Environmental Regulations and Economic Activity: Influence on Market Structure

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Abstract

We survey recent developments in the theoretical and empirical literature on the economic effects of environmental regulation on various aspects of market structure including entry, exit, and size distribution of firms and market concentration.

1. INTRODUCTION

The environment and the economy are inextricably linked; policy makers cannot discuss the former without the conversation turning immediately to the latter. In light of the recent economic crisis in the United States, combined with the growing concern over climate change, circumventing the rhetoric and understanding the impact of environmental regulation on economic activity are crucial. Here, we provide a (necessarily incomplete) survey of one aspect of this literature. Specifically, we focus on the effect of environmental regulation on market structure.

Although significantly smaller than the literature assessing the impact of environmental regulation on trade and investment flows and plant location, the literature analyzing the potential effect of environmental regulation on market structure of regulated industries is growing. The market structure of an industry mainly refers to the degree of market concentration that depends on the number of firms in the industry and the distribution of market shares (and the related size distribution of firms). Environmental regulation may affect market structure by modifying, among other things, the possibility of entry of new firms, exit of incumbent firms, and the relative competitive advantage of active firms. Much of the existing literature assessing the impact of environmental regulation on market structure tends to focus on entry, exit, and the number of active firms. A somewhat smaller literature examines the impact on size distribution of firms; their degree of asymmetry; and the market share, entry, and exit of large versus small firms. Also, much of the literature tends to treat regulation as exogenous (with the exception of the rent-seeking literature that tends to view the level of regulation as endogenous).

The literature we survey is not homogeneous; one of the important sources of difference across various strands of the literature arises from variances in the underlying mechanism by which environmental regulation is presumed to influence market structure. We divide the literature into categories based on the underlying mechanism. In particular, we divide the literature into strands where environmental regulation impacts market structure through (*a*) simply raising production costs, (*b*) modifying the firm-level economies of scale (from the use of pollution abatement technologies), (*c*) technological innovation and investment to reduce future compliance and abatement costs, and (*d*) rent-seeking behavior by firms that strategically influence the level of regulation. In each category, we first discuss some key theoretical contributions and then provide a brief overview of the relevant empirical evidence.

Our decision to focus on market structure is based on two pillars. First, the ability of environmental regulation to alter market structure unintentionally has been, in our opinion, relatively neglected to date. In particular, this literature has taken a backseat to studies concerned with the impact of environmental regulation on competitiveness and productivity. Second, changes in market structure affect the degree of competition in the market, the extent of market power, and consumer and producer welfare. Furthermore, it may affect the government's ability to enforce environmental regulation and thus protect the environment. Understanding the impact of environmental regulation on market structure is crucial for assessing the effectiveness and welfare effects of such policies.

Perhaps the most well-known survey on environmental regulation within economics is provided by Jaffe et al. (1995). The authors discuss the literature concerning the effect of environmental regulation on competitiveness. In practice, this corresponds to studies addressing the impact of environmental regulation on international trade patterns, foreign versus domestic investment decisions, firm location, and total factor productivity. The authors conclude (Jaffe et al. 1995, p. 157), "Overall, there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined."

More recent surveys are provided by Jeppesen et al. (2002), Batabyal & Nijkamp (2004), and Press (2007). Jeppesen et al. (2002) and Press (2007) discuss the prior literature on the ability of environmental regulation to influence firm location, emphasizing the mixed empirical evidence to date. In addition, Press (2007) reviews the literature on the role of environmental regulation in technological innovation. Finally, Batabyal & Nijkamp (2004) provide a nice survey of a larger set of environmental issues within the regional science literature. Concerning the general topics of environmental regulation and economic activity, the authors discuss several empirical studies relating environmental regulation to regional economic development. Consonant with the conclusions drawn in Jaffe et al. (1995), the authors summarize that most empirical work fails to find an adverse impact of environmental regulation. However, the authors are quick to note that methodological issues may plague much of this literature. Lastly, additional surveys by Fullerton (2001, 2008), Jaffe et al. (2003), and Requate (2005) address issues related to the choice of regulatory instrument (e.g., taxes, subsidies, command and control, permits, etc.), incentives for technology adoption and diffusion, and the larger distributional implications of environmental policy.

Before turning to our review of the literature on the impact of environmental regulation on market structure, it is worth updating and extending some of the statistics provided in Jaffe et al. (1995). These statistics provide a vital backdrop for understanding the concern over the potentially deleterious economic effects of environmental regulation. As noted in Jaffe et al. (1995), between 1970 and 1990, aggregate annual (air) emissions of sulfur dioxide declined by 26%, volatile organic compounds by 36%, carbon monoxide by 45%, and lead by 97%. **Table 1** reveals that these declines, as well as for particulate matter, ammonia, and nitrogen oxides, continued over the period 1990–2007. Moreover, declining emissions between 1990 and 2007 occurred despite gross domestic product (GDP) rising 63%, vehicle miles traveled increasing 45%, U.S. population growing 21%, and energy consumption rising 20% (U.S. EPA 2008).

Achieving such reductions is not without cost. Pollution-abatement capital expenditures by manufacturing establishments with 20 or more employees were $7.88 billion in 1994 (U.S. Census Bureau 1996). Moreover, these expenditures are not distributed uniformly throughout the United States, either by industry or geography: Seventy-three percent occurred in four industries (chemicals and allied products, petroleum and coal products, paper and allied products, and primary metal industries), and 35% occurred within three states (Texas, California, and Louisiana). Aggregate operating costs related to pollution-abatement activities were $20.67 billion in 1994. Air pollution was responsible for $10.45 billion of the total pollution abatement capital expenditures and operating costs ($28.55 billion).

In 2005, the most recent year such data were collected, pollution-abatement capital expenditures by manufacturing establishments with 20 or more employees declined to $5.91 billion (U.S. Census Bureau 2008). Again, though, the expenditures were not distributed uniformly; the same four industries discussed above accounted for 63%, and Texas, California, and Louisiana continued to account for over 30%. Aggregate operating

Table 1 Change in annual national emissions by source category from 1990–2007[a]

Pollutant	Source category				Total change	Percent change
	Stationary fuel combustion	Industrial and other processes	Highway vehicles	Nonroad mobile		
$PM_{2.5}$	−693	−224	−223	−49	−1189	−51%
PM_{10}	−722	−43	−235	−62	−1062	−33%
NH_3	40	−353	152	−28	−189	−4%
SO_2	−9036	−844	−412	−25	−10,267	−45%
NO_x	−4894	229	−4029	383	−8311	−33%
VOC	621	−2809	−5786	−12	−7986	−35%
CO	−207	8442	−68,645	−2685	−63,095	−44%
Pb[b]	−0.410	−2.621	−0.421	−0.153	−3.604	−72%

[a]Amounts are measured in thousands of tons. Abbreviations: NH_3, ammonia; CO, carbon monoxide; NO, nitrogen oxide; Pb, lead; PM, particulate matter; SO_2, sulfur dioxide; VOC, volatile organic compound. Source: **http://www.epa.gov/air/airtrends/2008/report/AirPollution.pdf**.
[b]Emission changes are from 1990 to 2002 only.

costs related to pollution-abatement activities were $20.68 billion in 2005. Between 1994 and 2005, combined pollution-abatement capital expenditures and operating costs attributable to air pollution were $12.51 billion; thus, the fraction devoted to air pollution rose from roughly 37% to 47% over this period.

The Enforcement and Compliance Program of the Environmental Protection Agency (EPA) provides further confirmation that environmental regulations have economic consequences in the United States. The EPA conducted between 20,000 and 23,000 inspections/evaluations annually in fiscal years 2004–2008. The criminal enforcement program initiated at least 300 environmental crime cases per annum over this time period as well (see **http://www.epa.gov/compliance/resources/reports/endofyear/eoy2008/fy2008results.pdf**). Civil and criminal enforcement actions concluded in fiscal year 2008 alone required polluters to invest roughly $11.8 billion in pollution reduction, clean up of contaminated land and water, achievement of compliance, and implementation of environmentally beneficial projects (see **http://www.epa.gov/compliance/resources/reports/endofyear/eoy2008/fy2008.html**). This is up from approximately $5.5 billion in fiscal year 2004. In total, the EPA touts that, "EPA enforcement actions have required companies to invest an estimated inflation adjusted total of $45 billion in pollution control equipment and clean up plus environmentally beneficial projects over the last 5 years. This is equal to $36 million/work day" (see **http://www.epa.gov/compliance/resources/reports/endofyear/eoy2008/fy2008results.pdf**).

Finally, although comparative data on international environmental regulatory stringency are still relatively difficult to obtain, information is becoming increasingly available. One recent assessment, provided in Esty et al. (2008), sheds some light on the severity (or lack thereof) of environmental regulation in the United States. The authors compute an Environmental Performance Index (EPI) for 2008 for 149 countries. The EPI focuses on two main objectives: environmental health and ecosystem vitality. These objectives are then mapped into six main policy categories: environmental health, air pollution, water, biodiversity and habitat, productive natural resources, and climate change. Finally, the six policy categories are measured using a total of 25 environmental indicators including sanitation, air pollution, water quality, habitat protection, pesticide regulation, and industrial carbon intensity. According to the EPI, the United States ranks 39th out of 149, placing it ahead of seven E.U. countries and prominent Asian economics such as China, India, South Korea, and Taiwan.

In sum, although many may not consider the United States to be a global, environmental leader, the potential for current environmental regulation to have an adverse effect on economic activity is one that cannot be neglected. Moreover, growing concern over climate change is likely to lead to more stringent regulation in the future. However, sound policy-making requires accurate information on just what those adverse effects may be.

In Section 2, we discuss the literature emphasizing rising production costs under environmental regulation. Section 3 reviews the literature stressing economies of scale in the compliance with environmental regulation. Section 4 assesses the literature on the interplay between environmental regulation and technological innovation. Section 5 discusses a small literature on rent-seeking behavior arising from opportunities created by environmental regulation. Finally, Section 6 concludes by offering some directions for future research.

2. PRODUCTION COSTS

The primary mechanism by which environmental regulation may affect market structure is through the cost of production of firms. The theoretical literature emphasizing the production-cost aspect of environment has studied the effect of regulation on the equilibrium number of firms in a static framework. Although this literature allows for endogenous entry and exit of firms, it has abstracted from issues related to economies of scale (say, in the abatement technology); furthermore, the static framework precludes the introduction of technological innovation. Consequently, greater production costs adversely affect the profitability of firms, thereby altering incentives for the entry and exit of firms into the market.

In particular, a significant strand of literature has focused on the theoretical analysis of symmetric (identical firms) oligopolistic markets with endogenous entry and exit. The goal of such analysis is to characterize the comparative statics of regulation on the equilibrium number of active firms. Much of the analysis is carried out under the assumption that firms compete in quantity (Cournot competition). While allowing for fixed cost of entry, the production technology of firms that enter is generally assumed to be characterized by nonincreasing returns to scale (convex net cost functions). A negative relationship between the number of firms and regulatory stringency indicates that more stringent regulation has a negative effect on the entry of new firms and a positive effect on the exit of existing firms.

Katsoulacos & Xepapadeas (1996) consider the special case of a linear demand function and a cost function that is additively separable in outputs and emissions. Under this setup, the authors find that the equilibrium number of firms in the market is decreasing in the unit emission tax. Building on this result, Katsoulacos & Xepapadeas (1995) show that the second-best socially optimal outcome can be achieved by a regulatory scheme that combines an entry license fee and an emission tax because the second-best optimal emission tax does not restrict the number of firms to the second-best social optimum. Shaffer (1995) and Lee (1999) extended this analysis to more general demand and production-cost functions, while assuming that emissions are proportional to output. Here, the effect of an increase in the emission tax on firm output is ambiguous, but the impact on the equilibrium number of firms in the market is always negative.

More recently, Lahiri & Ono (2007) analyze the effect of an increase in an emission tax on a symmetric oligopoly when firms can reduce emissions using abatement technologies (in addition to modifying output). The authors find that an increase in the emission tax unambiguously decreases aggregate output, but it has an ambiguous effect on output per firm, with the direction depending on the curvature of the inverse demand function. If the inverse demand function is concave (a relatively standard assumption in the Cournot model), output per firm is unambiguously higher as a result of an increase in the emission tax, implying a decline in the equilibrium number of firms in the market. However, the converse may be true if the inverse demand function is convex.

The analysis in Lahiri & Ono (2007) is similar to that contained in Requate (1997), who also discusses the effect of absolute versus relative emission standards on the equilibrium number of firms. An absolute standard is one that taxes firms per unit of emission; a relative standard restricts emissions per unit of output by firms. Requate (1997) finds that a more stringent absolute emission standard always reduces the equilibrium number of firms. However, the effect of a more stringent relative emission standard on market structure is ambiguous. The latter result is also noted in Lahiri & Ono (2007). In their model, an increase in the relative emission standard reduces aggregate output at the industry level, but it also reduces output per firm if the inverse demand function is convex. As such, the effect on the number of firms in the market is ambiguous. If the inverse demand function is concave, the effect on output per firm is ambiguous, continuing to yield no clear prediction on the change in the number of firms in equilibrium.

Abandoning the oligopoly setup, Lange & Requate (1999) and Requate (2005) analyze the effect of an increase in an emission tax on the equilibrium number of firms in theoretical models of symmetric monopolistic competition. Here, the authors find an inverse relationship between the severity of the tax and the equilibrium number of firms under reasonable parametric restrictions.

Finally, in a symmetric Cournot oligopoly with endogenous entry, Farzin (2003) treats environmental quality as complementary to the consumption of the industry product. The author derives conditions under which this assumption generates a positive relationship between the stringency of the emission standard and the equilibrium number of firms. In particular, the author finds that the rate of entry increases with the price elasticity of the industry demand function.

In sum, theoretical analysis of static markets with endogenous entry and symmetric firms indicates that an increase in absolute standards discourages entry, induces exit, and increases market concentration unless the improvement in environmental quality resulting from the change in standard has a significant positive effect on demand for industry output. An increase in emission tax leads to similar qualitative effects under (at least) three conditions: (*a*) There is no viable abatement technology available to firms (and therefore firms can reduce emissions only by reducing output), (*b*) the demand function for the final good produced by the industry satisfies restrictions on curvature (such as concavity), or (*c*) firms do not have sufficient strategic interaction in the market (as in the case of monopolistic competition). In contrast, the effect of an increase in a relative emission standard on the equilibrium number of firms is quite ambiguous; no easily interpretable conditions exist under which the net effect on the number of firms can be signed in either direction.

There exists a relatively sizeable empirical literature assessing the impact of environmental regulation on various aspects of market structure: location decisions by plants, entry and exit propensities, employment. Interpretation of the results is, however, not necessarily straightforward; one must pay attention to the source of the variation that is used to identify the effect of environmental regulation. If the variation arises spatially—across counties or states—then negative effects of more stringent environmental regulation may not affect the level and structure of the market at the industry level, but instead only the spatial distribution of economic activity is affected. Unfortunately, most existing empirical studies rely on this type of variation.

Early empirical studies of the effect of environmental regulation on firm location are provided in Bartik (1988), McConnell & Schwab (1990), and Levinson (1996). Bartik (1988) and Levinson (1996) rely on variation in compliance costs across states, whereas McConnell & Schwab (1990) rely predominantly on intercounty variation arising from differences in attainment status under the Clean Air Act. All three studies obtain relatively small or insignificant effects of environmental regulation on new plant location decisions.

More recent studies, however, have built on McConnell & Schwab (1990) by identifying the impact of environmental stringency through spatial and temporal variation arising from differences in county-level attainment status. These studies find statistically and economically meaningful impacts of environmental regulation. Once again, it is not clear whether these results reflect only a shift in production from nonattainment to attainment counties, a shift in production overseas, a decrease in aggregate output, or some combination thereof.

Henderson (1996) finds that three consecutive years of nonattainment status by a county reduce the stock of establishments located therein. In addition, the effect is larger for plants in more pollution-intensive sectors. Becker & Henderson (2000) estimate large reductions in the number of new plants in pollution-intensive industries opening in counties when in nonattainment (relative to when in attainment) using data over the period 1967–1992. The authors find that sectors with larger plants are differentially affected, thereby shifting the structure of the market to new, single-plant firms in less regulated areas. In addition, the authors provide some evidence that survival rates of new plants are higher in nonattainment counties during some periods, perhaps owing to grandfathering provisions contained in environmental regulation or owing to greater sunk costs acting as a barrier to exit (Rivoli & Salorio 1996).

Similarly, Greenstone (2002) finds significant reductions in economic activity of pollution-intensive plants (relative to nonpolluters) in nonattainment counties (relative to counties in attainment). Using data spanning the period 1972–1987, counties in nonattainment under the Clean Air Act suffered a loss of approximately 600,000 jobs and $75 billion (in 1987 dollars) in output in pollution-intensive industries relative to counties in attainment. Using panel data on counties in the state of New York over the period 1980–1990, List et al. (2003b) find that counties in nonattainment obtain significantly fewer new manufacturing plants in pollution-intensive (relative to nonpolluting) manufacturing sectors. List et al. (2003a), relying on the same data, find that nonattainment counties are significantly less likely to be the location choice of relocating, pollution-intensive plants.

Two other studies that do not rely on variation in county-level attainment status for identification are of note. Gray (1997) uses state-level, panel data on new plant "births" from 1963 to 1987 along with several measures of state-level environmental stringency. The author finds that states with more stringent environmental regulation have a lower birth rate of new manufacturing plants, although, surprisingly, the magnitudes of the effects are no greater for industries deemed to be high-pollution industries. Building on this work, Gray & Shadbegian (2002) use panel data on the pulp and paper industry from 1967 to 2002. The authors find that firms shift production across state lines, reallocating production shares to states with less stringent regulation. However, two-thirds of this reallocation occurs within existing plants; the remaining one-third is equally attributable to plant openings and closings.

The fact that such interstate shifting occurs is significant, and it reinforces the above claim that the results of the studies discussed to this point do not necessarily indicate a reduction in industry-level output from more stringent environmental regulation. Greenstone (2002, pp. 1211–12) summarized this succinctly:

> It would be informative if the estimated regulation effects could be used to determine how much production (and employment) was shifted abroad as a result of the non-attainment designations. This would provide one measure of the national costs of these regulations. Unfortunately, such a calculation is not possible because it cannot be determined whether the lost activity in non-attainment counties moved to foreign countries or attainment counties. Since it is likely that the regulation effects partially reflect some shifting of manufacturing activity within the United States, they probably overstate the national loss of activity due to the non-attainment designations. Moreover, the possibility of intra-country shifting means that the regulation effects are also likely to overstate losses in non-attainment counties. The reason is that the identification strategy relies on comparisons between non-attainment and attainment counties, which leads to 'double counting' when production is moved from a non-attainment county to an attainment one.

Studies at the industry level address this shortcoming at least to some extent, although then the issue of whether the resulting estimates reflect a causal effect of environmental regulation becomes more prominent.

In this vein, Ollinger & Fernandez-Cornejo (1998) analyze the role of sunk environmental regulatory costs on the number of innovative pesticide firms over the period 1972–1989. The authors find a sizeable negative effect of sunk costs related to environmental and health regulation. The negative impact is markedly stronger on the number of smaller firms. In sum, the authors conclude that greater regulatory costs force firms to expand, and firms unable to do so suffer a loss in profits and ultimately exit the industry.

Two more recent studies in a similar spirit are provided by Blair & Hite (2005) and Ryan (2006). Blair & Hite (2005) analyze the effect of environmental regulation on the structure of the public landfill market in Ohio over the period 1989–1997. More stringent federal regulation emanating from concern over groundwater contamination and other negative externalities was implemented during the sample period. The authors estimate that the more stringent regulation led to a 16.6% reduction in the probability of a county containing a public landfill, resulting in a more concentrated market. Ryan (2006) analyzes the dynamic effects of environmental regulation under the Clean Air Act on the cement industry in Portland, Ohio. The primary finding is that regulation leads to a sizable increase in the sunk cost of entry. This entry barrier leads to greater concentration in the industry.

A smaller literature has focused explicitly on the exit decision of firms. Deily & Gray (1991) analyze data from 1977 to 1986 on EPA enforcement activity, finding that steel mills facing the likelihood of stringent regulatory enforcement (i.e., those with higher predicted probabilities of future inspections) were more likely to close. However, the authors also find that inspectors are more likely to bypass mills with a higher likelihood of closing if inspected. Similarly, Helland (1998) analyzes EPA inspections of pulp and paper mills in one EPA region over the period 1990–1993. The author finds that less profitable mills are less likely to be inspected, mitigating at least some of the potential impact of environmental regulation on closures. Snyder et al. (2003) estimate the impact of regulation on the exit decisions of chlorine-manufacturing plants using data from 1976 to 2001. The authors find some evidence that exits were induced by more stringent regulation, leading to a greater market share by cleaner firms. List et al. (2004) find moderate evidence of an effect on closure rates of pollution-intensive (relative to nonpolluting) plants from nonattainment status. Interestingly, the only statistically significant effect the authors find is for closures accompanied by a partial or complete move to a different state. This result is consonant with spatial variation in environmental regulation affecting the distribution of economic activity—and not necessarily the aggregate level of activity.

Of note, there is some empirical support for regulation actually discouraging exit in Europe. Analyzing Norwegian data for three manufacturing sectors, Golombek & Raknerud (1997) find that regulated establishments had significantly lower probability of exit than the nonregulated units in two of three sectors; results for the third sector are statistically insignificant. Using the same Norwegian data, Biorn et al. (1998) estimate the exit probability of a regulated establishment to be approximately one-third that of a nonregulated one.

3. ECONOMIES OF SCALE

Environmental regulation may alter the economies of scale for individual firms. In particular, the economies and diseconomies of scale associated with the cost of regulatory compliance and the pollution abatement technology available to firms (to bring down their compliance costs) may affect the level and shape of the net average and marginal cost curves of firms, thus impacting their minimum efficient scale. This, in turn, affects the number and size of firms in the market in equilibrium. The precise effect of regulation on scale economies is likely to be sensitive to the particular instruments used for regulation, as well as the political environment surrounding the enforcement of regulation and the legal environment in which the firm operates. As in the theoretical literature emphasizing production costs, the theoretical literature on economies of scale is carried out in a static framework, with entering and exiting firms typically being "small" (i.e., price takers).

In such a setup, Conrad & Wang (1993) analyze the impact of an increase in emissions tax in a market with endogenous entry of price-taking firms. The assumptions in the papers on production and abatement technology imply decreasing returns to scale; they show that the optimal scale of firms declines with increase in regulation. As the effective marginal cost curve increases with regulation, equilibrium price increases and the total output sold in equilibrium declines. The net effect of an increase in regulation on the equilibrium number of firms is therefore ambiguous. Conrad & Wang (1993) also show that the equilibrium number of firms declines with an increase in the emission tax if the demand function for the final product is sufficiently elastic. If the demand function is sufficiently inelastic, however, the equilibrium number of firms may rise. For the case of a dominant firm with a competitive fringe, the authors show that an increase in the emission tax reduces the number of firms if the elasticity of the residual demand curve is high and/or the marginal cost curve of the competitive firms is steep. In a comment on Conrad & Wang (1993), Kohn (1997) argues that if there are sufficient economies of scale in the abatement technology, then the optimal scale and output of polluting firms may increase with emission tax and, in such situations, the imposition of a (Pigouvian) emission tax is more likely to reduce the number of firms (even if the demand curve for the final product is sufficiently inelastic).

Taking a different approach, Spulber (1985) compares various regulatory instruments assuming free entry and exit. The author finds that if an optimal per-firm environmental standard is employed, excessive entry of small firms will occur. Moreover, aggregate pollution will exceed the social optimum, and production level of each firm will be below the socially efficient scale.

A significant number of empirical findings have indicated the presence of positive economies of scale with respect to environmental regulation that, in turn, leads to reduced entry and greater exit of firms. Dean & Brown (1995) provide evidence that environmental regulation is a net deterrent on the entry of new manufacturing firms. Although the authors do not assess empirically the underlying mechanisms behind this finding, they do provide an extensive review of the arguments, suggesting an increase in the minimum efficient scale of production from greater regulatory stringency. Pashigan (1984) provides evidence for the manufacturing industry as a whole indicating that the minimum efficient scale increases with the stringency of environmental regulation. Pittman (1981) provides similar evidence for pulp and paper mills. Examining new business formations across 170 manufacturing industries over a ten-year span, Dean et al. (2000) find that more stringent environmental regulation is associated with fewer small business formations; no impact is found on the creation of new, large establishments. Becker & Henderson (2000) find that new plants in nonattainment areas are significantly larger than those originating in attainment counties, reflecting greater initial capital investment. However, plant sizes converge across in attainment and nonattainment counties over time. Finally, Berman & Bui (2001) analyze the effect of environmental regulations adopted in Los Angeles Basin (California) over the period 1979–1992 on labor demand at manufacturing plants. The results indicate little adverse effect on labor demand and even some positive effects attributable to the complementarity between labor and abatement activity. Together, these findings suggest a unit cost advantage to larger firms resulting from environmental regulation and a resulting greater market share for larger establishments. Similar evidence is available from Norway; Golombek & Raknerud (1997) find that regulated establishments increase employment levels.

More recently, Yin et al. (2007) directly address the issue of exit of firms/facilities upon imposition of one specific environmental regulation, namely underground storage tanks, on the petroleum retail market. The authors identify economies of scale and liquidity constraints as the fundamental reasons behind the exit of small outlets/firms from the industry. Large outlets enjoy a competitive advantage in the market, as it is difficult for the smaller outlets to pass on the compliance costs to the customers in the presence of economies of scale. Similarly, liquidity-constrained, smaller firms are forced to exit the industry because they are unable to replace or upgrade equipment as required by standards for underground storage tanks.

The discussion on economies of scale to this point has implicitly assumed that firms are homogeneous. Thus, stricter regulation has identical effects on all firms, and any intra-industry variation in firm size is attributable to spatial variation in environmental regulation. However, this may be unrealistic. Environmental regulation may be associated with differences in abatement costs (and related scale economies) across firms, thereby creating different incentives for firms to adopt or develop new abatement technology.

Brock & Evans (1985) provide a theoretical model addressing the question of whether the government should practice regulatory tiering (i.e., regulate smaller firms less stringently than larger firms). Although not directly relevant to the question here, the model posits that firm size is increasing in access to a scarce factor—interpreted as managerial ability—and that this factor also reduces the administrative costs associated with regulatory compliance. Thus, absent regulatory tiering, the cost of compliance with environmental regulation varies across firms and is decreasing in firm size. Empirical evidence concerning compliance costs with nonenvironmental regulation affirms the negative relationship between firm size and compliance costs (for citations, see Brock & Evans 1985).

Of more direct relevance is the theoretical model provided in Carraro & Soubeyran (1996). Analyzing an asymmetric oligopoly, the authors show that a uniform emission tax imposed on all firms can increase the market share of a firm if the firm is already relatively large (i.e., enjoys an initial cost advantage). As a result, the dispersion in market share increases as a result of environmental regulation.

The empirical literature provides some validation; there is evidence of heterogeneous responses to environmental regulation within an industry. Gray & Shadbegian (2002), discussed above, find differential reallocation of production across states in response to variation in state-level environmental regulatory stringency. Specifically, firms with high compliance rates with environmental regulation appear to slightly favor states with more stringent regulation. The authors attribute such heterogeneity to differences in the cost of regulatory compliance across firms: Firms facing high costs of compliance prefer to reallocate production to more environmentally lax states, whereas firms with low costs of compliance have a slight preference for environmentally stringent states.

Millimet (2003) finds that the number of establishments of a certain size located within a county depends on environmental regulation measured at both the state and industry level. Only if both are strict (i.e., establishments belong to a heavily regulated industry measured at the national level and are located in a state with strict regulations) does the stock of large establishments increase and the stock of small establishments decline. In other words, if state-level environmental regulation becomes more strict, then the stock of large (small) establishments in industries that face relatively stringent environmental regulation nationally becomes larger (smaller). However, the stock of large (small) establishments in industries that face relatively lax environmental regulation nationally becomes smaller (larger). This result is consonant with firms finding it optimal to comply with stricter state-level regulation and, as a result, becoming larger only when competitors located elsewhere also face strict regulation. In the absence of stringent regulation on competitors, establishments either downsize or are replaced with new, smaller establishments perhaps to avoid detection of noncompliance.

4. TECHNOLOGICAL INNOVATION

The discussion to this point, particularly within the theoretical literature, has been static in nature. Understanding the impact of environmental regulation on market structure, however, is incomplete without accounting for dynamic considerations. In a dynamic setting, environmental regulation affects the incentive of firms to invest in technology adoption, innovation, and research and development (R&D) in pollution abatement to bring down future compliance and abatement costs. Such investment, in turn, affects current and future economies of scale (i.e., changes future average and marginal cost curves of firms) and potentially contributes to heterogeneity in firm size. It also creates the need to generate surplus to compensate firms for past investment. These, in turn, affect the dynamic incentives for entry and exit of firms.

The existing literature on environmental regulation and investment has predominantly focused on the so-called Porter hypothesis (Porter 1991, Porter & van der Linde 1995). According to the hypothesis, stringent environmental regulation encourages firms to innovate and develop more cost-effective methods of achieving regulatory compliance. However, in the process, firms may also discover new technologies that reduce emissions and production costs. As stated in Section 1, surveys on the productivity effects of environmental regulation, as well as the impact of regulatory instruments on technology investments, are provided elsewhere. However, very little is known about the interrelationship between environmental regulation, technological investments, and the entry and exit of firms and their intertemporal size distribution.

Parry (1995) considers an upstream market that carries out R&D to develop new abatement technology for a downstream polluting sector. Both markets are characterized by free entry and success in R&D is stochastic. The upstream firm that succeeds in developing a new abatement technology becomes a monopolist and sets a license fee that must be paid by any downstream firm wishing to adopt it. The author shows that an increase in an emissions tax raises the license fee and reduces the number of firms in the downstream market.

Mason & Swanson (2002) consider the ability of a patent-holding incumbent firm to utilize environmental regulation to gain a competitive advantage or act as a barrier to entry. Specifically, the authors consider the case where regulation is used to ban further consumption of a natural resource as an input in the production process once the usage reaches a certain limit. Thus, the combination of regulation and technological innovation result in a less competitive industry.

Recently, Sengupta (2008) shows in a two-period model that an exogenous environmental regulation imposed on a competitive industry induces *ex ante* identical firms to undertake investment to reduce their future cost of regulatory compliance. This, in turn, generates interfirm heterogeneity and shake-out of firms over an equilibrium dynamic path. Policy-induced investment by firms enables the firms that choose to be cleaner and larger to survive, whereas firms that choose to be dirtier and smaller may eventually exit as the industry matures. Under certain conditions, the equilibrium dynamic path of the competitive industry entails greater heterogeneity among firms and shake-out of firms with relatively stringent regulation. However, conditions exist under which exit may not occur.

There is no empirical evidence, to our knowledge, on the role of regulatory-induced technological innovation affecting market structure. There is, however, evidence related to the ability of environmental regulation to induce technological change. Gray & Shadbegian (1998) find that more stringent environmental regulation alters the technology choices of paper mills: Mills in states with more strict regulation choose cleaner production technologies. In addition, investment in abatement technology crowds out investment in productive technology at the plant level. At the firm level, productive investments are reallocated to plants located in states with more lax environmental regulation. Using data on offshore oil and gas production in the Gulf of Mexico from 1968 to 1998, Managi et al. (2005) find that environmental regulation induces technological change (measured by a shifting out of the production frontier). Jaffe & Palmer (1997) analyze panel data at the industry-level from 1974 to 1991. The authors find that lagged abatement expenditures are positively related to current R&D. However, they fail to find any link between lagged abatement expenditures and innovative output, measured by patent activity. Similarly, Snyder et al. (2003) fail to find any regulatory-induced effect on the decision by chlorine-manufacturing plants to adopt cleaner, membrane cell technology. Conversely, Brunnermeier & Cohen (2005) analyze panel data on manufacturing industries from 1983 to 1992 and find abatement expenditures to be positively associated with successful environmental patent applications. However, greater enforcement of environmental regulation did not provide any additional incentive to innovate.

In a somewhat different vein, List et al. (2004) study the impact of the New Source Review (NSR) provision of the Clean Air Act. Under the NSR, existing plants that wish to undertake modifications that are expected to yield a net increase in emissions must comply with pollution-control standards for new sources. As such, modifications relieve the plant of any grandfathering privileges it may possess. Because the NSR requirements are more strict for plants located in nonattainment counties, List et al. (2004) analyze the impact of nonattainment status on plant-level modification decisions in pollution-intensive (relative to nonpolluting) sectors. The authors find a statistically and meaningful deterrent effect of the NSR on modifications. Consequently, grandfathering provisions of environmental regulation encourage the continued use of inefficient technologies as well as potentially higher pollution levels.

5. RENT-SEEKING BEHAVIOR

The final mechanism by which environmental regulation may alter market structure is through strategic behavior on the part of incumbent firms. Incumbent firms may strategically invest in new abatement technology to reduce their abatement cost so as to create incentives for the regulator to increase future regulation that can, in turn, place other firms at a competitive disadvantage. This is particularly relevant when some firms have exclusive access to a technology or other cost advantage over rival firms. In such cases, firms may even lobby for novel and stricter regulations to exploit their first-movers' advantage. By increasing rivals' costs through induced regulation, innovating firms may cause rivals to exit, limit entry by potential competitors, or increase heterogeneity in market shares among existing firms in the industry.

The potential for environmental regulation to raise rivals' costs and act as a barrier to entry creates demand for more stringent regulation by those possessing some initial advantage (Salop & Scheffman 1983; Barrett 1991, 1992; Fri 1992). Firms that have adopted investments with little to no reversibility wish for the government to impose a regulatory standard that is at par with their environmental performance, and this creates additional impediments for potential entrants in the industry.

Buchanan & Tullock (1975) were the first to point out that regulation that relied on a nontransferable permit to limit a firm's pollution-producing output creates a barrier to entry and, consequently, generates rents for incumbents. This rent-creating potential for incumbent firms through entry barriers continues to exist when such permits are coupled with environmental standards (such as technology forcing) that reduce the scale economies for individual firms (Maloney & McCormick 1982).

More recently, Denicolò (2008) shows that when firms choose abatement technology and have private information about their own production costs (resulting from any choice of abatement technology), an incumbent firm may voluntarily choose a cleaner technology (than the one mandated by existing regulation) in order to signal low production cost (when it adopts this cleaner technology) so as to induce the government to impose more stringent regulation. This, in turn, can deter potential entry (in the presence of a fixed entry cost) or reduce the scale of the entrant (if the entrant has a higher compliance cost). Thus, voluntary overcompliance can be used by firms in a strategic attempt to signal that the existing regulation is not overly burdensome. If the government then acts on this signal by effecting stricter regulation in the future, the overcompliant firm can retain or increase market dominance. See Lyon & Maxwell (2004) for a more comprehensive review of environmental overcompliance by firms. Similarly, Schoonbeek & de Vries (2008) discuss a model where a monopolist faces a potential entrant. They show that the socially optimal level of regulation may preserve the monopoly and, as such, that the preferences of the welfare-maximizing government and the incumbent firm may coincide.

Some empirical support for this line of thought is contained in Helland & Matsuno (2003), who find that an increase in compliance cost due to environmental regulation increases the rent (Tobin's q) for larger firms. Additional support comes from two case studies. First, DuPont broke from the industry norm in the mid-1980s and lobbied in favor of stricter regulation concerning the use of chlorofluorocarbon because they held the patent rights on chlorofluorocarbon substitutes. Resulting tighter regulation did increase DuPont's market position (Lyon & Maxwell 2004, Denicolò 2008). Consonant with Rivoli & Salorio (1996), once an irreversible investment is made by a firm, the cost is sunk; thus, *ex post*, it acts as an exit barrier. Second, in the early 1990s, California implemented a new phase of regulation on reformulated gasoline. Whereas most of the industry opposed the move, the state's largest gasoline retailer, Arco, supported the regulation. Brown (2008) finds that the regulation resulted in greater industry concentration and higher profits for surviving firms as the resulting price increase for wholesale gasoline exceeded the increase in average variable compliance costs.

Strategic positioning by incumbent firms in markets for tradable emission permits can also act as entry barriers (e.g., Sartzetakis 1997, Koutstaal 2002). Focusing on the tradable permit market, Misiolek & Elder (1984) examine if firms with market power use exclusionary manipulation to reduce competition in the product market from rivals or potential entrants. Bohm (1994) argues that, under imperfect capital markets, grandfathering of permits can act as a barrier to entry. Koutstaal (1997) finds empirical support for this hypothesis in the context of carbon dioxide emission trading in the Netherlands. In a study of the E.U. electrical utility sector, Svendsen & Vesterdal (2002) find evidence that the grandfathering of emission permits acts as barrier to entry.

6. SOME DIRECTIONS FOR FUTURE RESEARCH

The most important development in the field of industrial organization over the past 20 years is the systematic empirical investigation and establishment of observed regularities related to the dynamics of industries and the product life cycle (including entry, exit, turnover, growth, and survival of firms as well as changes in their size distribution, age distribution, scale, and capital structure over time). A large theoretical literature on industry dynamics has followed in which evolutionary and competitive (both perfectly competitive as well as strategic) models of dynamic industries with endogenous entry, exit, and technological change (through investment or learning) are analyzed to explain the various empirical regularities.

Perhaps the most striking gap in the literature on environmental regulation is its inability to connect to this rich literature on dynamic industry models in order to understand the long-term impacts of environmental regulation on industries and firms. The response of firms to any level of environmental regulation is spread over time as firms gradually adjust their investment in the development and adoption of abatement technology, their production capacity, their cost of compliance, and their entry and exit decisions. Learning about more efficient means of complying with regulation will also affect firms' responses to environmental regulation. These, in turn, have spillover effects and affect other firms (both incumbents and potential entrants). Furthermore, the outcomes of endogenous learning and investment, as well as the propagation of externalities, are subject to uncertainty.

The resulting industry dynamics are interesting from the standpoint of both positive and normative economics. From a positive point of view, they enable us to understand the lagged effects of regulation on market structure, size and age distribution, and turnover of firms. From a normative point of view, they determine the true intertemporal cost and benefit of regulation (including the dynamic environmental impact of any regulation), which, in turn, are useful for determining the appropriate levels of environmental regulation. Static analysis of the impact of regulation on industries misses out on these important positive and normative aspects. In addition, important insights can be derived from empirical studies of specific industries along the lines of the literature concerning product life cycle and by accounting for historical changes in levels of environmental regulation on such industries.

Differences in the enforcement of regulation also affect the impact of such regulation on size distribution of firms as well as entry and exit. Certain regulations may favor smaller firms through regulatory tiering, and, in many circumstances, smaller firms can evade or escape compliance with little probability of being penalized (by the government as well as from lawsuits or negative publicity brought by individuals or groups). This, in turn, may create incentives for firms to limit their scale of production and forego the economies of scale in order to save on compliance costs, which, in turn, can lead to the coexistence of larger, more efficient, compliant firms with noncompliant, smaller firms. This endogenous difference between firms created through regulation, along with the relative market shares and technologies of the different types of firms in the market, determines the eventual net benefit to society from regulation (including the impact on the environment). A proper economic analysis of the strategic endogenous compliance and investment/capacity decisions of firms under weak, and possibly politically motivated, regulatory enforcement is clearly needed.

Finally, the existing literature focuses predominantly on the private costs of environmental regulation incurred by firms and the benefits of environmental quality enjoyed by society. Relatively neglected is the potential for firms to benefit from environmental regulation, not for reasons put forth in the Porter hypothesis, but from an increase in product demand by "green" consumers. If such green consumerism is of sufficient magnitude, stricter environmental regulation may encourage the entry of new firms in the industry. However, it is unclear whether mandatory regulation is sufficient to generate increases in consumer demand or if positive demand effects are realized only when the regulation is self-imposed (through voluntary regulation where none exists or through overcompliance).

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