

Ignore, Avoid, Abandon, and Embrace: What Drives Firm Responses to Environmental Regulation?

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Abstract A regulator's ability to incentivize environmental improvement among firms is a vital lever in achieving long-term sustainability. However, firms can and do respond to environmental regulation in a variety of ways: complying with its intent; avoiding the regulation by offshoring or by abandoning the market; or ignoring the regulation by continuing with entrenched business practices. The path a profit-maximizing firm will choose depends, in part, on the expected cost of non-compliance, which is a product of the regulator's stated penalty, the likelihood that noncompliant practices are detected, and the likelihood that detected violations are punished. The form of regulatory regime and three important cost thresholds also drive firm response. In this chapter, through examples of regulatory failures and successes, we develop a framework for understanding how these thresholds interact with the type of regulatory regime being considered and the expected cost of non-compliance to determine whether profit-maximizing firms ignore, avoid, or embrace environmental regulation.

Introduction

In April, 2010, about 40 miles off the Louisiana coast in an area called the Macondo Prospect, the *Deepwater Horizon* drilling rig exploded. The blast claimed the lives of 11 workers and hemorrhaged an estimated 3.2 million barrels of oil into the Gulf of Mexico, causing significant damage to the Gulf's environment and economy (Crooks, 2015).

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The disaster at the *Deepwater Horizon* offshore oil rig is well-documented. What is not as well-known is that 20 years prior to the *Deepwater Horizon* incident, and in response to the *Exxon Valdez* oil spill of 1989, the US Congress passed the Oil Pollution Act of 1990 (OPA) as an amendment to the Clean Water Act, in part to prevent this sort of disaster (US Environmental Protection Agency, 2015). The OPA “streamlined and strengthened [the] EPA’s ability to prevent and respond to catastrophic oil spills,” and increased the penalty for noncompliance (US Environmental Protection Agency, 2014a, 2015). In September 2014, a US District Court judge found that BP had acted with gross negligence and willful misconduct prior to the spill, citing an “extreme deviation from the standard of care and conscious disregard of known risks” (United States of America v. BP Exploration & Production, Inc., et al, 2014). In other words, the judge found BP to be in violation of the Clean Water Act. In this instance, it is clear that environmental regulation failed to have its intended effect.

On the other hand, there are numerous examples of regulatory intervention that have been credited with driving environmental improvement. For example, in textiles, the Cotton Dust Standard is credited with improving worker health while achieving compliance significantly faster and at lower cost than had been estimated (Glindmeyer et al, 1991; Occupational Safety and Health Administration, 2000); and in power generation, the Acid Rain Program amendment to the Clean Air Act has been credited with reducing sulfur dioxide (SO₂) emissions by roughly two-thirds relative to their baseline levels (Ellerman et al, 2000; Ellerman, 2003; Stavins and Schmalensee, 2012). This begs the question: what determines whether or not the regulation of firms’ production technologies and processes will ultimately be successful in abating environmental harm? To explore that question, one must first understand: (1) the primary characteristics of environmental regulation that influence a profit-maximizing firm’s decision-making; and (2) the strategic options that a profit-maximizing firm has when faced with costly environmental regulation. Before turning our attention to these two points, however, it is useful to first understand when and why the regulation of firms’ production processes and technologies is necessary.

1 Production Technology and Environmental Impact

At the highest level, the environmental impact of a good, or collection of goods, can be viewed through the lens of the well-known “IPAT” equation, which was introduced by Ehrlich and Holdren (1971).

$$(\text{I})\text{mpact} = (\text{P})\text{opulation} \times (\text{A})\text{ffluence} \times (\text{T})\text{echnology} \quad (1)$$

Considering the global economy (as Ehrlich and Holdren were), environmental impact is a product of the world’s population, “affluence” which is a proxy for per capita consumption, and “technology” which is a measure of per unit environmental

harm. Population and “affluence” co-determine aggregate consumption. As illustrated in Figs. 1 through 3, both population and per capita consumption have grown considerably over the past decades, propelling tremendous growth in aggregate consumption.

Fig. 1 Global population increased to roughly 7 billion by 2011, with 92.3% of the increase from roughly 4 billion in 1970 occurring in emerging economies (Global Financial Data, 2013).

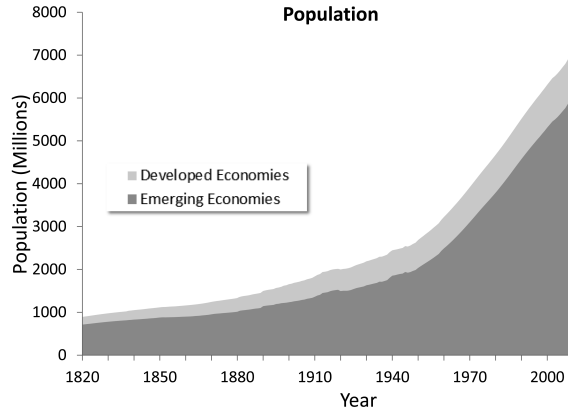
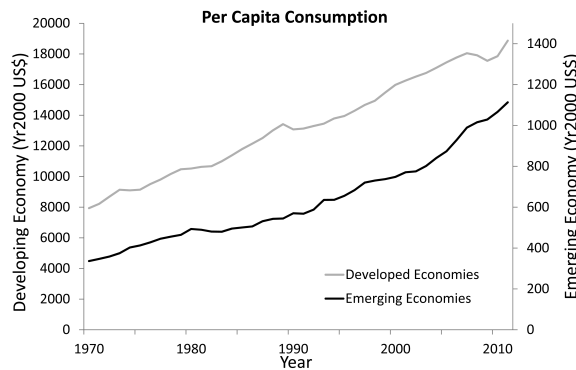


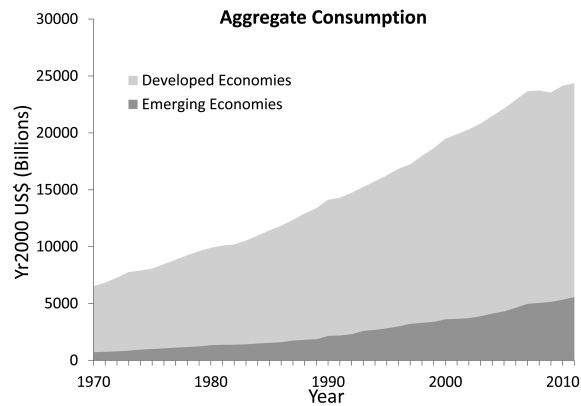
Fig. 2 Per capita consumption in the developed world grew to \$18,869 by 2011, roughly 2.4 times 1970’s levels, and to \$1,113 in emerging economies, or roughly 3.3 times 1970’s levels (World Bank, 2013).



As is evident in Fig. 2, per capita consumption in emerging economies is only 1/17th the level of per capita consumption in developed economies (World Bank, 2013). As Drake and Spinler (2013) note, we should expect continued per capita growth as emerging economies close this consumption gap. Combined with projected population growth through this century (United Nations, 2011), this suggests that we should expect continued growth in aggregate consumption for the foreseeable future. In the effort to abate environmental impact, these trends leave “T” as the most promising lever.

While the “T” from the IPAT equation nominally represents “technology”, for our purposes, it is better interpreted as the per unit environmental harm done by a given product or service. This includes the environmental harm or risk related to

Fig. 3 Since 1970, population and per capita consumption trends have driven roughly a 225% increase in aggregate consumption within developed economies and an astonishing 676% increase in aggregate consumption within emerging economies (World Bank, 2013).



the given product's or service's material sourcing, production, distribution, use, and disposal.

At times, firms take responsibility for reducing this per unit damage themselves. In its early days, for example, Patagonia phased out the production of a steel piton used for mountaineering when they realized the damage being done to the rock faces of the mountains on which it was used—at the time, the steel piton was Patagonia's top-selling product (Patagonia, 2015). Decades later, after learning of damages resulting from fertilizers and pesticides used in conventional cotton farming, the firm voluntarily transitioned to organic cotton for the manufacture of their cotton shirts, even though this roughly doubled their production cost (Bonner, 1997). Large, multi-national firms have also demonstrated such stewardship. Unilever, for example, co-founded the Roundtable on Sustainable Palm Oil (RSPO) in 2004 to eliminate deforestation and forest degradation resulting from palm oil sourcing. By 2014, the RSPO included over 2,000 members representing over 40% of all palm oil production worldwide (Unilever, 2014). Nike, Dow Chemical, and others have also been lauded recently for their voluntary efforts to reduce the environmental impact of their operations (MarketWatch, 2014; Roston, 2012).

Despite these examples, however, market forces and/or corporate cultures can be such that regulatory intervention is required to drive environmental improvement. When a product's principle environmental impact derives from sourcing, manufacturing, or distribution, then that regulatory intervention is generally best-directed toward firms' operations. As noted above, at times such regulation succeeds and in other instances it fails. The remainder of this chapter focuses on such regulation, with the aim of developing insight into the factors that determine its outcome.

2 Regulatory Dimensions: Expected Cost of Noncompliance and Asymmetry

The expected cost of noncompliance and asymmetry in the stringency of regulation between regions are two of the primary dimensions that determine the effect of regulation on firm decisions (regulatory uncertainty—whether or not regulation will be implemented, or whether and how regulation may be changed—can also play an important role, but is beyond the scope of this chapter). In deciding how to respond to enacted regulation, profit-maximizing firms will weigh the expected cost of compliance against the expected cost of noncompliance. If the product is transportable, then firms will compare these costs across regions, a setting in which regulatory asymmetry becomes an important consideration.

2.1 *Expected Cost of Noncompliance*

In 1272, King Edward I banned the domestic burning of coal due to the smog that it created, ultimately making its use punishable by death. The ban was ignored and the use of coal as a source of heat continued unabated (Urbanito, 1994). With such a severe penalty for disobeying the coal ban, how did King Edward's prohibition fail to have its intended effect?

The expected cost for violating enacted regulation is not determined by the stated penalty alone. The expected cost is a product of three drivers: (i) the stated penalty for noncompliance; (ii) the likelihood that noncompliance will be detected by the regulator; and (iii) the likelihood that detected violations will incur the penalty.

$$\begin{array}{l} \text{Expected Cost} \\ \text{of noncompliance} = \end{array} \begin{array}{l} \text{Penalty} \\ \text{Magnitude of penalty} \\ \text{for noncompliance} \end{array} \times \begin{array}{l} \text{Detection} \\ \text{Probability that} \\ \text{noncompliant behavior} \\ \text{will be discovered} \end{array} \times \begin{array}{l} \text{Enforcement} \\ \text{Probability that} \\ \text{detected noncompliance} \\ \text{will be penalized} \end{array}$$

For regulation to prove effective, not only must there be a meaningful penalty for noncompliant behavior, there must also be a reasonable chance for the regulator to detect noncompliance and, once detected, a reasonable likelihood that the regulator will enforce the penalty. If any of these three components are insufficient, then regulation is unlikely to alter decision-making.

In the coal example, King Edward's ban did little to change behavior because there was little effort made to detect its use, and thankfully the punishment was not generally enforced when coal use *was* detected (the first citizen found burning coal in violation of the ban was executed, but no others were). King Edward's ban also failed because there was no feasible alternative to turn to; wood was available, but so expensive that few could afford it (Urbanito, 1994). In other words, the cost of compliance (switching from coal- to wood-burning for needed heat) was sufficiently steep that it was unachievable for most under King Edward's rule.

While King Edward's coal ban is an extreme and certainly unjust example of environmental regulation, it is illustrative. Implementing regulation with sufficiently meaningful expected penalties to incentivize improvement is not just a matter of the policy's stated penalties. It is also a matter of having appropriate monitoring infrastructure in place, having the will to enforce penalties when detected, and ensuring that feasible alternatives are available and/or discoverable. As we will see in Sect. 3, well-intended regulation does not always achieve these ends.

2.2 Regulatory Asymmetry

In the early 2000s, amidst electricity market deregulation, rolling blackouts, and a growing population, power needs in California became difficult to meet domestically. To meet demand, US energy companies increased generating capacity across the border in northern Mexico—where relatively lax environmental regulations and a much faster licensing process (in addition to lower construction costs) made for cheaper electricity production—which could be imported via cross-border transmission lines to the US (Carruthers, 2007; Weiner, 2002; Blackman et al, 2012; California Energy Commission, 2012). In 2003 two large power plants, InterGen's La Rosita Power Project and Semptra Energy's Termoeléctrica de Mexicali plant, began operating near Mexicali, Mexico over the objections of environmental and citizens groups on both sides of the border (Carruthers, 2007). Opponents said pollution from the plants' operations would not only degrade human health and the environment in Mexico, but would likely cross the border to reduce already impaired air quality in California's Imperial Valley and increase respiratory illnesses among residents (Blackman et al, 2012; Imperial Irrigation District, 2010; Government Accountability Office, 2005).

In 2010, California passed a bill (California AB-2037) that required Mexican power generators to comply with California air quality regulations in order to sell electricity to California utilities (Blackman et al, 2012). However, this law only applied to new power plants, not existing plants (Bussewitz, 2010). In response to the controversy the Mexicali plants eventually installed some pollution control measures, but would still not comply with the stricter environmental standards in the US (Carruthers, 2007; Blackman et al, 2012).

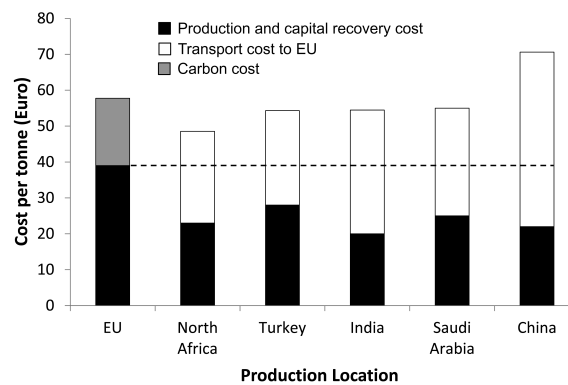
2.2.1 Regulatory Asymmetry and "Leakage"

In the example above, regulatory asymmetry led to facilities in each region operating to different standards. To that extent, the regulation in place at the time in the US seems to have successfully led to environmental improvement in the operations over which they applied. However, those environmental standards also resulted in a phenomenon known as "leakage"; the relocation of production from the higher-regulatory-standard region to the lower-regulatory-standard region. The cement in-

dustry under the European Union Emissions Trading Scheme (EU-ETS) provides another illustration of the risk of such leakage.

Cement possesses a low margin-to-mass ratio, making it relatively expensive to transport. It is also composed primarily of limestone, which is widely available. These two facts have historically made cement (in most cases) infeasible and unnecessary to ship significant distances. As evident in Fig. 4, production and capital recovery costs (the black portion of each column) are greater in Europe than in regions in which they could potentially receive imports. However, after accounting for transport costs from those regions to Europe (the white portion of the column for each potential exporting region), European cement manufacturers have traditionally had the distinct cost advantage (Boston Consulting Group, 2008b). As a consequence, less than 1.5% of European cement revenues were generated by imports from extra-EU regions (European Commission, 2009). The EU-ETS, however, could dramatically change this competitive balance.

Fig. 4 Total landed cost (production and capital recovery cost plus transport cost) is greater outside of Europe than within Europe. However, emissions regulation threatens to put European cement manufacturers at a cost disadvantage, potentially resulting in imports displacing the production of cement in Europe. (sources: Boston Consulting Group, 2008b; Thomson Reuters, 2014)



The EU-ETS applies carbon costs to goods produced within Europe, but not to goods produced outside Europe that are imported into the region. Consequently, as illustrated in Fig. 4, carbon costs projected to be incurred by European manufacturers under Phase 4 of the policy (to be implemented in 2020) swing the advantage to potential exporting regions.¹ Due to the regionally-asymmetric nature of carbon regulation, cement manufacturers in North Africa are expected to have a significant cost advantage over European manufacturers, and manufacturers in Turkey, India, and Saudi Arabia are expected to have a slight cost advantage.

Unabated, this setting is likely to lead to leakage, with European production being displaced by production elsewhere. Indeed, Boston Consulting Group (2008a) projects that at an emissions allowance price of €25 per ton of CO₂, all production in Italy, Greece, Poland, and the United Kingdom would be displaced by imports from

¹ The carbon cost per ton of cement in Fig. 4 assumes a cost of €25 per ton of CO₂, roughly in line with Point Carbon's projected average cost of €23 per ton for 2020 to 2030 (Thomson Reuters, 2014).

countries beyond the umbrella of the EU-ETS. When leakage arises, regulation fails to have its intended effect. Rather than abate environmental harm, regulation that leads to leakage simply relocates it. By doing so, the regulation can have adverse effects. In the cement example here, Boston Consulting Group (2008a) estimates that, as a result of the leakage described above, global emissions would *increase* by 7 million tons of CO₂, in part due to the difference in production technologies employed, and in part due to the increased transportation required to ship cement to the EU.

3 Examples of Environmental Regulation Outcomes

As is clear from the discussion above, well-intentioned environmental regulation varies considerably in its effect on firm decisions. In some instances, the regulation is ignored by the firms it targets, in others it results in firms exiting the region or abandoning the market entirely, and in many other instances it results in the desired abatement. The expected cost of noncompliance (relative to the expected cost of compliance) and the degree of regional asymmetry in regulatory stringency are two of the most important determinants of firms responses. Here, we offer examples where firm decisions were driven by each.

3.1 Expected Cost of Noncompliance is Too Low

There are many instances where environmental regulation fails to have its desired effect, or any effect at all, on firm abatement efforts. In such cases, an insufficient expected cost for remaining noncompliant with the regulation is often to blame. As noted above, the expected cost of noncompliance might not drive change because the stated penalty itself is insufficient, or because there is inadequate monitoring to detect violations and/or too little enforcement of the regulatory controls.

3.1.1 Insufficient Penalty—Leak Detection in Gasoline Storage

One of the most obvious ways in which the expected cost of noncompliance can prove insufficient is if the established penalty for violations is not substantial enough to encourage compliance.² In September, 2011, the State of California accused Chevron USA and Chevron Stations of, among other things, tampering with leak detection equipment. At issue was the placement of sensors that are intended to alert operators if underground gasoline storage tanks at the stations were leaking. Such leak detection sensors are only effective when installed within a certain, known,

² Penalties can result from administrative, civil, or criminal actions (Stafford, 2002).

distance from the tanks, and many of Chevron's sensors had been placed out of that range, rendering them useless. Chevron settled with the State a week later, agreeing to pay \$24.5 million and submit to a statewide compliance program to correct the violations (State of California Department of Justice, Office of the Attorney General, 2011).

Almost a year and a half later, in January 2013, the State sued Phillips 66 and ConocoPhillips (State of California Department of Justice, Office of the Attorney General, 2013b), and a month later sued BP and their ARCO gas stations for many of the same violations levied against Chevron (State of California Department of Justice, Office of the Attorney General, 2013a). In some cases, the State alleges that BP instructed station owners to improperly install the sensor equipment (CBS San Francisco and Bay City News Service, 2013). Presumably these firms were aware of Chevron's settlement and the State's continued detection efforts. Thus, the detection and enforcement of similar violations was likely. Both Phillips 66/ConocoPhillips and BP/ARCO had plenty of time to correctly place any improperly installed sensors, but, ultimately, they were accused of running afoul of the same regulations as Chevron, suggesting that the penalty (signalled through Chevron's settlement) may have been insufficient to catalyze action.

3.1.2 Insufficient Detection—The Deepwater Horizon disaster

The presidential commission responsible for investigating the *Deepwater Horizon* disaster found that the explosion and spill were preventable. They claimed several poor decisions and omissions had contributed to the disaster, including failure to use a sufficient number of centralizers to keep the pipe in the center of the well, poor selection in the type of steel used, and a failure to heed or share test results that indicated that the well seal was subject to failure (Graham et al, 2011). Why, with regulation in place to address offshore oil drilling safety, did BP operate *Deepwater Horizon* horizon drilling this way?³ Arguably, they deemed it was unlikely that they would be caught; i.e., the detection of noncompliant operation was insufficient because the monitoring organization was found to be compromised (Graham et al, 2011).

Monitoring the compliance of offshore drilling operations with the Clean Water Act was the responsibility of the then-named Minerals Management Service (MMS). However, in addition to monitoring compliance, the MMS also collected revenue for offshore drilling rights from the same facilities it was tasked to monitor. The presidential commission found that a "culture of revenue maximization" at the MMS had led to poor oversight of offshore drillers in US waters. In fact, every Director of the MMS for the 15 years prior to the *Deepwater Horizon* disaster, has

³ While multiple companies are being held liable for the accident and spill to different degrees, the burden is mostly BP's. Federal judge Carl Barbier recently ruled that BP is 67% responsible, Transocean 30%, and Halliburton 3% (United States of America v. BP Exploration & Production, Inc., et al, 2014).

since acknowledged the primacy of royalty collection over regulatory oversight at the agency (Graham et al, 2011).

It was in this compromised regulatory environment that BP ignored the industry's best practices in order to save money and time (Graham et al, 2011). Despite the presence of protective laws on the books, the company chose to ignore them and (absent the disaster that ultimately arose) they could do so with little fear that they would be caught. The expected cost of noncompliance was low because detection efforts were insufficient.

One of the outcomes of the scandal surrounding the MMS's failures to prevent the BP disaster was a total reorganization of the agency into three new agencies in order to separate the collection of oil and gas royalties from regulatory oversight: the Bureau of Ocean Energy Management; the Bureau of Safety and Environmental Enforcement; and the Office of Natural Resources Revenue (Bureau of Ocean Energy Management, Regulation and Enforcement, 2015; Salazar, 2010). In direct response to the *Deepwater Horizon* disaster, the Department of Interior also recently proposed new regulations to "improve equipment reliability" and reform rules "in well design, well control, casing, cementing, real-time well monitoring and subsea containment" (US Department of Interior, 2015).

3.1.3 Insufficient Enforcement—New Mexico's Dairy Industry

Dairy farming has been part of life in the US Southwest since Spanish colonization. However, nitrate, a by-product of dairy farming, can contaminate sources of drinking water in the absence of adequate containment (Doremus, 2003). This is of particular concern in the arid state of New Mexico where 90% of drinking water is sourced from aquifers (South Central Climate Science Center, 2015; US Environmental Protection Agency, 2011), some of which are relics of the last ice age (Plummer et al, 2004).

Nitrate enters groundwater through porous soil if dairy farmers dump waste from their cows into unlined or inadequately lined retention lagoons, among other avenues (Doremus, 2003). Once nitrate contaminates the water, it's expensive and difficult to remove. Consuming contaminated water is especially dangerous to infants, potentially causing "blue baby syndrome" (low blood oxygen in babies), and death (US Environmental Protection Agency, 2014b). To prevent such contamination, New Mexico has set limits on several contaminants, including nitrate, allowed in its groundwater (Olson, 2015). To monitor compliance, all dairies are required to have permits, and all permits require monitoring wells, with sampling results submitted to the Ground Water Quality Bureau (McGrath, 2010). By 2010, nearly all permitted dairies in New Mexico had monitoring wells installed (McGrath, 2010).

Despite the near-universal monitoring, and the existence of technology to prevent contamination (in this case, the installation of synthetic liners), most New Mexico dairy farmers operate out of compliance. Many opt not to line their wastewater storage lagoons, or to line them with clay, manure, or compacted earth, which do little to prevent contamination. As a result, nitrate groundwater contamination has been

discovered at 60% of the state's dairies, with nitrate levels at 20 times the allowable limits in some cases (McGrath, 2010).

In this case, the issue is one of insufficient enforcement. The agency responsible for overseeing compliance—the Ground Water Quality Bureau—has experienced high turnover of key staff (Keller, 2013; Paskus, 2013), is chronically understaffed,⁴ and is currently awaiting the outcome of administrative hearings to determine whether the permitting process will remain in place or become less rigorous in terms of groundwater protection, which the industry is pushing for (Keller, 2013; New Mexico Environment Department, 2014; Olson, 2015). As a consequence, they have been unable to enforce compliance in the manner intended, and dairy farmers can operate out of compliance with little risk of punishment. In fact, if this scenario were to change and enforcement were made more likely, some operators have expressed an intent to take their business elsewhere: “we will go to Texas, or we will go to Oklahoma, or we will go to Colorado” (Ogburn, 2011).

3.2 Expected Cost of Noncompliance is Too High

As suggested by the threat above to take dairy business to states other than New Mexico if groundwater controls there were fully enforced, the expected cost of complying with regulation can cause firms to offshore or abandon a market altogether. Examples from lead smelting demonstrate this risk of offshoring and market abandonment.

3.2.1 Offshoring—Secondary Lead Smelting in the US

Spent (i.e., depleted) lead-acid batteries (SLABs) provide raw material for secondary lead smelters (defined as smelters that use sources other than raw lead ore), with these SLAB smelters responsible for 90% of US lead production. Further, approximately 90% of the lead consumed in the US is in the form of lead-acid batteries (Guberman, 2014). Lead production in the US therefore has many characteristics of a closed loop supply chain—lead-acid battery recovery enables production that serves lead-acid battery demand—except there is a hitch.

There is an extremely high recycling rate for SLABs in the US, on the order of 98% recovery (The Battery Council International, 2013). However, many hazardous materials can be emitted in the recycling process, including lead, so the process is strictly controlled by US environmental regulations, which drives significant compliance costs (US Environmental Protection Agency, 2014c). To prevent *leakage*—the relocation of production from the regulated region to less-regulated regions—it has been made illegal in the US to send unauthorized batteries to be recycled in other countries (US Environmental Protection Agency, 2012). Nevertheless, due to

⁴ Based on the authors' personal experience and the Ground Water Quality Bureau's organizational chart (New Mexico Environment Department, Ground Water Quality Bureau, 2014).

regional variation in compliance costs, significant volumes of the SLABs recovered in the US are exported to regions with lower regulatory standards, including Mexico, with roughly a 500% increase in known SLAB exports from the US to Mexico between 2004 and 2011.⁵ By 2012, US exports supplied up to 60% of the SLABs recycled in Mexico (Lloyd, 2012).

Rather than the regulation succeeding in abating the targeted toxic emissions, leakage results in their relocation and potential exacerbation. In the case of Mexican SLAB recycling, for example, the standards for worker exposure and environmental contamination are much lower in authorized Mexican facilities than in US facilities, and nonexistent in unauthorized facilities, of which there are many (Lloyd, 2012). As a result, contamination poses a significant problem—Mexican workers in one recycling plant were found to have blood lead levels five times higher than workers in a US plant (Occupational Knowledge International and Fronteras Comunes, 2011), and soil sampled by the New York Times at an elementary school playground outside of another Mexican plant had lead levels five times higher than considered safe by the US EPA (Rosenthal, 2011).

3.2.2 Abandonment—Primary Lead Smelting in the US

Until recently, the US was home to both secondary and primary lead smelting. However, the last primary lead smelter—located in Herculaneum, MO, and operated by the Doe Run Company—closed in late 2013. The company made an agreement with the EPA to shut down rather than upgrade the plant with new technology that would reduce SO₂ and lead emissions at a cost of around \$100 million (The Doe Run Company, 2013; Jones, 2013). In the words of Doe Run Company's general manager Gary Hughes:

We are aware of no primary lead smelting process that will meet the standard for ambient air at the Herculaneum site. We believe the only existing technology that can meet today's standards in Herculaneum, as well as potential future standards, is the new electrowinning lead metal process we announced in 2010. We hoped to be building such a plant by now, however constructing a full-scale plant given other regulatory compliance spending requirements puts our company at financial risk (The Doe Run Company, 2013).

In this case, rather than reducing the environmental intensity of primary lead smelting, regulation forced the smelters to shutter their business. Whether or not this would be beneficial or harmful to the environment depends on how the demand that had been served by primary smelters is satisfied post-abandonment. If consumption decreases or demand is served by less environmentally-intensive producers as a result of abandonment, then the environmental performance would improve as a consequence of abandonment. However, if the production in the regulated region is simply displaced by less-regulated production outside the region (i.e., *leakage* results from abandonment), then abandonment can increase environmental intensity

⁵ The US ambient air standards for lead became even more restrictive in 2008, which led to a surge in lead battery exports (Lloyd, 2012).

due to the use of more toxic processes and technologies and the additional transport required to deliver the goods to the regulated market.

3.3 Expected Cost of Noncompliance is On-Target

Environmental regulation will incentivize firms to invest in abatement effort when: (i) the expected penalties for noncompliance exceed the cost of compliance; and (ii) the cost of compliance are more favorable than offshoring production or exiting the market. In such settings, not only do the odds of a firm embracing regulatory requirements through the adoption of proven technologies increase, but innovation related to abatement efforts can be catalyzed as well, as the following examples from the textile and power generation sectors illustrate.

3.3.1 Adoption—The Cotton Dust Standard

Cotton dust, a waste by-product emitted during yarn manufacturing and automated knitting and weaving, was known to cause byssinosis (“brown-lung disease”), which is a respiratory illness resulting in wheezing, shortness of breath, and sometimes death among the exposed (Sutcliffe, 2000). The Occupational Safety and Health Administration (OSHA) passed the Cotton Dust Standard to keep cotton dust emissions within levels deemed safe for worker health. Producers fiercely fought the regulation, claiming that it would cause them to bear an economic burden that would undermine their ability to compete in the global market (The Wall Street Journal, 1981). In 1981, the US Supreme Court upheld the Standard, deciding that OSHA was not obligated to consider the cost-benefit of regulation when protecting worker health (Viscusi, 1985). Producers ultimately complied with the Standard, with actual compliance costs coming in more than an order of magnitude *under* industry projections (The Wall Street Journal, 1981; Occupational Safety and Health Administration, 2000).

Contrary to the sector’s protestations, compliance with the Cotton Dust Standard was credited with improving the global competitiveness of US textile manufacturing. At the time, *The Economist* reported that US textile exports increased 45% year-over-year due to the regulation catalyzing a technological advantage, stating that “tighter dust control rules for cotton plants caused firms to throw out tonnes of old, inefficient machinery and to replace it with the latest available—to produce better quality and higher output speeds of fabrics” (1980).

Industry compliance with the regulation occurred faster than required, more cheaply than predicted, and was successful in protecting worker health by greatly reducing the incidence of brown lung disease among textile workers (Glindmeyer et al, 1991; Occupational Safety and Health Administration, 2000). The Cotton Dust Standard proved successful because alternative, compliant technology existed, and the cost of compliance was significantly less than the penalties firms would have

incurred had they failed to comply—in fact, by *The Economist's* account (1980), the cost of compliance was negative in this case, improving firm profitability. The US textile industry was behind the times, technology-wise, and the Cotton Dust Standard provided the incentive to update its core technologies, boosting productivity even as the operators came into compliance with the new standards. Regulation spurred widespread adoption of an available technology. As we will see through the example below, well-designed regulation can also catalyze innovation to enable the adoption of new technologies.

3.3.2 Innovation—The Acid Rain Program

The Acid Rain Program (ARP) provisions of the 1990 Clean Air Act Amendments were implemented to address concerns over air pollution and the effects of acid rain caused by SO₂ and nitrogen oxide (NO_x) emissions from coal-fired power generation. The ARP is a classic cap and trade regime wherein the EPA determines the total number of SO₂ allowances to issue each year (i.e., they set the “cap”), and then coal-fired power generators buy and sell allowances from that fixed pool (i.e., they “trade”). If they over-comply relative to the number of allowances that they own, firms can sell their excess. If a firm emits more SO₂ than they have allowances for, they can purchase more allowances from the issued allowance-currency. This trading sets the allowance market price. To reduce the amount of SO₂ emitted, the EPA lowers the cap (i.e., total allowance currency) over time.⁶

The targeted reduction of SO₂, which was significantly more expensive to control than NO_x (Smock, 1991), was set at 10 million tons below 1980 levels annually, representing roughly a 60% reduction (Ellerman et al, 2000; Ellerman, 2003; Stavins and Schmalensee, 2012). Compliance with the SO₂ program was largely achieved by power generators switching to lower-sulfur coal and the use of flue-gas desulfurization systems; i.e., “scrubbers” (Ellerman, 2003). The benefits have been substantial, with up to a 50-1 benefit-to-cost ratio, based largely on positive human health effects—reductions of respiratory disease and mercury toxicity—rather than acid rain reduction itself (Chestnut and Mills, 2005; Stavins and Schmalensee, 2012).

Unlike compliance with the Cotton Dust Standard, technological innovation (as opposed to the adoption of proven technologies) played a central role in the effectiveness of the ARP program. In order to reduce their SO₂ emissions, coal-fired power generators learned how to mix various kinds of coal to create lower sulfur blends and how to develop financially feasible “scrubber” systems (Stavins and Schmalensee, 2012, citing Bellas and Lange, 2011; Ellerman et al, 2000; Frey, 2008; Popp, 2003). The ARP also led many companies to adopt new internal processes to account for allowance price uncertainty and risk when making operational decisions (Kruger, 2005).

⁶ If a reduction of SO₂ emissions does not arise when the cap is lowered, then the allowance price increases through standard demand and supply economics. As the cap is reduced further, this results in a cost trade-off that eventually favors improved abatement effort.

The regulatory landscape for power generators is politically loaded these days, but there was relatively little pushback when operators were faced with the ARP. Operators had a hand in designing the program, and the cap-and-trade design of the regulation provided the flexibility for improvements to be made where they were most cost efficient (while allowing others to “pay to pollute” through the purchase of allowances).

4 Decision Framework: Ignore, Avoid, Abandon, and Embrace

As discussed above, firms’ responses to environmental regulation can run the gamut from ignoring the regulation, to implementing the intended improvements, to closing down or offshoring their business. Which path a profit-maximizing firm would take is determined, in part, by the expected cost of noncompliance p and the cost that they would incur to offshore F . Two other factors help determine a firm’s response to environmental regulation: (i) the class of environmental regulation the firm faces; and (ii) relative expected cost of noncompliance thresholds.

There are two broad classes of environmental regulation that a firm may face: a command-and-control/compliance-based regime, or a “pay-to-pollute”/market-based regime. Under compliance-based regulation—such as the New Mexico “Dairy Rule”, the ambient air quality standards of the Clean Air Act amendments, and the Cotton Dust Standard—firms are either in compliance or out of compliance. Under a compliance-based regime, if the firm operates within the established standard it faces no penalty. They are only at risk of being penalized if they operate outside the standard (i.e., if they are noncompliant). Under a “pay-to-pollute” regime—such as the Acid Rain Program of the Clean Air Act Amendments and carbon emissions regulation under European Union Emissions Trading Scheme—there is no set standard *per se*. Under such a regime, each and every unit of the regulated pollutant that the firm emits is costly (i.e., causes them to consume a permit).

There are three expected cost of noncompliance thresholds that affect a profit-maximizing firm’s decision-making in this context. First is the expected cost of noncompliance at which the firm is (economically) indifferent to compliance and noncompliance, p_c . Under compliance-based regulation, this is the break-even expected penalty for compliance. Under “pay-to-pollute” regulation, this can be viewed as the break-even expected penalty for clean technology adoption—i.e., it is the expected penalty at which the firm earns equal expected profits with a clean and dirty technology. Second is the expected noncompliance cost break-even for domestic and offshore production, $p_o(F)$, which increases as the cost to offshore increases (the profit-maximizing firm is willing to operate in the regulated domestic region at greater expected noncompliance costs if the cost to offshore is greater). And third is the expected cost of noncompliance threshold at which out-of-compliance production becomes unprofitable in the regulated region, p_e . These thresholds are summarized in Table 1.

Table 1 Expected cost of noncompliance thresholds

p_c	Expected noncompliance cost break-even for compliance / clean-tech adoption
$p_o(F)$	Expected noncompliance cost break-even for domestic and offshore production
p_e	Expected noncompliance cost beyond which domestic production is unprofitable

The relative magnitudes of these thresholds determine a profit-maximizing firm's response to environmental regulation under both compliance-based and "pay-to-pollute" regimes.

4.1 Decisions Under Compliance-Based Regulation

A profit-maximizing firm's potential responses to compliance-based environmental regulation depend on whether: (i) the compliance threshold is less than the offshoring threshold for any fixed offshoring cost, $p_c \leq p_o(0)$; (ii) the compliance threshold is greater than the offshoring threshold at some offshoring cost, but less than the exit threshold, $p_o(0) < p_c \leq p_e$; or (iii) the compliance threshold is greater than the exit threshold, $p_e < p_c$.

If the break-even for compliance is less than the break-even between domestic and offshore profit at any offshoring cost, $p_c \leq p_o(0)$, then the firm will either ignore or embrace the regulation (as illustrated in Fig. 5a). If the expected cost of non-compliance, p , is greater than the expected cost of compliance, p_c , then the firm adheres to the regulation. Otherwise, the profit-maximizing firm ignores the regulation and continues operating as it had (e.g., *Deepwater Horizon* and the compromised monitoring of the MMS due to conflicts of interest).

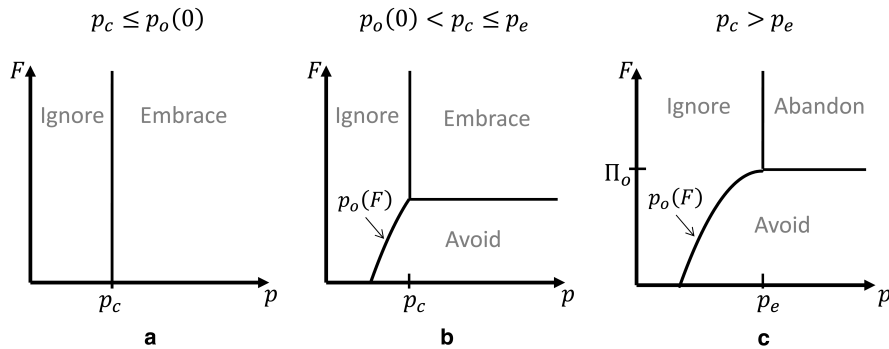


Fig. 5 Ignore, embrace, avoid, and abandon decisions under compliance-based regulation when: **a** the compliance threshold is less than the offshoring threshold, $p_c \leq p_o(0)$; **b** the compliance threshold is between the offshoring threshold and exit threshold, $p_o(0) < p_c \leq p_e$; and **c** the compliance threshold is greater than the exit threshold, $p_c > p_e$.

Figure 5b illustrates the case where $p_o(0) < p_c \leq p_e$; i.e., the expected cost of compliance is greater than the break-even between domestic and offshore profit at some fixed offshoring cost and it is less than the cost at which domestic production becomes unprofitable. In such a setting, the regulator can only induce compliance if the expected cost of noncompliance *and* offshoring costs, F , are sufficiently great. If the cost a firm incurs when offshoring is small enough, then (because $p_o(0) < p_c$) a profit-maximizing firm would relocate their operations at a sufficiently great expected noncompliance cost rather than comply. Secondary lead smelting (discussed in Sect. 3 above), with its 500% increase in SLAB exports to Mexico for processing there rather than in the US, provides one such example with relocation was deemed a more attractive option to firms than compliance.

Lastly, the case where the expected cost of compliance exceeds the expected cost of noncompliance at which domestic production becomes unprofitable, $p_c > p_e$, is illustrated in Fig. 5c. In this setting, the regulator cannot induce a profit-maximizing firm to adopt more stringent standards at any expected cost of noncompliance. At sufficiently great noncompliance costs, firms will either avoid the regulation by offshoring production (if the cost to offshore is sufficiently small), or they will abandon the market if offshoring costs exceed the profit that they could earn by relocating, Π_o . Primary lead smelting in the US provides an example of this context, where increasingly stringent air quality standards contributed to the Doe Run Company closing the last primary lead smelter in the country. If the demand that the abandoning firm had served is satisfied by less environmentally impactful providers, then abandonment by the worst performers can be a beneficial outcome. However, if market abandonment results in the abandoning firms market share falling to more environmentally harmful producers (as can often be the case when demand shifts to less regulated regions due to abandonment), then the regulatory standards that drove abandonment would have an adverse effect on environmental performance.

4.2 Decisions Under “Pay-to-Pollute” Regulation

As with compliance-based regulation, firms’ response to a “pay-to-pollute” regime depend on the relative magnitude of the clean technology adoption, offshoring, and exit thresholds, p_c , $p_o(0)$, and p_e , respectively. The key difference between compliance-based and “pay-to-pollute” regulation is that, under the latter, firms incur environmental costs regardless of the technology they operate (unless they fully eliminate the regulated pollutant), while the firm avoids further environmental cost under a compliance-based regulation so long as they meet the specified standard. As a consequence, it is possible for “pay-to-pollute” regulation to “overshoot”, leading to offshoring or market abandonment rather than clean technology adoption.

The potential to overshoot is evident in the case where the clean technology adoption threshold is less than the offshoring threshold, $p_c \leq p_o(0)$, illustrated in Fig. 6a. If the penalty for each unit of pollutant emitted, p , is sufficiently greater than the clean technology adoption threshold, regulation can result in offshoring or aban-

donment (depending on whether offshoring costs, F , are sufficiently small), which sharply contrasts the compliance-based setting illustrated in Fig. 5a. Similarly, overshooting is possible when the clean technology adoption threshold is greater than the offshoring threshold, but less than the exit threshold, i.e., $p_o(0) < p_c \leq p_e$, as illustrated in Fig. 6b.

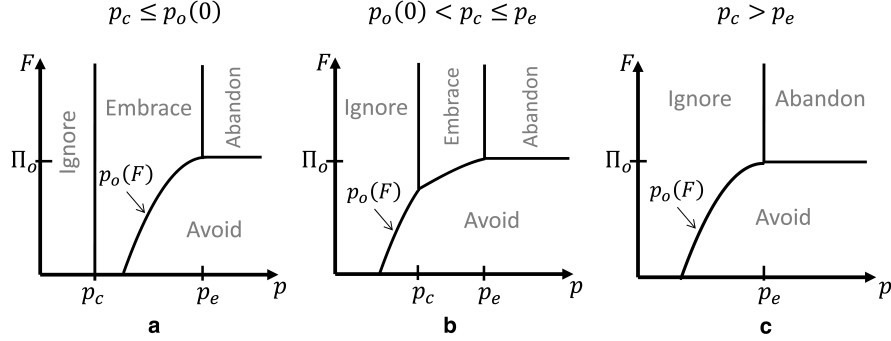


Fig. 6 Ignore, embrace, avoid, and abandon decisions under “pay-to-pollute” regulation when: **a** the clean technology adoption threshold is less than the offshoring threshold, $p_c \leq p_o(0)$; **b** the adoption threshold is between the offshoring threshold and exit threshold, $p_o(0) < p_c \leq p_e$; and **c** the adoption threshold is greater than the exit threshold, $p_c > p_e$.

If the clean technology adoption threshold exceeds the exit threshold, $p_c > p_e$, then overshooting is not a concern because, as in the case with compliance-based regulation, there is no region in which the regulator can induce environmental improvement (as illustrated in Fig. 6c. This appears to be the setting with carbon capture and storage in cement under the EU-ETS as described in Sect. 2.2.1, where the emission price that would incentivize the adoption of carbon capture and storage technology (European Cement Research Academy, 2009) is greater than the emissions price at which cement production would offshore or abandon the market (Boston Consulting Group, 2008a).

5 Conclusion

A regulator’s ability to incentivize environmental improvement among firms is vital in achieving long-term sustainability, particularly with continued growth in aggregate consumption projected. However, firms can and do respond to environmental regulation in a variety of ways: complying with its intent; avoiding the regulation by offshoring or by abandoning the market; or ignoring the regulation by continuing with entrenched business practices.

The path a profit-maximizing firm will choose depends, in part, on the expected cost of noncompliance, which is a product of the regulator’s stated penalty, the likelihood that noncompliant practices are detected, and the likelihood that detected vi-

ulations are punished. However, the type of regulatory regime—compliance-based or “pay-to-pollute”—and three cost thresholds also drive firm response: (i) the compliance or clean technology adoption threshold; (ii) the offshoring threshold; and (iii) the exit threshold. Understanding how these thresholds interact with the type of regulatory regime being considered and the expected cost of noncompliance to determine whether firms ignore, avoid, or embrace the regulation is a vital first step in the design of efficacious environmental policy.

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