Chapter 4

Regulatory and Non-Regulatory Approaches to Environmental Policy

This chapter describes several regulatory and non-regulatory approaches used in environmental policy making. It also highlights a few key advantages and disadvantages of each approach, provides an overview of cross-cutting policy design issues, and offers references for those interested in a more in-depth discussion. This chapter covers four general approaches to environmental policy making: (1) command-and-control regulation; (2) market-based approaches; (3) hybrid and other approaches; and (4) voluntary programs.[1] While command-and-control regulation has been a commonly used approach to environmental regulation in the United States, market-based and hybrid approaches can sometimes offer increased flexibility and lower costs. Voluntary programs may encourage environmental improvements or allow new approaches to be tested in areas not traditionally regulated by the U.S. Environmental Protection Agency (EPA).

The policy approaches discussed here are conceptually distinct, but they can sometimes be designed in ways to achieve similar benefits and costs. The approaches can also be combined into hybrid policy instruments, and multiple instruments can be used in tandem to address environmental problems caused by multiple market failures.[2] As such, the approaches discussed in this chapter represent an overlapping continuum of policy design tools.

4.1 Traditional Command-and-Control or Prescriptive Regulation

A prescriptive regulation is a policy that stipulates how much pollution an individual source or plant is allowed to emit and/or what types of control equipment or approaches it must use to reduce pollution. Prescriptive regulations are also known as "direct regulatory instruments" or "command-and-control" regulations (Goulder and Parry 2008; Ellerman 2006). Despite the introduction of potentially more cost-effective approaches for regulating emissions, this type of regulation is still often used and is sometimes required by law. It is almost always available as a "backstop" if other approaches do not achieve desired pollution limits.

A common approach to prescriptive regulation is to issue a license or permit to an individual facility or firm that specifies the allowable level of pollution and the conditions under which it can be released into the environment. For instance, a permit issued to a hazardous waste treatment facility typically stipulates what

1 Baumol and Oates (1988), particularly Chapters 10-14; Kolstad (2010); Field and Field (2021); Tietenberg and Lewis (2014); and Phaneuf and Requate (2016) are useful references on the economic foundations of many of the approaches presented here.

2 This chapter uses the terms "approaches" and "instruments" interchangeably when discussing various policy or regulatory tools.

waste management activities can be conducted at the site. It may also include requirements for safety and training, insurance, monitoring and reporting. The EPA may also set minimum standards when the licenses or permits are issued by another authority, such as states or tribes.

It is also common for a prescriptive regulation to be defined in terms of a source-level emission rate, which means that it does not directly control the aggregate emission level. In such cases, aggregate emissions will depend on the number of polluters and the output of each polluter. As either production or market size increase, so will aggregate emissions. Even when the standard is defined in terms of an emission level per polluting source, aggregate emissions will still be a function of the total number of polluters.

When abatement approaches and costs are similar across regulated sources, a source-level standard may be reasonably cost-effective. However, when abatement costs vary substantially across polluters, reallocating abatement activities so that some polluters abate more than others could lead to substantial cost savings. For example, if reallocation were possible through a less prescriptive market-oriented approach, a polluter facing relatively high abatement costs could continue to emit at its current level but would have to pay an emissions tax or purchase allowances, while a polluter with relatively low abatement costs could reduce its emissions, allowing it to avoid the tax or sell its allowances (see Section 4.3 for more discussion of these approaches).[3]

Note that regulators can account for some variability in costs by allowing prescriptive regulations to vary according to size of the polluting entity, production processes, geographic location, or other factors. However, a prescriptive regulation usually does not allow for reallocation of abatement activities to take place — each entity is still expected to achieve a specified emission rate or use certain abatement technologies.

Prescriptive regulations can involve restricting — or in the most stringent case, prohibiting — the production, use, or disposal of specific products or substances. For instance, the EPA has banned most uses of chlorofluorocarbons (CFCs) and certain pesticides. This approach to regulation is potentially useful in cases where the level of pollution that maximizes social welfare is at or near zero. Prescriptive regulations include technology or design standards and performance-based standards, discussed below.

4.1.1 Technology or Design Standards

A technology or design standard mandates the use of specific control technologies or production processes an individual facility must use. This type of standard constrains firm behavior by mandating how a source must reduce pollution, regardless of whether such an action is cost-effective. Technology standards may be particularly useful in cases where the cost of emissions monitoring is high but determining whether a specific technology or production process has been put in place (and is operating properly) to meet a standard is relatively easy. However, since these types of standards specify the abatement technology required to reduce emissions, sources do not have an incentive to invest in more cost-effective types of abatement or to explore new and innovative abatement strategies that are not permitted by regulation.

Key advantages:[4]

- Technology or design standards can yield environmental improvements with a high level of certainty.
- Technology or design standards can approximate an economically efficient outcome if the regulated industry is relatively small and has limited options and similar abatement costs across firms.

3 Tietenberg and Lewis (2014) discussed empirical studies on the cost-effectiveness of prescriptive air pollution regulations. Of the 10 studies included, eight found that prescriptive regulations cost substantially more than the most cost-effective strategy. Harrington et al. (2004) compared the costs and outcomes of command-and-control and market-based approaches in the United States and Europe. Newell and Stavins (2003) generated rules of thumb to help determine when market-based incentives may result in cost savings over prescriptive regulations.

4 The discussion of key advantages and disadvantages of each approach is intended to highlight a few notable features but is not intended to be exhaustive.

- If it is costly or infeasible to directly monitor emissions or environmental damages, technology standards may provide an easier approach to monitor compliance with regulatory requirements.

Key disadvantages:

- Technology or design standards are less likely to be economically efficient when there are a large number of diverse firms with varying abatement options because they do not allow for flexibility in the approach to pollution reduction or in the distribution of pollution reduction across sources.
- These standards do not create incentives for innovation of new technologies and approaches to achieve the environmental improvements at lower cost.
- These standards could motivate rent-seeking by firms seeking to secure a guaranteed market for specific pollution control technologies.

4.1.2 Performance-Based Standards

A performance-based standard requires that polluters meet a source-level emission standard but allows a polluter to choose among available methods to comply with the standard. At times, the available methods are constrained by additional criteria specified in a regulation. Performance-based standards that are technology-based do not specify a particular technology, but rather consider what is possible for available and affordable technology to achieve when establishing a limit on emissions.[5]

A performance-based standard can be defined in terms of an emission *level* or an emission *rate* (i.e., emissions per unit of output or input). A standard that specifies an emission level allows a source to choose to implement an appropriate technology, change its input mix or reduce output to meet the standard. An emission rate may be more restrictive depending on how it is defined. If the emission rate is defined per unit of output, then it does not allow a source to meet the standard through a reduction in output. If the standard is defined as an average emission rate over a certain time period, then the source may reduce output to meet the standard.

While performance-based standards encourage firms to meet the standard at lower cost, they generally do not provide incentives to reduce pollution beyond what is required to reach compliance. Also, because permitting authority is often delegated to the states, approval of a technology in one state does not ensure its use is allowed in another. For both of these reasons, there is limited incentive for regulated firms to develop new, less expensive and potentially superior technologies (Swift 2000; Johnstone et al. 2010).

Key advantages:

- Performance standards, like technology and design standards, can yield environmental improvements with a high level of certainty.
- Performance standards can allow more flexibility to achieve environmental benefits at lower cost compared to technology or design standards.
- Performance standards create greater incentives for technological innovation than technology or design standards.

5 As an example, Reasonably Available Control Technology (RACT) specifies that the technology used to meet the standard should achieve "the lowest emission limit that a particular source or source category is capable of meeting by application of control technology that is reasonably available considering technological and economic feasibility."

Key disadvantages:

- Performance standards are unlikely to be as economically efficient as market-based policies if abatement costs vary substantially across sources.
- Performance standards do not incentivize sources with low abatement costs to make environmental improvements beyond what the standard requires.
- If technological innovation yields lower-cost abatement opportunities in the future, the standard may need to be tightened over time to more closely approximate an economically-efficient outcome.

4.2 Market-Based Approaches

Market-based regulatory approaches create an incentive for the private sector to incorporate pollution abatement into production or consumption decisions and prompt innovation to explore cheaper methods of abatement. Market-based approaches can differ from more traditional regulatory approaches in terms of economic efficiency, cost-effectiveness and the distribution of benefits and costs. Because market-based approaches do not mandate that each polluter meet a given emission standard, they typically allow firms more flexibility than prescriptive regulations and capitalize on the heterogeneity of abatement costs across polluters to reduce aggregate pollution efficiently. Environmental economists generally favor market-based policies because they tend to be less costly, they place a lower information burden on the regulator and they provide incentives for technological advances.

Market-based policies create incentives for regulated firms to find the cheapest way to reduce pollution. This may involve a reduction in output (and in the extreme, exiting the industry), a change in inputs, the installation of pollution control equipment or a process change that prevents the creation of pollution. Polluters decide individually how much to control their emissions based on the costs of control and the financial incentives created by the policy. While difficult to implement in the case of a non-uniformly mixed pollutant, policy makers can approximate the ambient impact of emissions by incorporating adjustment factors for fluctuations in marginal damages across time, geographic area or populations affected.

Four market-based approaches are discussed in this section:

- Allowance trading systems;
- Emissions taxes;
- Environmental subsidies; and
- Tax-subsidy combinations.[6]

While operationally different, these market-based approaches put similar incentives in place. This is particularly true of emissions taxes and cap-and-trade systems, which can be designed to achieve the same goal at equivalent cost.

6 Goulder and Parry (2008), Olmstead (2012), and Keohane and Olmstead (2016) compile theoretical and empirical information on the use of economic incentives.

4.2.1 Allowance Trading Systems

Several forms of emissions trading exist, including cap-and-trade and project-based trading systems. The common element across these programs is that sources can trade credits, offsets or allowances so that those with opportunities to reduce emissions at lower costs have an incentive to do so. Emission-rate trading systems, a hybrid approach between tradable allowances and command-and-control, are discussed in Section 4.3.1.3.

4.2.1.1 Cap-and-Trade Systems

In a cap-and-trade system, the government sets the level of aggregate emissions, allowances are distributed to polluters, and a market is established in which allowances may be bought or sold. An allowance is a right to emit one unit of pollution; polluters must own an allowance for each unit emitted. The price of emission allowances is determined by supply and demand in the market and can vary over time.

For a uniformly mixed pollutant where marginal damages are identical for all sources and in all locations, if the cap is set at the efficient level, then the equilibrium price of allowances adjusts so that it equals the marginal damages from a unit of pollution. This equivalency implies that any externality associated with emissions is completely internalized by the firm. For polluters with marginal abatement costs greater than the allowance price, the cheapest option is to purchase allowances and continue to emit. For polluters with marginal abatement costs less than the allowance price, the cheapest option is to reduce emissions and forego purchasing allowances (or to sell any allowances that they own at the market price). As long as the price of allowances differs from individual firms' marginal abatement costs, firms will continue to buy or sell them. Trading will occur until marginal abatement costs equalize across all firms.[7] If the allowance price is lower than the marginal damages from pollution, this implies that the cap is set at an inefficiently high level.

When the government sells allowances at auction, the revenue represents a transfer from the purchasers to the government. Allowance auctions can be designed in a variety of ways. Typically, allowances are purchased through a bidding process that reveals buyers' willingness to pay, with allowances going to the highest bidder.

The government could also decide to allocate allowances to polluters for free according to a specified rule. This represents a transfer from the government to polluting firms, some of which may find that the value of allowances exceeds the firm's aggregate abatement costs (i.e., rents). Economic rents are any payment to the owner of capital or a resource above what it would cost to induce them to engage in a certain behavior.[8] The way in which allowance allocations occur can also affect firm entry and exit decisions. For example, when allowances are allocated based on historical emissions, some old, dirty plants may continue to operate to qualify for allowances.

Additional considerations in designing an effective cap-and-trade system include the number of market participants, transaction costs, banking and hotspots. The United States' experience suggests that a market characterized by low transaction costs and being "thick" with many buyers and sellers is critical if pollution is to be reduced at the lowest cost. This is because small numbers of potential traders in a market can inhibit

7 Schmalensee and Stavins (2017) provide an overview of emission trading programs and lessons learned regarding implementation, system design and performance.

8 Tietenberg (2006) defined scarcity rent as, "producer's surplus which persists in long-run competitive equilibrium." In the context of a cap-and-trade market, these rents occur because firms are given allowances that can be bought and sold in the market. For a discussion of scarcity rents created by environmental regulations through pollution restrictions and captured by firms in the form of higher profits, see Fullerton and Metcalf (2001). Buchanan and Tullock (1975) discussed the potential for scarcity rents under a cap-and-trade system where permits are distributed for free.

competitive behavior, and fewer trading opportunities result in lower cost savings. Likewise, the number of trades that occur could be significantly hindered by burdensome requirements that increase the transaction costs associated with each trade.

Banking introduces increased flexibility into a trading system by allowing polluters to save unused allowances for future use. A firm may reduce emissions below the allowance level earlier and bank remaining allowances to cover excess emissions or sell to another polluter at a later time. In this way, polluters that face greater uncertainty regarding future emissions or that expect increased regulatory stringency can bank allowances to offset potentially higher future marginal abatement costs.

Cap-and-trade systems for non-uniformly mixed pollutants have the potential to create temporal or spatial spikes or "hotspots" — areas in which the pollution level has the potential to increase as a result of allowance trading. While one potential solution to this problem is to adjust trading ratios (i.e., the rate at which allowances from one source can be traded with another) to equalize the impact of particular polluters on overall environmental quality, determining the appropriate adjustments to these ratios can be costly and difficult. Another possible solution is zone-based trading.

Two reviews of the literature found little evidence of spatial or temporal spikes in pollution resulting from the use of market-based approaches (Burtraw et al. 2005; Harrington et al. 2004). In fact, market-based approaches have led to smoothing of emissions across space in some cases. These results come primarily from studies of the SO_2 and NOx trading programs (see Text Box 4.1). If the market-based policy is not carefully designed, the results may not transfer to other pollutants that have more localized effects.

4.2.1.2 Project-Based Trading Systems

Offsets and bubbles (sometimes known as "project-based" trading systems) allow restricted forms of emissions trading across or within sources to allow sources flexibility in complying with emission limits or facility-level permits.[9] An offset allows a new polluter to negotiate with an existing source to secure a reduction in the latter's emissions. A bubble allows a facility to consider all sources of emissions of a specific pollutant within the facility to achieve an overall target level of emissions or environmental improvement.

Offsets, which entail cross-firm emissions trading, have been historically hindered by high administrative and transaction costs due to the case-by-case negotiation to convert a technology or emission rate limit into tradable emissions per unit of time, to establish a baseline and to determine the number of offsets generated or required (U.S. EPA 2001). Regulators can improve the efficiency of offsets by allowing third parties, who are not themselves polluters, to participate in the market. Offsets have also been included in cap-and-trade programs for greenhouse gas emissions such as the Clean Development Mechanism of the Kyoto Protocol. Such systems allow entities covered under the cap to purchase offsets for emission reductions or carbon sequestration from firms in industries or locations not covered under the program, increasing the flexibility and reducing the costs of meeting the aggregate greenhouse gas emissions target.

Key advantages:

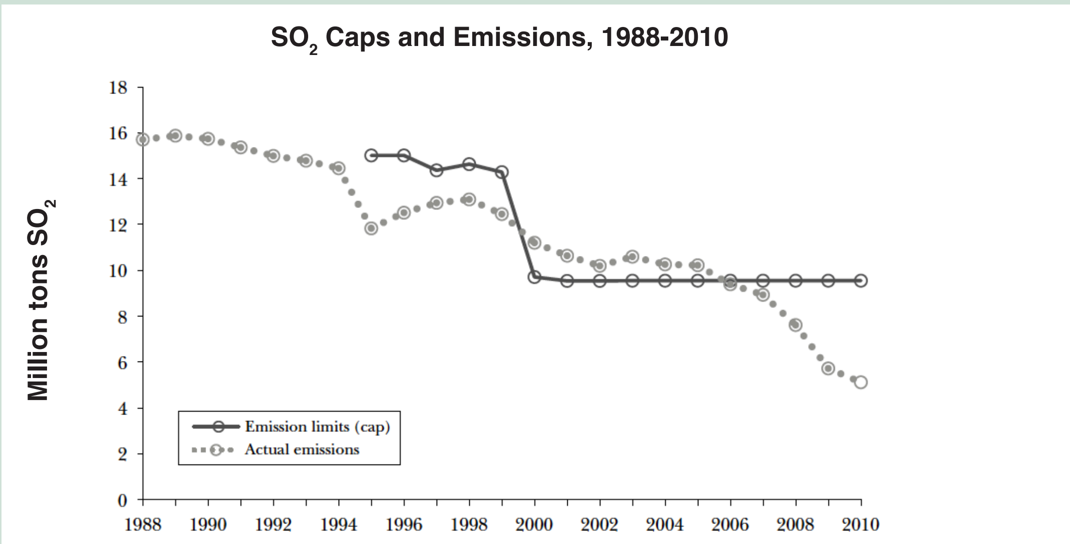
- Like other market-based policies, tradable allowance systems can be more economically efficient than prescriptive regulations, particularly when there are many heterogenous market participants.
- Like other market-based policies, tradable allowances create incentives for innovation as firms compete for new ways to reduce emissions as least cost.

9 Bennear and Coglianese (2012) evaluated how these types of flexibilities have worked in the United States.

Text Box 4.1 - Acid Rain Trading Program for Sulfur Dioxide (SO_2)

In 1995, Title IV of the 1990 Clean Air Act Amendments established a cap-and-trade system for SO_2 emissions to address the problem of acid rain. The 263 highest SO_2-emitting units at 110 electric utility plants were selected to participate in the first phase of the trading program, which limited emissions of SO_2 to 8.7 million tons in 1995. Of the plants that participated in Phase I, most were coal-fired units located east of the Mississippi River. Allowances were allocated to units on a historical basis, after which they could use the allowances, sell them to other units, or "bank" them for use in subsequent years. Phase I plants were required to install continuous emission monitoring systems, which allowed the government to easily monitor and enforce emission restrictions in accordance with the allowances. The second phase of the program, initiated in 2000, imposed a national SO_2 emissions cap of 10 million tons and brought almost all SO_2-emitting units into the system.

Evaluations of the first phase of implementation suggest that the SO_2 trading system significantly reduced emissions. Compliance costs were estimated to be between 15 and 90% lower than an equally stringent command-and-control alternative. The success of the program continued into the second phase. Chan et al. (2018) estimated Phase II annual cost savings at several hundred million dollars compared to a simulated uniform performance standard.



Source: Schmalensee and Stavins (2013)

Schmalensee and Stavins (2013) reported that emissions declined by 36% between 1990-2004, even as coal-fired electricity generation increased. One reason for such large emission reductions was the ability to bank allowances for future use. In addition, incentives to innovate continued to reduce abatement costs over time (Bellas and Lange 2011; Frey 2013). Railroad deregulation and investment by utilities in mining and infrastructure also played a role by making low-sulfur coal cheaper. That said, researchers have observed that there was less inter-firm trading than expected, which meant that marginal abatement costs were not equalized across plants (Swift 2001; Swinton 2004). Estimates of the SO_2 allowance program's annual benefits range from $59-116 billion with estimated annual costs of $0.5 to $2 billion (in 2000$) (Schmalensee and Stavins 2013).

Congress did not grant the EPA the authority to adjust the cap in response to new information on either the costs or benefits of reducing emissions. For this reason, the EPA pursued additional reductions in SO_2 emissions via more traditional regulatory approaches, which restricted the ability of sources to trade and reduced allowance prices to zero by 2012 (Schmalensee and Stavins 2013).

For more information, see Chestnut and Mills (2005); U.S. EPA (2007); Schmalensee and Stavins (2013); Chan et al. (2018); and Evans and Woodward (2013).

- Tradable allowance systems provide more certainty about the total level of emissions than emissions taxes or subsidies; as such, they may be preferable to emissions taxes when marginal damages increase with the level of emissions.

Key disadvantages:

- If the pollution cap is set at an inefficiently high (low) level, then allowance prices will be lower (higher) than the marginal damages from pollution, and an inefficiently low (high) level of abatement will occur.
- Tradable allowance systems raise complicated issues regarding the distribution of allowances, including auction design and rent-seeking by regulated firms.
- If marginal pollution damages vary geographically, an efficient tradable allowance system might require regulators to set trading ratios, which can raise analytical and administrative challenges.

4.2.2 Emissions Tax

Emissions taxes are a charge per unit of pollution that is imposed by the government. Under an emissions tax, the polluter will abate emissions up to the point at which the additional cost of abating one more unit of pollution is equal to the tax. For any remaining emissions, the polluter prefers to pay the tax rather than to abate further. The tax will result in an efficient outcome if it is set equal to the external damage caused by the last unit of pollution emitted.[10]

User or product charges are a variation on emissions taxes. These charges may be imposed on users of publicly operated facilities or on intermediate or final products whose use or disposal harms the environment. User or product charges may be effective approximations of an emissions tax when the product is closely related to environmental damage. User and product charges will not result in an efficient level of pollution if they are set at a level only sufficient to recover the *private costs* of operating a public system, rather than incorporating the marginal social damages of pollution.

Emissions taxes, like tradable allowance systems that distribute the allowances using an auction, raise revenue for the government. The welfare and distributional effects of an emissions tax depend on how the revenues are used and how the tax interacts with other distortions in the economy. If distributed to households or firms, the revenues can be used to compensate individuals made worse off by the policy or to address other distributional priorities of the policymaker, though it can be difficult to accurately target individuals for compensation (Cronin, Fullerton and Sexton 2019). If the revenues are instead used to reduce other distortionary taxes, such as labor taxes, then this "revenue recycling" could yield economic gains due to a resulting increase in employment or investment (e.g., Goulder 2000). However, emissions taxes or allowances can also exacerbate pre-existing tax distortions, causing an increase in deadweight loss. Analysts should consider the opportunity costs associated with collecting and spending public funds. Section 8.3.1 of these Guidelines discusses general equilibrium approaches to examine these types of economy-wide effects.

10 These taxes are called "Pigovian" after the economist, Arthur Pigou, who first formalized them (Pigou 1932).

Emissions taxes should lead to outcomes similar to those from allowance trading systems when both are designed to achieve the same level of emissions. Rather than specifying the total quantity of emissions, taxes specify the effective "price" of emitting pollutants. However, these two types of policy instruments differ in their usefulness when there is uncertainty about the costs or benefits of abatement. Section 4.6.5 discusses instrument choice under uncertainty.

Key advantages:[11]

- Like tradable allowances, emissions taxes are an efficient approach to incentivize pollution reduction, allowing flexibility to reduce emissions multiple ways and/or to pay the tax for remaining emissions.
- Like tradable allowances that are distributed via auction, emissions taxes raise revenue that can be used to compensate individuals made worse off by the policy or to offset other distortionary taxes, increasing economic efficiency throughout the economy.
- Emissions taxes are advantageous in situations where there is uncertainty about abatement costs, but damages do not change much with additional pollution.

Key disadvantages:

- Emissions taxes do not set either source-level or aggregate limits on emissions and could lead to emissions spikes or hotspots.
- Emissions taxes may be difficult to implement efficiently when pollution damages vary over space and time.
- Emissions taxes are less well-suited to situations in which contaminant releases are difficult to measure and are not directly related to a marketed input or output.

4.2.3 Environmental Subsidies

A subsidy is a payment or financial assistance made to encourage a certain behavior. Subsidies paid by the government to firms or consumers for technology-neutral reductions in pollution create similar abatement incentives as emissions taxes. Economic theory predicts that firms will reduce pollution up to the point where the additional private costs are equal to the subsidy.

Unlike an emissions tax, an environmental subsidy lowers a firm's total and average costs of production, encouraging production by both existing and new firms. The result may be a decrease in emissions from individual polluters but a smaller net decrease (or even an increase) in overall pollution.[12] However, it is possible to minimize the entry and exit of firms resulting from subsidies by redefining the subsidy as a partial repayment of verified abatement costs, instead of defining it as a per-unit payment for emissions reductions relative to a baseline. Defining the subsidy in this way also minimizes strategic behavior because no baseline must be specified.[13] An environmental subsidy also differs from an emissions tax because it requires government expenditure (versus generating government revenue).

11 See Fullerton, Leicester and Smith (2010) for more discussion of the advantages and disadvantages of emissions taxes.

12 See Sterner and Coria (2012) and Goulder and Parry (2008) for a discussion and examples of environmental subsidies.

13 Strategic behavior is a problem common to any instrument or regulation that measures emissions relative to a baseline. In cases where a firm or consumer may potentially receive funds from the government, they may attempt to make the current state look worse than reality to receive credit for large improvements. If firms or consumers are responsible for paying for emissions above a given level, they may try to lobby for that level to be set at a fairly high level so that they pay less in fines or taxes.

Government funding for research and development of technologies to reduce pollution and improve environmental quality is another form of subsidy. The private market does not always have an incentive to invest in the socially optimal level of innovation and diffusion of new technologies because these activities can create positive information spillovers that benefit other firms. In addition, network externalities, which occur when the marginal cost of adopting a new technology decreases as the number of users increases, can inhibit the spread of otherwise promising innovations (Jaffe, Newell and Stavins 2005).[14] Subsidies for technology development and demonstration can be used to address these types of market failure, complementing other environmental policy approaches. Research on new technologies and approaches to improve environmental quality may also yield data that could be useful in future analyses of regulatory or non-regulatory approaches to environmental policy.

Cost-sharing constitutes another type of subsidy, with examples that include reduced interest rates, accelerated depreciation, direct capital grants, loan assistance or guarantees for investments, and government "buy-backs." Under a buy-back program, the government offers a payment for the return of an older, high-polluting product or a rebate on a new, cleaner substitute if the older model is turned in. For example, the EPA has funded changeout programs to encourage the replacement of old wood stoves with EPA-certified gas, electric or wood appliances that reduce indoor air pollution (U.S. EPA 2014). Buy-back programs also exist to promote the scrapping of old, high-emission vehicles. In 2009, the U.S. government offered rebates for trading in old, inefficient, but still drivable vehicles for new, fuel-efficient vehicles to stimulate auto sales during a recession through a program called "Cash for Clunkers."

The effectiveness of subsidies depends on the degree to which they motivate behavior that would not have already occurred without the subsidy (an effect called "additionality"). In the Cash for Clunkers program, researchers estimated that most of the funds were received by consumers who would have purchased a vehicle in 2009 regardless, though the program did induce sales of more fuel-efficient vehicles than would have been purchased without the subsidy (Li, Spiller and Lin 2013). Similar to allowance trading systems, auctions can be incorporated into subsidy programs to incentivize participants to reveal their opportunity costs and avoid payments in excess of this amount. In these programs, sometimes referred to as conservation or reverse auctions, subsidies are awarded to the lowest bidder (de Vries and Hanley 2016).

A subsidy for specific technologies — a policy approach that is sometimes termed "picking winners" — is typically not as economically efficient as a subsidy (or tax) per unit of emission reduction or other environmental outcomes. This is because, similar to prescriptive regulation, such programs do not encourage flexibility in the way firms or individuals reduce their adverse environmental impacts, and the government may not have good information on what technology will ultimately be the most efficient abatement option.

Key advantages:

- Technology-neutral environmental subsidies are an efficient way to encourage pollution reduction because they create incentives to reduce emissions up to the point at which marginal abatement costs equal the subsidy.
- Subsidies for research and development of new pollution abatement technologies and approaches can help mitigate market failures that inhibit technological innovation.
- Subsidies provide flexibility to polluters about whether and how much to abate and impose no mandatory requirements on the public.

14 Electric vehicle adoption provides one example of network externalities. The cost and convenience of electric vehicle use depends on the availability of a network of electric charging stations. Spreading the cost of this infrastructure across many users lowers the costs for each individual user.

Key disadvantages:

- Subsidies have limited effectiveness if most market participants would have undertaken the environmentally beneficial action without the subsidy — in this case, the subsidy acts as a transfer and results in no net social benefit.
- Subsidies for specific technologies are less efficient than technology-neutral subsidies because they allow less flexibility for achieving environmental improvements.
- Like emissions taxes, subsidies provide less certainty that source-specific or aggregate emissions will remain below a particular level; emission spikes or hotspots could occur.

4.2.4 Tax-Subsidy Combinations

Emissions taxes and subsidies can be combined to achieve the same level of abatement as when each instrument is used alone. One example of this type of instrument is a deposit-refund system. Under a deposit-refund system, firms or consumers pay an upfront deposit that serves as a tax on the production or use of certain goods. A refund is then provided if firms or consumers demonstrate that they used a cleaner form of production or engaged in proper disposal, acting as a subsidy.[15]

A tax-subsidy combination functions best when there is a direct relationship between use of a product and emissions. For instance, a tax on the production or use of hydrochlorofluorocarbons (HCFCs) combined with a refund for HCFCs recycled or collected in a closed system is a good proxy for an HCFCs emissions tax.

The main advantage of a combined tax and subsidy is that both parts apply to a market transaction. Because the taxed and subsidized items are easily observable in the market, this type of economic instrument is appealing when it is difficult to measure emissions or to control illegal dumping. In addition, polluters have an incentive to reveal accurate information on abatement activity to qualify for the subsidy. Because firms have access to better information than the government does, they can measure and report their actions with greater precision and at a potentially lower cost.

A disadvantage of the combined tax-subsidy system is potentially high implementation and administrative costs. In addition, while it is possible to adjust an emissions tax to account for variation in marginal damages, a tax on output cannot be matched temporally or spatially to emissions during production. Likewise, if inputs contribute differentially to environmental damages, then it is necessary to tax them at different rates to achieve efficiency. When firms are heterogeneous and select a different set of inputs or abatement options based on firm-specific cost considerations, then the subsidy needs to be adjusted for these differences. Given these complications, other market-based approaches may have lower implementation costs when emissions are easily monitored.

Conceptually similar to the tax-subsidy combination is the requirement that firms post performance bonds that are forfeited in the event of damages, or that firms contribute upfront funds to a pool. Such funds may be used for pollution abatement or to compensate individuals harmed by pollution if environmental damages occur. If the company demonstrates it has fulfilled certain obligations, the contribution is usually refunded.[16]

15 When a deposit-refund encourages firms to use a less-polluting input, a deposit on output induces the firm to reduce its use of all inputs, both clean and dirty (i.e., the output effect). The refund provides the firm an incentive to switch to a specific input such as a cleaner fuel (i.e., the input substitution effect).

16 For more information on the use of financial assurance or performance bonds, see Davis (2015), Dana and Wiseman (2013), and Boyd (2002).

Key advantages:[17]

- Like tradable allowances and emissions taxes, tax-subsidy combinations can be an economically efficient approach to achieve environmental improvements.
- A tax-subsidy combination can be useful when it is less costly to observe market outputs and inputs than it is to observe emissions or environmental damages.
- Performance bonds, a conceptually similar approach, create a pool of funds that can be used to abate pollution or to compensate individuals affected by environmental damages.

Key disadvantages:

- Tax-subsidy combinations can involve high implementation and administrative costs.
- It is difficult to adjust tax-subsidy combinations to account for heterogeneity in environmental damages.
- Like other market-based policies, the lack of a limit on individual sources means that hotspots with a high concentration of pollution can occur.

4.3 Hybrid and Other Approaches

In addition to the instruments discussed above, several other approaches have been used alone or in combination. This section discusses the following approaches:

- Combining prescriptive and market-based approaches;
- Liability rules and insurance requirements;
- Information disclosure;
- Behavioral economics and "nudge" approaches.

4.3.1 Combining Prescriptive and Market-Based Approaches

Some policies combine aspects of prescriptive and market-based policies. As such, they may not represent the most economically efficient approach. The cost of the policy is likely to be greater than what would be achieved using a pure market-based approach. Nevertheless, such approaches are appealing to policy makers because they combine the certainty associated with a standard or technology with some flexibility, allowing firms to comply at a lower cost. Combining standards and pricing and tradable performance standards are two hybrid approaches.

4.3.1.1 Combining Standards and Pricing

Emissions taxes restrict costs by allowing polluters to pay a tax on the amount they emit rather than undertake excessively expensive abatement. Taxes, however, do not set a limit on the quantity of emissions and leave open the possibility that pollution may be excessively high. Some researchers suggest a policy that limits both costs and pollution by combining quantity and pricing instruments, referred to as a "safety-valve" approach to regulation (Roberts and Spence 1976; Spence and Weitzman 1978; Jacoby and Ellerman 2004). In the case of a prescriptive standard and tax combination, an emission standard is imposed on all

17 The main advantages and disadvantages of deposit-refund systems are discussed in Walls (2013) and Fullerton and Wolverton (2001, 2005). Fullerton and West (2010), Walls (2013), and Sterner and Coria (2012) provide more discussion and examples of tax-subsidy combinations.

polluters, but polluters can pay a unit tax for emissions in excess of the standard. Safety-valve systems can also be entirely market-based, by combining a cap-and-trade policy with an emissions tax (i.e., an allowance price ceiling and/or floor) if allowance prices go above or below a certain level (Burtraw, Palmer and Kahn 2010).

This policy combination has several attractive features. First, it allows for more certainty in the expected environmental and health effects of the policy than would occur with a pricing approach alone.[18] Second, overall abatement costs are lower than under a prescriptive standard because polluters with low abatement costs reduce pollution while polluters with high abatement costs pay taxes.

4.3.1.2 Tradable Performance Standards

Rather than establish an emissions cap, a tradable performance standard establishes a standard or emission rate. Sources that perform better than the standard can earn credits and sell them to sources that perform worse. A credit allows a source to emit one unit of a pollutant in excess of what would normally be permitted (e.g., reducing emissions below a baseline or existing emissions cap).

In rate-based trading systems, sources able to reduce their emission rate at low cost have an incentive to do so since they can sell the resulting credits to sources facing higher costs of abatement. Rate-based trading programs have been used in the United States to phase out lead in gasoline (Newell and Rogers 2006; Schmalensee and Stavins 2017) and to control emissions of light-duty and heavy-duty vehicles (Bento et al. 2020; Leard and McConnell 2017). Similarly, state Renewable Portfolio Standards require the use of renewable energy sources — such as wind or solar — for electricity generation, but they incorporate tradable credits so that firms can meet the overall standard at least cost. These approaches encourage cleaner transportation or electricity, but they do not allow reducing output or consumption as a way to comply with the standard (e.g., reducing vehicle miles traveled or electricity consumption). Emissions may increase under these programs if sources increase their production or if new sources enter the market. The regulating authority may need to periodically impose new standards to maintain the desired emission target, which may lead to uncertainty in the long term for regulated sources.

Key advantages:

- Combining prescriptive and market-based approaches can achieve a particular emission rate or technology adoption target at least cost.
- Combining approaches can increase certainty about achieving an emission rate or technology adoption target.
- "Safety-valve" systems that combine cap-and-trade with an emissions tax (a price floor and/or price ceiling) achieve the economic efficiency of market-based policies while mitigating uncertainty about abatement costs and emission reductions.

Key disadvantages:

- A combined prescriptive and market-based policy is typically not the most economically efficient approach because it limits flexibility in the way that environmental improvements are achieved.
- A tradable emission rate is not the most efficient approach to improving environmental quality because it does not create incentives to reduce output or consumption.

18 Section 4.5.5 elaborates on instrument choice under uncertainty.

- Like prescriptive regulations, if the hybrid approach does not set an overall limit on emissions across the regulated sector, then it is possible for total emissions to increase even if source-level emissions decline.

4.3.2 Information Disclosure

Market failure due to asymmetric information occurs when firms or consumers are unable to make optimal decisions due to lack of information on emission levels, health and ecological risks, or approaches to mitigate these risks. Requirements for disclosure of environmental information are well-suited to minimize inefficiencies associated with asymmetric information.[19] Information disclosure can also be an important component of non-regulatory EPA programs. By collecting and making information publicly available, firms, government agencies and consumers can become better informed about the environmental and human health consequences of their production and consumption decisions.

In some cases, the availability of this information may encourage more environmentally benign activities and discourage environmentally detrimental ones. For example, warning labels on hazardous substances that describe risks or safe-handling procedures may encourage consumers to take greater precautions or switch to less-damaging substitutes. A community with information on a nearby firm's pollution activity may exert pressure on the firm to reduce emissions, even if regulations to limit pollution are weak or nonexistent.[20]

Requirements for information disclosure need not be tied to an emission standard. However, such requirements might allow members of the public to easily understand the level of emissions in the context of existing standards. As with market-based instruments, polluters have the flexibility to respond to community pressure by reducing emissions in the cheapest way possible.

The use of information disclosure or labeling rules has other advantages. When expensive emissions monitoring is required to collect such information, reporting requirements that switch the burden of proof for monitoring and reporting from the government to the firm might result in lower costs, because firms are often in a better position to monitor their own emissions. However, random inspections may be needed to ensure that monitoring equipment functions properly, and that firms report results accurately. Information disclosed to regulators or the public through such programs could be useful for analysis of other potential regulatory approaches in the future.

Information disclosure alone does not typically result in a socially efficient level of pollution when externalities are present. Several conditions are necessary for it to be effective and welfare-improving. The information must be complete and accurate. Consumers must be able to access the information and understand it. In addition to complete information, Coase (1960) identified low transaction costs and the possibility of bargaining as two conditions necessary for a private agreement between affected parties to lead to an efficient level of pollution (see Chapter 3's Text Box 3.1). A community's ability to bargain with or exert pressure on an emitting plant may be related to socioeconomic status. Lower income, less-educated populations tend to exert less pressure than communities with richer, well-educated populations (see Hamilton 1993; Arora and Cason 1999; and Earnhart 2004). The effect that public pressure has on behavior may also vary by firm and depend on factors such as the firm's market power and societal reputation. Finally, even if information is complete and consumers can access it readily — which may be strong assumptions — individuals do not always act to further their own best interests. As discussed in Section 4.3.4, the behavioral economics literature has documented some examples in the latter category.

19 See OMB (2010b) for guidance issued to regulatory agencies on the use of information disclosure and simplification in the regulatory process.

20 For more information on how information disclosure may help resolve market failures, see Pargal and Wheeler (1996), Tietenberg (1998), Tietenberg and Wheeler (2001), and Brouhle and Khanna (2007).

The most studied environmental disclosure program is the Toxics Release Inventory (TRI), but researchers offer a mixed view on the extent to which it has changed firm behavior. Some studies have found that high-polluting firms experienced stock price declines on the day the TRI was publicly released, and that those with the largest drop in stock prices reduced reported emissions the most in subsequent years (Hamilton 1995; Konar and Cohen 1997).[21] Others found no evidence of a negative stock price effect (Bui 2005). Bae et al. (2010) found that making raw TRI data available did not result in significant changes in environmental risk, even when emissions declined. However, when data were processed and presented to the public in more digestible terms, they found a significant decline in environmental risk. The economics literature has also found evidence that consumers respond to product labels in specific cases.[22]

Key advantages:

- Information disclosure requirements are well-suited to addressing market failures due to asymmetric information.
- Information programs can complement other approaches, including emission standards, market-based approaches and nudges.
- Reporting requirements that make new information available to the public and to government agencies can yield new data useful for developing improved regulatory analyses in the future.

Key disadvantages:

- On their own, information disclosure requirements are not well-suited to addressing market failures due to externalities; conditions necessary for Coasian bargaining to result in an efficient outcome are not typical of most markets.
- It may be particularly difficult for disadvantaged communities to exert pressure on polluters to reduce their environmental damages in response to information disclosure.
- Information programs have not been studied extensively, and empirical evidence on their effectiveness is mixed.

4.3.3 Liability Rules and Insurance Requirements

Liability rules impose a legal responsibility for polluters to pay for environmental damages after they occur. These instruments serve two main purposes: (1) to create an economic incentive for firms to incorporate the cost of environmental damages into their decision-making processes; and (2) to compensate harmed individuals when damages occur. These rules are used to guide compensation decisions when the court rules in favor of the victim. To the extent that polluters are aware that they will be held liable before the release occurs, they have an incentive to minimize damages to others.

While a liability rule can be constructed to mimic an efficient market solution in certain cases, there are reasons to expect that this efficiency may not be achieved. First, payments need not reflect the social damages. The amount that polluters are required to pay after damages have occurred is dependent on the

21 Khanna, Quimio and Bojilova (1998), Bui and Mayer (2003), Banzhaf and Walsh (2008), and Mastromonaco (2015) also have investigated how the TRI has affected firm behavior, stock market valuation and housing markets.

22 For example, Teisl et al. (2002) and Bjørner et al. (2004) studied the effects of labels for dolphin-safe tuna and paper products, respectively, on consumer purchases. Brounen and Kok (2011) examined the extent to which energy performance labels are capitalized into housing prices.

legal system and may be limited by an inability to prove the full extent of damages or by the ability of the firm to pay. Second, liability rules can generate large transaction costs, both in terms of assessing the environmental damage caused and the resources used to take legal action.[23]

Liability rules are most useful in cases where damages requiring compensation are an infrequent occurrence (e.g., accidental releases) and where monitoring compliance with other regulatory approaches is difficult. Finally, the scope of liability may affect overall economic efficiency. Under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), for example, new owners of contaminated land are defined to be potentially responsible parties that can be held liable for past pollution, creating disincentives for the redevelopment of contaminated land (Jenkins et al. 2009).[24] Depending on the effectiveness of liability rules to provide incentives to firms to minimize environmental damages, they can be either an alternative or a complement to other regulatory approaches.

Strict liability and negligence are two types of liability rules. Under strict liability, polluters are held responsible for all health and environmental damages caused by their pollution, regardless of actions taken to prevent the damages. Under negligence, polluters are liable only if they do not exhibit "due standard of care." Regulations that impose strict liability on polluters may reduce the transactions costs of legal actions brought by affected parties. This may induce polluters to alter their behavior to reduce the probability of a pollution release that causes damages.

Requiring polluters to carry insurance is another approach that can be used to reward risk-reducing and penalize risk-increasing behavior through the setting and adjustment of insurance premiums. This instrument also generates a pool of money that can be used for remediation when contamination occurs. Dana and Wiseman (2013) discussed this approach in the context of oil and gas well development. Insurance has also been discussed to pool risk against extreme weather events in the context of climate change (Linnerooth-Bayer and Hochrainer-Stigler 2015).

Key advantages:

- Liability rules and insurance requirements can incentivize polluters to adopt behaviors that reduce the risk of environmental damages.
- Liability rules and insurance requirements are most useful for situations in which environmental damages are infrequent and monitoring compliance with other types of regulatory requirements is costly.
- Liability rules and insurance requirements both involve mechanisms to compensate those harmed by contaminant releases.

Key disadvantages:

- Payments by polluters to harmed individuals under liability rules are determined by the legal system and need not be equal to social damages; therefore, on their own, they may not create an incentive for polluters to undertake an efficient level of mitigation.
- Insurance requirements will only yield an efficient level of environmental protection if premiums are set to encourage firms to undertake abatement up to the level at which marginal costs equals marginal social damages.

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23 Segerson (1995) and Alberini and Austin (2001) discussed different types of liability rules and the efficiency properties of each.

24 The Small Business Liability Relief and Brownfields Revitalization Act eased some of CERCLA's liability provisions to encourage the redevelopment of potentially contaminated industrial sites, known as brownfields.

Text Box 4.2 - Nudging Through Labels

Product labels represent an intriguing opportunity to examine whether the way information is presented can nudge consumers toward environmentally friendly purchases. For example, some research has found that the EPA's ENERGY STAR logo encourages investments in energy efficient appliances more effectively than information on energy use and expenditures alone (Newell and Siikamäki 2014).

The EPA also collaborated with the U.S. Department of Transportation in 2011 on the redesign of labels to convey the fuel efficiency and environmental attributes of light duty vehicles. They considered elements like color, layout, graphics and alternative rating scales. One issue they confronted was which metric to use to represent fuel economy. Research by Larrick and Soll (2008) pointed out that miles per gallon (mpg) can mislead consumers about fuel expenses and tailpipe emissions because mpg is not linearly related to fuel consumption. Consumers are especially likely to undervalue small changes in mpg for less fuel-efficient vehicles because most are not aware that shifting from 10 to 12 mpg, for example, saves more fuel than increasing from 33 to 50 mpg for the same number of miles driven. Larrick and Soll proposed "gallons per 100 miles" as an alternative measure of fuel economy that is linear in fuel consumption. The agencies used focus group testing to compare the different metrics and found that many participants preferred mpg due to its familiarity (U.S. EPA 2010a, 2010b). For the final label, the agencies kept the mpg metric, as required by law, but also included the gallons per 100 miles information in smaller print. In addition, the label prominently featured fuel cost savings compared to the average new vehicle, a highly relevant metric for consumers that allows for easy comparisons across vehicles.

- Determining payments through the legal system entails high transaction costs, including resources used in the legal process and to measure environmental damages.

4.3.4 Behavioral Economics and "Nudge" Approaches

The neoclassical economics paradigm that has helped inform the design of market-based and other policy instruments makes several simplifications about human behavior — for instance, that people are rational, well-informed, self-interested and disciplined. While these may be reasonable assumptions in many contexts, they do not always hold in the real world. Behavioral economics is a subfield at the intersection of economics and psychology that examines departures from the neoclassical or standard economics model. Such behavioral anomalies include cognitive limitations, altruism, inequality aversion, procrastination, status quo bias and loss aversion, among others.[25]

Behavior that is altruistic, short-sighted or inattentive may have important implications for the way environmental policies are designed and enforced.[26] Inattentive or impatient behavior may help explain some consumers' reluctance to invest in energy-saving appliances or fuel-efficient cars that cost more upfront but save money in the long run. Altruism and social norms may lead people to purchase eco-labeled products even absent regulation or price signals.

Insights from behavioral economics can be relevant to the design of many types of policy instruments. In addition, they present the opportunity to design policies that "nudge" people to make choices that improve their well-being. Nudges have been proposed as an approach to encourage socially beneficial actions by making small changes to the context in which people make decisions. Thaler and Sunstein (2008)

25 Loss aversion occurs when individuals facing risky choices place greater weight on losses compared to gains of an equivalent value. Empirical research suggests that many people tend to give losses double the weight of gains (Kahneman and Tversky 1979, Tversky and Kahneman 1992). Loss aversion can contribute to status quo bias, which describes a preference for avoiding any change from the current situation.

26 Shogren and Taylor (2008), Shogren et al. (2010), and Croson and Treich (2014) provide in-depth discussions of the intersection between behavioral economics and environmental economics.

define a nudge as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives," elaborating that, "the intervention must be easy and cheap to avoid. Nudges are not mandates."

While market-based policies are typically designed to correct externalities, nudges may be especially relevant in situations where the market under-provides environmental quality due to lack of information, cognitive limitations, procrastination or other behavioral anomalies. In contrast to the use of information disclosure alone as a policy instrument, nudges emphasize the visual design, timing, delivery method and other aspects of the way information is presented to make it more salient and useful to the public. Other strategies that have been used as nudges include default rules that require individuals or firms to opt out of a program instead of opting in, moral suasion or pro-social messages that appeal to a sense of altruism or fairness, ordering choices to put the most beneficial option first, and the use of social norms that tap into individuals' desire to match or outperform their peers.[27] Examples of nudges outside the realm of environmental policy include automatic enrollment of employees into retirement savings plans (Madrian and Shea 2011) and rearranging cafeterias to make healthy foods more convenient or eye-catching (Hanks et al. 2012).

There are many potential applications of nudges to environmental policy. For example, research has shown that providing residential consumers with real-time information about electricity consumption and prices can reduce electricity use, which can lead to decreased pollution from fossil-powered electricity generation. Signals conveyed visually, such as with a "glowing orb" that changes color to reflect changes in prices or demand, have been shown to be particularly effective.[28] Residential consumers who received reports comparing their own consumption of water or electricity to that of their neighbors also reduced their resource consumption (Allcott 2011b; Ferraro and Price 2013). Text Box 4.2 describes a few EPA examples.

Nudges that are effective in one situation are not always transferable to different contexts. For example, the residential electricity consumption reports mentioned above led to larger reductions in electricity use for high-user households and for environmentalists, while they have been less effective for other households (Allcott 2015). In addition, research on electricity consumption has yielded mixed results on the effectiveness of combining various nudges and financial incentives (Pellerano et al. 2017; Brandon et al. 2019). These examples highlight the importance of using rigorous empirical approaches such as randomized controlled trials to test the effectiveness of new nudges before adopting them on a wide scale (List and Metcalfe 2014; Allcott and Mullainathan 2010; Hahn and Metcalfe 2016).

Beyond nudges, behavioral economics insights can be applied in the design of other policy instruments. The implementation of plastic bag taxes provides one example. Standard economic models predict that individual consumers will respond similarly to market incentives regardless of whether they are presented as a tax on damaging activities or a subsidy for beneficial activities. However, research has found that consumers faced with a fee for disposable bags cut their bag use by more than 40%, but no change occurred in response to a subsidy for reusable bag use (Homonoff 2018). This result is consistent with loss aversion and suggests that consumer responsiveness to market-based policies can depend on how the incentives are framed.

Key advantages:

- Nudges can address environmental problems that occur or are exacerbated due to inattention, impatience or other behaviors inconsistent with rational choice.

27 Executive Order 13707, "Using Behavioral Insights to Better Serve the American People" (The White House, Sept. 15, 2015), encouraged federal agencies to consider behavioral science strategies with particular attention to access to programs, presentation of information to the public, the structure of choices within programs and the design of financial and non-financial incentives.

28 Allcott (2011a) and Jessoe and Rapson (2014) focused on real-time electricity pricing, while Houde et al. (2013) examined the effect of real-time electricity consumption information.

- Nudges can complement other approaches, particularly information disclosure requirements.
- Nudges are low-cost and impose no mandatory requirements on the public.

Key disadvantages:

- On their own, nudges are not well-suited to addressing market failure due to externalities.
- Nudges are not well-suited to addressing sectors in which rational, profit-maximizing behavior is well documented.
- Empirical evidence on nudges' effectiveness in improving environmental outcomes is limited.

4.4 Voluntary Programs

The EPA has sometimes used voluntary programs as an alternative to regulations to reduce emissions and other environmental hazards. Many EPA voluntary programs encourage polluting entities to go beyond what is mandated by regulation. Other voluntary programs address environmental quality in areas that may be regulated in the future but are currently not regulated.[29] Voluntary programs can offer the EPA the opportunity to pilot new approaches or to work with new industries before implementing a regulation with mandatory requirements.

The EPA typically designs voluntary programs through consultation with affected industries or consumers. In many cases, voluntary programs facilitate problem solving between the EPA and industry because information on practices that reduce pollutants and waste are shared through the consultative process. Voluntary programs also frequently encourage peer education and resource sharing among participants. Data on abatement costs that are generated or disclosed through voluntary programs could help to inform future programs, analysis or regulatory action in the sector.

Voluntary programs can have either broad environmental objectives targeting a variety of firms from different industries or focus on specific environmental problems relevant to a single industrial sector.[30] They often use one or more of the following four approaches:

(1) Encourage firms or facilities to set specific environmental goals

Implementation-based goals are typically EPA-specified, program-wide targets designed to provide a consistent objective across firms. Target-based goals are usually qualitative and process-oriented so that a firm may set a unique target.

(2) Promote firm environmental awareness and encourage process change within firms

Programs designed to promote environmental awareness and process change often involve implementing a system to evaluate firms' operations and to provide information on new technologies. These programs may also promote or recognize use of third-party industry standards for products and materials.

29 While this chapter only discusses EPA-led voluntary program, other government agencies, industry, non-profits and international organizations have also organized voluntary programs to address environmental issues.

30 See Brouhle et al. (2005), Lyon and Maxwell (2007), Borck and Coglianese (2009), and Prakash and Potoski (2012) for discussions of how voluntary programs have been used in U.S. environmental policy.

(3) Publicly recognize firm participation

Voluntary programs that publicly recognize firm participation are designed to provide green consumers and investors with new information that may alter their consumption and investment patterns in favor of cleaner firms. Firms may also use their environmental achievements to differentiate their products from competitors' products.[31]

(4) Use labeling to identify environmentally responsible products

Product labeling can be applied to either intermediate inputs or to a final good. Labels on intermediate goods encourage firms to purchase environmentally responsible inputs. Labels on final goods allow consumers to identify goods produced using a relatively clean production process. Section 4.3.4 and Text Box 4.2 discuss how labeling can be made more effective by using behavioral economics concepts.

The economics literature has not systematically evaluated the effectiveness of these four approaches. Like mandatory information disclosure programs, economic theory suggests that approaches involving sharing information among firms or labelling consumer products may be most useful in situations where imperfect or asymmetric information leads to adverse environmental outcomes.

Most empirical studies of EPA voluntary programs have focused on the effectiveness of a few large, multi-sector programs such as 33/50, Green Lights and ENERGY STAR. They have found mixed evidence regarding the extent to which these programs have reduced participant emissions. In addition, many studies failed to account for what would have occurred in the baseline absent the program — potentially overstating reductions. The potential for beneficial information or technology spillovers from program participants to other firms in the target industry can make it difficult to measure a program's impact (Lyon and Maxwell 2007).[32] The effects of many smaller regulatory programs remain unstudied.

Key advantages:

- Voluntary programs allow agencies the opportunity to pilot new approaches to working with industries or on environmental problems not yet subject to regulation, which could be particularly useful if there is substantial uncertainty about the benefits or costs of regulation.
- Voluntary programs involving data gathering and reporting by program participants could yield new data useful for future analyses or regulatory actions.
- Voluntary programs with a labeling or information disclosure component could be well-suited to address market failures due to asymmetric or imperfect information.

Key disadvantages:

- If voluntary programs only attract participants that are already industry leaders in environmental protection, they may not yield significant improvements in environmental outcomes relative to a baseline without the voluntary program.

31 See Konar and Cohen (2001), Videras and Alberini (2000), Brouhle et al. (2005), Morgenstern and Pizer (2007), and Borck and Coglianese (2011) for more information on the main arguments for why firms participate in voluntary programs.

32 One thread of literature points to the role a regulatory threat plays in improving voluntary program effectiveness. When the threat of regulation is weak, abatement levels are lower. However, when the threat of regulation is strong, Segerson and Wu (2006) showed that levels achieved are closer to those that would be achieved under a standards-based approach. See also Morgenstern and Pizer (2007); Brouhle et al. (2009); Lange (2009); Vidovic and Khanna (2011); Kim and Lyon (2011); Brouhle et al. (2013); and Ferrara and Lange (2014).

- Economic theory suggests that firms or individuals are unlikely to participate if the private benefits exceed the private costs, even if the social net benefits of participating would be positive.
- Empirical studies on the effectiveness of voluntary programs in improving environmental outcomes are limited, and the available evidence is mixed.

4.5 Cross-Cutting Issues When Comparing Regulatory and Non-Regulatory Approaches

Using a simplified theoretical framework, Fullerton (2001) demonstrated that a variety of regulatory and/or non-regulatory approaches can be designed to achieve the same level of economic efficiency.[33] In practice, there are likely to be important tradeoffs across approaches. Economic analysis can play an important role in identifying these tradeoffs.

Analysts can provide insight into the approaches that maximize net benefits and how they vary in efficiency over time (i.e., dynamic efficiency). One regulatory feature that reduces economic efficiency is "grandfathering" — a practice in which older polluters are exempted from new regulations or are subjected to a less stringent standard than newer polluters. Grandfathering creates a bias against constructing new facilities and investing in new pollution control technology or production processes. As a result, grandfathered older facilities with higher emission rates tend to remain active longer than they would if the same emission standard applied to all polluters (Helfand 1991; Stavins 2006). In general, varying regulatory requirements by firm age, size, location or other attributes may be justified to address heterogeneous abatement costs or benefits, but it can also reduce the efficiency of a policy if the design creates perverse incentives to shift production away from more regulated firms toward less regulated firms. Chapter 3 provides more discussion of these policy design features.

There are several other cross-cutting issues that may be useful to analyze when evaluating potential tradeoffs across approaches. These include distributional and equity impacts; administrative, monitoring and enforcement costs; interactions with other distortions; degree of flexibility; information requirements and uncertainty; and the nature of the environmental problem.[34] Analysts can evaluate these factors using methods discussed in Chapters 7 through 10. Stringency is another important consideration for regulatory design that is discussed in Chapter 3.

4.5.1 Distributional and Equity Impacts

The distribution of costs and benefits across firms, workers, governments, households and individuals over time and space is often of interest to decision makers.[35] For example, market-based instruments that directly affect the price of the goods produced by polluting firms will likely have different distributional and equity consequences than prescriptive regulations if the cost of the abatement technologies is not fully passed on to the consumer (Berck and Helfand 2005).

33 Fullerton (2001) assumed no administrative costs, perfect information, no enforcement issues, perfect labor mobility and competitive firms.

34 Many of these criteria are also highlighted in Fullerton (2001). Another criterion discussed by Fullerton (2001) is political and ethical considerations. The approach ultimately chosen will also depend on statutory and other legal limitations. This chapter does not expand on these considerations because analysts have a limited role to play in evaluating them.

35 See Chapter 9 for approaches to quantify the economic impacts of approaches under consideration. See Chapter 10 for discussion of impacts on minority, low-income or Indigenous populations and on children and older adults.

The distribution of economic rents may also differ across approaches. If allowances are auctioned or sold to polluters, the distributional consequences of a cap-and-trade policy will be similar to those of emissions taxes. If allowances are instead distributed for free, distributional consequences will depend on the allocation approach (e.g., historical output or inputs), who receives the allowances and the ability of the recipients to pass the costs onto their customers. Likewise, for approaches that raise revenue — such as emissions taxes or a cap-and-trade policy that auctions allowances — the way revenue is used will affect the distributional outcomes (Burtraw et al. 2010).[36]

Differing treatment applied to sources based on age, size, location or other attributes can also affect the distribution of revenues, expenses and rents within the economy under both prescriptive and market-based approaches.

4.5.2 Administrative, Monitoring and Enforcement Costs

Analysts can help shed light on differences in the cost of administering, monitoring and enforcing the approaches under consideration. For instance, what are the costs and foreseeable challenges for ensuring compliance? Is pollution observable, or will it need to be estimated based on inputs and technology used? Are technologies available to decrease the costs of monitoring and reporting?

When pollutant emissions or concentrations can be easily measured, it is more feasible to directly regulate the level of the pollutant. For example, continuous emissions monitoring equipment at power plants allowed for direct measurement of pollution and facilitated the use of a cap-and trade system to regulate SO_2 emissions (see Text Box 4.1). If a source has fewer allowances than the monitored emission levels at the end of a compliance period, it is in noncompliance and the source must provide allowances to cover its environmental obligation and pay a penalty.[37]

If monitoring and enforcement costs are high, a regulation may fail to deliver environmental benefits due to widespread noncompliance (e.g., illegal dumping).[38] In these cases, it may be easier to regulate a related input or output to leverage approaches that incentivize sources to reveal information about their production or abatement processes (e.g., a tax-subsidy combination). Mandating the use of specific abatement technologies can sometimes reduce monitoring and enforcement burdens, as noted in Section 4.1.1. In addition, it may be easier to monitor and enforce regulations on a smaller number of "upstream" sources (e.g., oil refineries) rather than a larger set of "downstream" sources (e.g., gasoline consumers) (Mansur 2012).

4.5.3 Interactions with Other Distortions

Analysts should consider the potential distortionary effects of any policy option considered. Even if a policy is relatively efficient on its own, it may interact with pre-existing environmental, trade, tax or agricultural policies in ways that exacerbate distortions in the economy and result in additional social costs. One such distortion occurs when imperfect competition due to market power results in lower output than would occur in a competitive market, which results in a loss in economic welfare. Policy instruments that cause

36 To explicitly weight economic efficiency alongside distributional or equity considerations, analysts would need to employ a social welfare function that aggregates welfare across individuals into a single value to allow an explicit ranking of different policy options (see Adler 2008, 2012). However, a social welfare function is based on a normative judgement, and while it makes the criteria explicit regarding how society prefers to distribute resources across individuals, there is no consensus regarding those preferences. Thus, distributional information is typically analyzed and presented separate from efficiency considerations.

37 The U.S. Acid Rain Trading Program has high levels of compliance and requires fewer than 50 EPA staff to administer since penalties are automatically levied for each ton of excess emissions (Napolitano et al. 2007).

38 However, Sigman (2012) presented a theoretical model showing that compliance need not decrease when regulations are broadened beyond industries with low-cost monitoring to include those where monitoring costs are higher, but abatement costs are lower.

firms to restrict output (e.g., an emissions tax) may create additional inefficiencies in sectors where firms have some degree of market power (Baumol and Oates 1988). A combination of market-based instruments may work more effectively than a single instrument in this instance.

If costs differ between existing and new firms, the use of certain instruments may cause a change in market structure that favors existing firms by creating barriers to entry and allowing existing firms a certain amount of control over price. Cap-and-trade systems that set aside a certain number of allowances for new firms may guard against such barriers.

Instruments that involve the government collecting revenue, such as auctioned allowances or taxes, may create opportunities to reduce distortions.[39] At the same time, society also incurs a welfare loss from raising revenues through taxes due to the difference between the value of an additional dollar raised by the government and the value of that dollar to a private individual (termed the marginal cost of public funds). See Chapter 8 and Appendix A for more discussion of economy-wide distortions.

4.5.4 Degree of Flexibility and Dynamic Adjustment

Even if a regulation is set at an efficient level at the outset, changing conditions over time can result in inefficient levels of pollution control. To what extent does the approach allow for automatic adjustments in requirements or stringency over time in response to new information or technological improvements? Is the approach flexible enough to accommodate transition costs? Does the approach encourage innovation in abatement techniques that decrease the cost of compliance with environmental regulations over time?[40]

For instance, market-based approaches often differ from prescriptive approaches to regulation by encouraging firms to find the cheapest way to reduce emissions. The incentive to innovate means that the marginal abatement cost curve may shift downward over time as cheaper compliance options become available. If innovation causes the cost of pollution control to fall, the marginal cost of decreasing pollution levels could drop below the marginal benefit. A cap-and-trade approach incorporating a price floor below which allowances are removed from the market is one approach to dynamically adjusting a regulation. Similarly, a price ceiling above which additional allowances are introduced to the market can be used to ensure that marginal costs do not rise too far above marginal benefits (Fell et al. 2012). Features such as banking and borrowing also afford regulated plants some flexibility in the timing of reductions.

4.5.5 Information Requirements and Effects on Uncertainty

What information is required to implement the approach? How well does the approach perform under imperfect or asymmetric information, or when there is uncertainty about costs and/or benefits? Can the approach be designed in a way that will reveal new information about costs and benefits that can reduce uncertainty if additional analysis or regulatory action is considered in the future?

When abatement costs and benefits are certain, price-based instruments (e.g., emissions taxes) and quantity-based instruments (e.g., cap-and-trade) are theoretically equivalent and can be designed to achieve the same outcomes. However, this result may not hold when there is uncertainty about the benefits and costs of pollution control, or when marginal benefits and costs change substantially with the stringency of the

39 For more information on the how revenues raised via market-based instruments affect social welfare, see Bovenberg and Goulder (1996), Goulder (2013), Jorgenson et al. (2013), and McKibbin et al. (2015).

40 For a theoretical analysis of incentives for technological change, see Jung et al. (1996) and Montero (2002). Empirical analyses can be found in Jaffe and Stavins (1995), Kerr and Newell (2003), Requate (2005), and Newell (2010).

pollution control target (Weitzman 1974).[41] If uncertainty associated with the abatement costs exists but damages do not change much with additional pollution, then policy makers can limit costs by using a price instrument without having much impact on the benefits of the policy. If, on the other hand, there is more uncertainty associated with the benefits of controlling pollution, and policy makers wish to guard against high environmental damages, a quantity instrument is preferable. In some circumstances, this may come to resemble a more prescriptive approach that specifies zero allowable source-level emissions to avoid potentially costly or damaging mistakes. Hybrid approaches that combine features of price and quantity instruments can also address uncertainty (Pizer 2002; see Section 4.3.1.3).

Other types of regulatory and non-regulatory approaches may reveal information about emissions, abatement approaches, or abatement costs that can facilitate both retrospective analysis to understand how well an approach is working and prospective analysis of potential future regulatory actions.[42] Monitoring and reporting requirements can be used to compel regulated entities to release data on emissions or abatement approaches. Allowance trading systems can reveal information to regulators and the public about abatement costs because the equilibrium allowance price indicates the marginal cost of compliance with the regulation. Subsidy programs may also require participants to reveal information about abatement activities.

In some instances where there is a high level of uncertainty about costs and/or benefits, a voluntary program or pilot project may be a compelling alternative to regulation. Such an approach encourages environmental improvements but allows the government and regulated community to test out different abatement technologies or process changes and gather information on what works and what does not. Research and development efforts may also contribute to better understanding the costs and benefits of regulating. As technology improves or more data become available, analysts will be better able to analyze a variety of approaches. Value of information analysis could be used to examine whether more resources should be invested to reduce uncertainty before developing a regulation and which aspects of uncertainty to prioritize (Finkel and Evans 1987).[43]

4.5.6 The Nature of the Environmental Problem

Another important issue is the type of environmental problem being addressed. Are the sources heterogeneous? Does the pollutant vary across time and space? Do emissions derive from a point source or a nonpoint source? Do the pollutants persist in the environment or dissipate rapidly?[44] Point sources, which emit at identifiable and specific locations, are typically easier to control than diffuse, numerous nonpoint sources and are often responsive to a variety of approaches. Monitoring and control of nonpoint source emissions is more challenging (see Text Box 4.3). In instances where both point and nonpoint sources contribute to a pollution problem, a case can be made for a tax-subsidy combination (with taxes directed toward point sources and subsidies to nonpoint sources) or an allowance trading system with offsets.

Flow pollutants that dissipate quickly are responsive to a wide variety of market and hybrid instruments. In contrast, stock pollutants that persist in the environment may require strict limits to prevent bioaccumulation or detrimental health effects at small doses, making direct regulation appealing. Approaches that set a limit on the overall quantity of pollution may be also preferred if there are discontinuities or threshold values above which sudden or large changes in environmental damages could

41 Pezzey and Jotzo (2012) built on Weitzman (1974) by examining how revenue recycling affects the welfare implications of a price- versus quantity-based market instrument under uncertainty.

42 Chapter 5 (Text Box 5.1) provides more discussion of retrospective analysis.

43 For more discussion and examples of value of information analysis in environmental policy, see Cullen and Frey (1999), Dekay et al. (2002), Keiseler et al. (2014), Marchese et al. (2018), Thompson and Evans (1997), and Yokota and Thompson (2004).

44 For a more discussion of how the nature of the environmental problem affects instrument choice, see Kahn (2005); Goulder and Parry (2008); Parry and Williams (1999); Sterner and Coria (2012); Tietenberg and Lewis (2014); and Xabadia et al. (2008).

Text Box 4.3 - Water Quality Trading of Nonpoint Sources

In 2003, the EPA issued a "Water Quality Trading Policy" (U.S. EPA 2003d) that encouraged states and tribes to develop and implement voluntary water-quality trading to control nutrients and sediments in areas where it is possible to achieve these reductions at lower costs. A 2019 memo announced additional flexibilities available to states and tribes to further facilitate the uptake of water quality trading, particularly between point and nonpoint sources. The memo cited the increased availability of effective nonpoint emission reducing technologies and practices and enhanced monitoring capabilities as reasons to modernize the 2003 policy (U.S. EPA 2019).

Under the Clean Water Act, states are required to establish Total Maximum Daily Loads (TMDLs) of pollutants for impaired water bodies. The TMDL is not a regulation and does not establish an enforceable cap on discharges to the watershed, but it does provide a method for allocating pollutant discharges among point and nonpoint sources. Point sources are regulated under the Clean Water Act by the EPA and, as such, are required to hold National Pollutant Discharge Elimination System (NPDES) permits that limit discharges. Where a TMDL exists, the point source NPDES discharge limit is informed by the TMDL allocation. Nonpoint sources are not regulated under the Clean Water Act. However, many water bodies are still threatened by pollution from these sources. Nutrients and sediment from urban and agricultural runoff have led to water quality problems that limit recreational uses of rivers, lakes and streams; create hypoxia in the Gulf of Mexico and other coastal waters; and decrease fish populations in the Chesapeake Bay and other areas.

To account for uncertainties and differences associated with nonpoint source pollution, trading ratios are often applied. These ratios account for the differential effects resulting from a variety of factors, which may include:

- location of the sources in the watershed relative to the downstream area of concern;
- distance between the allowance buyer and seller;
- uncertainty about nonpoint source reductions;
- equivalency of different forms of the same pollutant discharged by the trading partners; and
- additional water quality improvements above and beyond those required by regulation.

Trading can allow continued growth in production while providing nonpoint sources with an incentive to reduce pollution through participation in the market. If it is cheaper for a nonpoint source to reduce pollution than to forgo revenues earned from the sale of any unused credits to point sources, economic theory predicts that the nonpoint source will choose to emit less pollution.

As of 2014, the EPA had identified 19 nutrient trading programs in 11 states, with the majority of trades occurring in just three states — Connecticut, Pennsylvania and Virginia (GAO 2017). Trading has been limited in many of these programs for several reasons. First, as previously mentioned there is no enforceable cap on discharges that applies to both point and nonpoint sources within a watershed. Reductions by nonpoint sources are voluntary absent state-level mandates. Point-source dischargers often explore trading as a way to expand production while meeting the requirements of their individual permits, but there is no general signal in the market to do so, and it can be challenging to encourage nonpoint source involvement. Second, these are often thin markets (i.e., markets with few trades). The lack of participants can make it difficult or expensive for an entity to identify and complete a trade. Third, while best management practices (BMPs) are typically used to define a pollution reduction credit from a nonpoint source, uncertain or changing climatic conditions, river flow and stream conditions make it difficult to measure the effect of a BMP on downstream water quality. This uncertainty makes it difficult to define appropriate trading ratios between point and nonpoint sources (Morgan and Wolverton 2008; U.S. EPA 2008). Such uncertainty also makes measuring and enforcing a pollution reduction from a nonpoint source difficult.

occur (Pindyck 2007). For pollutants that do not mix uniformly, it is important to account for differences in baseline pollution levels and in emissions across more- and less-polluted areas. Damages can also vary by time of day or season. For example, health impacts associated with vehicle emissions may be larger during rush hour because roads are congested, and cars spend time idling or in stop-and-go traffic. Differential pricing of resources used by these mobile sources (such as higher tolls on roads or greater subsidies to public transportation during rush hour) is a potentially useful tool.