (90 observations). Including 18 time dummy variables would be quite costly in terms of degrees of freedom. Second, the variable NUM exhibits a pattern common to all PADDS over time, a modest decline in the number of operating units. Therefore, the inclusion of time dummies would in effect be redundant.[18]

## 4. RESULTS

The results are presented in Table 3.[19] In the first column of results we find that most of the effects come through as hypothesized.

With respect to the environmental variables, we find that both increased regulatory pressure and increased concentration in Sierra Club membership tend to slow oil refinery growth. However, the resulting elasticities are relatively small. A 10 percent increase in pollutant releases (tending to prompt more environmental enforcement) results in a 0.13 percent slow-down in capacity growth. Moreover, a 10 percent increase in Sierra Club membership concentration relative to manufacturing employment in a region tends to slow capacity growth by 0.79 percent. The conclusion is that although environmental regulation and pressure groups do indeed slow oil refinery growth, the marginal impacts are relatively small.

The effects of other variables on refinery growth, for the most part, tended to come through as hypothesized. A larger number of refineries and larger average refinery size tend to slow growth. A 10 percent increase in the number of refineries in a region tends to slow growth by 2.75 percent while a 10 percent increase in the average size of refineries tends to slow capacity growth by 2.58 percent. Higher historical utilization rates, as expected, tend to prompt additional capacity expansion

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[17] It is more common to construct LQs using a national and regional population figure. This was done as well and similar results, available from the authors upon request, were obtained.

[18] An important assumption in the fixed effects model is that the cross-sectional effects are uncorrelated with the model's explanatory variables. Since this might not be the case, it is common to check for this using a Hausman test, and, if correlation is found, to estimate via a random effects model. However, with our model we cannot estimate a random effects model since the number of independent variables (6 variables) exceeds the number of cross-section dummy variables (5 PADDs). However, we did drop two variables that proved to provide the weakest explanatory power in our model (NUM and MARGIN), then estimated both a fixed and a random effects model. The resulting Hausman test favored the fixed effects specification. We also tested the fixed effects restrictions by dropping sets of two variables from the model. All such modifications also demonstrated that the fixed effects specification was reasonable. These results are available upon request from the authors.

[19] Note that we estimated our equation using White's cross-section robust standard errors and covariance matrix to account for any potential heteroscedasticity of unknown form. Moreover, we investigated the autocorrelation functions of the resulting residuals from each of our five PADDs. Inspection of each indicated no serial correlation in these residuals.

as well. A 10 percent increase in the utilization over a three-year period increases capacity growth by 2.41 percent.

**Table 3. Fixed Effects Regression Results**

Dependent Variable: $\ln(CAP_{i,t}/CAP_{i,t-1})$

| | Column 1 | | Column 2 | |
|---|---|---|---|---|
| | coef. | sig. | coef. | sig. |
| constant | 1.033 | | 0.629 | |
| | (0.142) | | (0.290) | |
| $\ln(NUM_{i,t-1})$ | -0.275 | ** | -0.242 | *** |
| | (0.013) | | (0.009) | |
| $Ln(CAP_{i,t-1}/NUM_{i,t-1})$ | -0.259 | *** | -0.201 | *** |
| | (0.010) | | (0.008) | |
| $avg(\ln(UTIL_i))$ | 0.241 | *** | 0.231 | *** |
| | (0.008) | | (0.003) | |
| $avg(\ln(MARGIN_i))$ | 0.019 | | 0.014 | |
| | (0.460) | | (0.574) | |
| $\ln(TRI_{i,t-2}/CAP_{i,t-2})$ | -0.013 | * | ------- | |
| | (0.087) | | | |
| $\ln(LQ_{i,t-1})$ | -0.079 | *** | -0.090 | *** |
| | (0.010) | | (0.001) | |
| Adj $R^2$ | 0.202 | | 0.205 | |
| F-statistic | 3.12 | *** | 3.551 | *** |

p-values reported in parentheses.
Estimated using White's cross-section standard errors & covariance matrix.
Cross sectional effects supressed in table.
* - 10 percent significance
** - 5 percent significance
*** - 1 percent significance

The results indicate the refinery margins have no impact on capacity growth. However, as previously discussed, MARGIN is statistically correlated with TRI/CAP so it may be that the estimated standard error on the MARGIN variable is biased upwards. Moreover, TRI/CAP and MEMBERSHIP have a degree of correlation as well. To address this potential collinearity problem we re-estimated our model by first dropping TRI/CAP to see if significance improved. Doing so did not seem to improve the significance of MARGIN in any meaningful way, nor did it qualitatively alter the sign and significance of the other model variables.[20]

[20] While the data don't generally suggest that MARGIN and UTIL are correlated, since it may be logical that they are in fact linked (and perhaps historical data might show this), we also estimated equation (2) by dropping UTIL. Again, this did not improve the standard errors on MARGIN's coefficient.

**Table 4: Fixed Effects Regression Results with Regional Variation in Environmental Variables**

Dependent Variable: $\ln(CAP_{i,t}/CAP_{i,t-1})$

| | Column 1 | | Column 2 | |
|---|---|---|---|---|
| | coef. | sig. | coef. | sig. |
| constant | 2.094 | * | 2.354 | * |
| | (0.052) | | (0.043) | |
| $\ln(NUM_{i,t-1})$ | -0.397 | *** | -0.376 | *** |
| | (0.004) | | (0.006) | |
| $Ln(CAP_{i,t-1}/NUM_{i,t-1})$ | -0.381 | *** | -0.371 | *** |
| | (0.002) | | (0.006) | |
| $avg(\ln(UTIL_i))$ | 0.225 | ** | 0.148 | * |
| | (0.019) | | (0.075) | |
| $avg(\ln(MARGIN_i))$ | 0.044 | | 0.015 | |
| | (0.158) | | (0.502) | |
| $\ln(TRI_{PADD1,t-2}/CAP_{PADD1,t-2})$ | -0.066 | | ------- | |
| | (0.148) | | | |
| $\ln(TRI_{PADD2,t-2}/CAP_{PADD2,t-2})$ | -0.014 | | ------- | |
| | (0.488) | | | |
| $\ln(TRI_{PADD3,t-2}/CAP_{PADD3,t-2})$ | -0.046 | ** | ------- | |
| | (0.044) | | | |
| $\ln(TRI_{PADD4,t-2}/CAP_{PADD4,t-2})$ | -0.020 | * | ------- | |
| | (0.080) | | | |
| $\ln(TRI_{PADD5,t-2}/CAP_{PADD5,t-2})$ | 0.016 | | ------- | |
| | (0.384) | | | |
| $\ln(LQ_{PADD1,t-1})$ | ------- | | 0.075 | |
| | | | (0.340) | |
| $\ln(LQ_{PADD2,t-1})$ | ------- | | -0.238 | ** |
| | | | (0.022) | |
| $\ln(LQ_{PADD3,t-1})$ | ------- | | -0.219 | ** |
| | | | (0.033) | |
| $\ln(LQ_{PADD4,t-1})$ | ------- | | -0.139 | ** |
| | | | (0.011) | |
| $\ln(LQ_{PADD5,t-1})$ | ------- | | -0.099 | * |
| | | | (0.077) | |
| $\ln(TRI_{i,t-2}/CAP_{i,t-2})$ | ------- | | -0.025 | ** |
| | | | (0.033) | |
| $\ln(LQ_{i,t-1})$ | -0.124 | *** | ------- | |
| | (0.001) | | | |
| Adj $R^2$ | 0.193 | | 0.241 | |
| F-statistic | 2.434 | *** | 2.903 | *** |

p-values reported in parentheses.
Estimated using White's cross-section standard errors & covariance matrix.
Cross sectional effects supressed in table.
* - 10 percent significance
** - 5 percent significance
*** - 1 percent significance

Since the results so far indicate that environmental enforcement and environmental pressure groups do adversely impact refinery growth, one might ask whether or not the magnitude of these impacts vary from region to region. Two final experiments were undertaken to evaluate this conjecture. In Table 4 we present results whereby we estimated equation (2) by first allowing for regional environmental regulatory enforcement to vary and then by allowing regional environmental interest group pressure to vary. It appears that environmental regulatory enforcement slows refinery growth in PADDs 4 (the Rocky Mountain states) and 5 (the West Coast states). Environmental interest group pressure appears to slow refinery growth in PADDs 2, 3, 4, and 5. Interestingly, the greatest adverse impact appears to be in PADD2, an area that includes the industrial states of Illinois, Michigan, Indiana and Ohio, where traditional manufacturing industries might be expected to influence oil companies to invest more in refinery capacity.

## 5. Conclusion

In this paper we empirically investigated the impact of environmental regulatory enforcement and environmental pressure groups on the US petroleum industry's decisions to invest in refinery capacity additions/subtractions. While there appears to be some evidence to support the notion that the environmental movement has depressed such investment, the impact appears to be relatively small in magnitude. Moreover, the regulatory and interest group influence does vary from region to region. Regulatory enforcement appears to have the greatest impacts in PADDS 4 and 5, while interest group influence is more widespread, impacting to varying degrees, refinery investment decisions in all regions but the North East (PADD1).

There are several avenues for future research. An empirical link between refinery capacity additions and gasoline (and other refined product) prices has yet to be established and measured. This would be a valuable link since our results suggest a small environmental impact on refinery growth. While this suggests that such environmental regulation and pressure group activity would have a small impact on prices, it would be beneficial to measure this. Moreover, given that higher energy prices are being experienced in all industrialized and industrializing nations, it might be beneficial to construct an international dataset to see what tends to influence refinery capacity growth worldwide. We leave these suggestions for future research.

## APPENDIX

### Table A1: PADD Breakdown

| PADD # | STATE |
|---|---|
| **PADD1 (East Coast)** | Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Florida, Georgia, North Carolina, South Carolina, Virginia, West Virginia. |
| **PADD 2 (Midwest):** | Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio, Oklahoma, Tennessee, Wisconsin. |
| **PADD 3 (Gulf Coast):** | Alabama, Arkansas, Louisiana, Mississippi, New Mexico, Texas. |
| **PADD 4 (Rocky Mountain)** | Colorado Idaho, Montana, Utah, Wyoming. |
| **PADD 5 (West Coast):** | Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington. |

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