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Second-best theory and the use of multiple policy instruments

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Abstract In many cases policy makers employ multiple instruments to address a single environmental problem, but much of the economics literature on instrument choice focuses on comparing properties of single policy instruments. We argue that under a fairly broad set of circumstances the use of multiple policy instruments can be justified as optimal in a second-best world. We examine two broad categories of second-best policy making: cases with multiple market failures only some of which can be corrected at any one time; and cases with exogenous (often political) constraints that cannot be removed. The fact that the use of multiple policy instruments can be justified economically in these two cases does not imply, however, that all multiple instruments employed in actual practice are economically justified.

1 Introduction

A major issue for policy makers in the environmental domain concerns identifying an appropriate policy instrument, an issue that was central to David Pearce's interests, in terms of both his scholarly research and his participation in the policy process (Pearce 1998a, b). Regulators may have at their disposal a portfolio of potential policy instruments, including product or process bans, technology standards, performance standards, taxes, subsidies, tradable permits, tort liability, information disclosure, industry self-regulation, and management-based regulation. Different instruments are appropriate for different types of problems in different

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circumstances. The challenge is to determine the conditions under which each instrument, or set of instruments, is the appropriate choice.

Several criteria can be brought to bear on this choice, including: (1) the efficiency criterion, which assesses an instrument's ability to attain a level of pollution control that maximizes net benefits; (2) the cost effectiveness criterion, which assesses an instrument's ability to achieve a given level of pollution reduction at the lowest cost; and (3) other economic and non-economic criteria, including distributional equity and political process transparency (Pearce 1998c, d, 1997, 1975; Helfand, et al. 2003; Baumol and Oates 1988; Revesz and Stavins 2005).

The normative literature on instrument choice is substantial, with the bulk focusing on the use of one instrument or comparisons of two or more instruments. More recently the literature has explored the economic properties of combinations of multiple instruments, particularly the use of hybrid instruments that combine a quantity and a price instrument. In contrast, in the policy world the use of combinations of multiple policy instruments is common and seldom takes the form of a hybrid instrument. To economists, such use of multiple instruments often appears ad hoc and unrelated to economic efficiency or cost effectiveness.

We postulate that the use of multiple policy instruments can be justified as optimal in a second-best world. An efficient general equilibrium, in the sense of the first theorem of welfare economics, requires a universal set of perfectly competitive markets. A general definition of the second-best problem is that if there is some constraint within the general equilibrium system that prevents attainment of at least one of the conditions of Pareto optimality, then attainment of the other Pareto optimal conditions is no longer necessarily welfare improving (Lipsey and Lancaster 1956).

There are two ways of thinking about the second-best problem in the context of our investigation of multiple policy instruments. One is that there are multiple constraints—these could be political constraints, market failures, or policy failures—but only some of these constraints can be addressed at any given time. What effect does the continued existence of the other constraints have on instrument choice? The other way to think about the second-best problem is that there is a single exogenous constraint that cannot be overcome, again this could be a political constraint, a market failure, or a policy failure. What effect does this exogenous constraint have on optimal instrument choice? We demonstrate that the second-best nature of problems addressed by policy makers justifies policy coordination and *can* justify the use of multiple policy instruments in a wide range of settings. Much research remains to be done, however, to understand the actual set of instruments that should be employed in such broad second-best settings.

We begin in Sect. 2 by describing some of the cases in which multiple policy instruments have been used in practice. This section illustrates the broad range of circumstances in the environmental and natural resource management fields where multiple policy instruments have been employed. In Sect. 3, we provide an overview of the second-best theory and one of its most studied applications in environmental policy—environmental policy in the presence of pre-existing distortionary taxes. This application highlights the importance of policy coordination in second-best settings. It also illustrates how the use of multiple policy instruments can be optimal in a second-best world. These findings turn out to be broadly applicable in environmental and resource management.

The remainder of the paper highlights several areas where multiple policy instruments can be justified using second-best theory. In Sect. 4, we examine the case where there are multiple constraints, but only a few can be addressed at a given time. This section focuses primarily on the existence of multiple market failures and demonstrates that these multiple constraints on the general equilibrium system also justify policy coordination and can often justify the use of multiple policy instruments. In Sect. 5, we examine the case where there is one exogenous constraint that affects the optimal choice of policy instruments for environmental policy. We conclude in Sect. 6.

2 The Use of Multiple Policy Instruments in Practice

The use of multiple policy instruments is the norm, rather than the exception in environmental and natural resource management. Here we describe the actual use of multiple policy instruments in three major areas: energy efficiency, toxic chemical control, and fisheries management. A full discourse on all of the combinations of policy instruments used throughout the world in these policy areas is well beyond the scope of this paper.[1] Rather, we intend to illustrate the prevalence of multiple instrument use over a broad range of environmental and resource issues.

2.1 Energy efficiency

A wide range of policy instruments has been used in pursuit of greater energy efficiency. For purposes of illustration we focus on the combinations used to regulate energy efficiency in the United States, but many of these combinations are used throughout the world (OECD 2004, 2005).

In the United States, national energy efficiency standards have been developed for commercial and residential appliances. Congress first mandated the development of these standards in the National Appliance Energy Conservation Act (NAECA) of 1987.[2] The U.S. Department of Energy develops and updates energy efficiency standards for household and commercial appliances, including: refrigerators and freezers, room air conditioners, fluorescent lamp ballasts, incandescent reflector lamps, clothes washers and dryers, dishwashers, kitchen ranges and ovens, pool heaters, and water heaters. Products cannot be sold in the United States unless they meet these minimum energy efficiency standards.

In addition to these standards, an information disclosure instrument is also used to promote energy efficiency. The Federal Trade Commission issued the Appliance Labeling Rule that became effective in 1980. This rule requires that all new refrigerators and freezers, water heaters, dishwashers, clothes washers and dryers, room air conditions, heat pumps and furnaces, and boilers sold must display an "EnergyGuide" label. These labels describe the estimated annual energy use of the appliance and how this energy use compares with other brands of appliances in the same category.

An additional labeling program, the Energy Star program, is jointly run by the U.S. Environmental Protection Agency and the U.S. Department of Energy. This program encourages the development and consumption of energy efficiency products by developing energy efficiency qualifications for numerous household and commercial appliances. Appliances that meet the qualifications can bear the Energy Star label. The Energy Star program also works with retailers to promote and market Energy Star labeled products and provides information to consumers on cost savings associated with Energy Star products.

There are also numerous voluntary programs used to promote energy efficiency. In the 1990s, the Green Lights program was a prominent voluntary program that encouraged

[1] For more examples of the use of multiple policy instruments in practice see OECD 2004 and OECD 2005.

[2] This was not the first attempt to develop national energy efficiency standards. The National Energy Policy and Conservation Act of 1975 required the U.S. Department of Energy to develop energy efficiency standards for appliances, but these standards were never finalized.

businesses to adopt more efficient lighting. Participating businesses signed a Memorandum of Understanding with EPA and agreed to survey their facilities and upgrade where profitable.[3] In exchange, EPA provided information on energy-efficient lighting technology, financing options, and public recognition opportunities. More recently, EPA has established the Climate Leaders program—a voluntary program designed to encourage businesses to reduce their greenhouse gas emissions (often through increased energy efficiency).[4] Participants set greenhouse gas reduction goals and conduct regular inventories to measure their progress toward achieving the goals. In exchange, EPA provides guidance on both setting and attaining goals and public recognition.

2.2 Toxic chemical control

There are at least six different policy instruments used in the United States to control pollution and minimize hazards from toxic chemicals—technology standards, information disclosure requirements, management-based regulations, government-industry partnerships, voluntary programs, and industry self-regulatory programs. While we illustrate the use of these multiple instruments with examples from the United States, many of these same combinations of instruments are used throughout the world for toxic chemical control.

There are technology-based standards regulating air releases of toxic chemicals in some industries in the United States under the Clean Air Act (U.S. Environmental Protection Agency 2000). Maximum attainable control technology standards are set at the industry level for hazardous air pollutants. The industries that are regulated (or scheduled to be regulated) range from electric utilities, metal smelters, dry cleaners, and numerous manufacturing industries, to publicly owned treatment works.

At the same time, most manufacturing facilities, electric utilities, federal facilities, and mining facilities are subject to information disclosure regulations. With the Emergency Planning and Community Right-To-Know Act (EPCRA) Congress required manufacturing facilities to publicly disclose their releases of nearly 300 different toxic chemicals as part of the Toxic Release Inventory program.[5] In addition to reporting releases of these chemicals to air, water, landfills, and underground injection, facilities must report amounts of listed substances that are sent off-site for treatment, disposal, or recycling. Facilities' annual reports on their releases, offsite-transfers, and recycling are made available via the Internet through the U.S. Environmental Protection Agency (EPA) and through third party sites, such as Environmental Defense's "Scorecard."[6]

Many facilities face additional regulation of toxic chemicals at the state level. Twelve states have adopted management-based regulations of toxic chemicals (Bennear 2006). These regulations require facilities to review their production processes and develop a set of goals and procedures that will reduce toxic chemical use and release. Similar management-based regulations have been imposed at the federal level for chemicals that can create industrial safety hazards. EPA requires manufacturers that use certain chemicals to develop risk management

[3] The exact agreement was to upgrade 60% of the square footage where upgrading was profitable without affecting lighting quality.

[4] See Smith and Swierzbinski (2007) and Ulph and Ulph (2007) in this collection for European and theoretical perspectives on this issue.

[5] Facilities are required to disclose releases if they have more than 10 full-time equivalent employees and either manufacture or process more than 25,000 pounds or otherwise use more than 10,000 pounds of a listed chemical. For lead, mercury, and persistent bioaccumulating toxins, the reporting thresholds are lower. The program has since been expanded to include other industry sectors and to include an additional 300 chemicals.

[6] The scorecard can be accessed at www.scorecard.org.

plans that assess the potential for accidents within their plant and evaluate alternatives for reducing or eliminating this risk (Kleindorfer et al. 2000; Coglianese and Lazer 2003).

Both EPA and the states have developed industry-government partnership programs to address toxic chemical use and release. The most widely known partnership program is EPA's Design for the Environment (DfE) program, which began after Congress passed the Pollution Prevention Act in 1990 (Lenox et al. 2000, Lenox and Ehrenfeld 1997, 1995) and involves government industry collaboration in assessing currently available technologies, identifying environmentally-friendly alternatives, and assessing the financial payoffs of these alternatives.

EPA also developed a voluntary program to address toxic chemical releases. The Industrial Toxics Program, generally referred to as the 33/50 program, was a voluntary program begun in 1991 where participants agreed to reduce their releases of 17 priority toxic chemicals by 33% by 1992 and 50% by 1995 (Khanna and Damon 1999; Gamper-Rabindrin 2006). In exchange companies received public recognition benefits.

2.3 Fisheries management

Multiple policy instruments are also used extensively in natural resource management. For example, combinations of instruments are used to manage fisheries in New Zealand. As with the other policy cases, some of the combinations of policy instruments used in New Zealand are used in other countries as well.

Since 1986, the primary tool for managing fisheries in New Zealand has been an individual transferable quota (ITQ) program. Commercial fishers were originally granted quotas that entitled them to a share of the total allowable catch of a species. These quotas can be bought and sold.[7] Currently, over 90 species of fish are regulated using the ITQ system.

While economists often argue that a successful ITQ system can be used in lieu of more traditional fisheries management methods such as gear restrictions and season closures, in New Zealand, several of these traditional management methods are used in conjunction with the ITQ system.

New Zealand established closed fishing areas for both commercial and recreational fishing. Quotas cannot be used to cover fish caught in closed areas. Similarly, many fisheries are subject to season closures, often during the breeding season. Quotas cannot be used to cover catch during the closed season. Size limits are imposed on fish caught by both recreational and commercial fishers. For example, blue cod must be at least 30 cm long to be considered allowable catch. Finally, New Zealand still imposes gear restrictions on some fisheries. These restrictions include things like the size of nets and the size of mesh in nets.

New Zealand also imposes restrictions on the trading of the quotas in the ITQ system. For example, there is a ceiling on the total number of permits any one firm can hold (Connor 2001; Runolfsson and Arnason 2001). In addition, there are limits on foreign-ownership of quotas and a requirement that quotas be associated with a fishing vessel to prevent absentee ownership (Connor 2001; Runolfsson and Arnason 2001).

These three cases illustrate that the use of multiple policy instruments is common in environmental and resource management. But is such use justified on economic grounds, and, if so, under what circumstances? It is to those questions that we now turn.

[7] Every month the total amount caught by a commercial fisher is compared to his quota. If a fisher exceeds his quota for the month he is assessed a penalty. The penalty is such that it eliminates any profit the fisher has from obtaining the excess fish.

3 Multiple instruments and policy making in a second-best setting—an overview

The second-best problem is generally defined as follows. If a constraint exists within the general equilibrium system that prevents attainment of one Pareto optimal condition, then attainment of other Pareto optimal conditions is no longer necessarily desirable, i.e., welfare improving (Lipsey and Lancaster 1956). The constraint may be a market failure, a policy failure, or a political constraint. For example, imagine a country that decides to reduce trade tariffs in a world where other countries utilize trade tariffs. A basic economic analysis would suggest that the decision to reduce trade tariffs by one country is welfare improving. However, given the existence of the exogenous constraint(s)—namely that other countries continue to use tariffs—this reduction in tariffs can actually be welfare reducing (Ozga 1955).

Another way to frame the second-best problem is that if there are multiple constraints that prevent the attainment of multiple Pareto optimal conditions, the elimination of only one of the constraints does not necessarily lead to a welfare improvement (Lipsey and Lancaster 1956). If the constraints are market failures, then second-best theory suggests that the elimination of one market failure, in a world with many market failures, may not be welfare enhancing. In fact, market failures can be *jointly ameliorating* (correction of one market failure ameliorates welfare losses from the other), *jointly reinforcing* (correction of one market failure exacerbates welfare losses from the other), or *neutral* (correction of one market failure does not affect the welfare losses from the other).

How does the theory of the second-best affect instrument choice for environmental and resource policy? The implications have been well studied for a few particular applications. For example, there is a substantial body of theoretical and empirical research that examines the interactions of environmental policy and "pre-existing" distortions that emanate from labor and capital taxes. If one ignores the pre-existing tax distortions and compares pollution taxes and tradable permits, under a broad set of circumstances, the cost-effectiveness and efficiency properties of these two instruments would be the same. However, this equivalency does not hold when one examines pollution control policy together with tax policy.

One reason for the difference between the first-best and second-best outcomes is that the use of a revenue-generating policy instrument for pollution control provides the opportunity to reduce the levels of other distortionary taxes. In particular, revenue from pollution taxes can be used to offset the marginal rate of other distortionary taxes, such as income and capital taxes (Lee and Misiolek 1986; Oates and Schwab 1988; Oates 1993; Repetto et al. 1992; and Terkla 1984). Such "revenue recycling" can lower the overall cost of environmental protection in the presence of distortionary taxes, generating a so-called "double-dividend."[8]

The use of revenue-generating instruments also leads to a tax interaction effect, whereby pollution taxes act as implicit taxes on labor and capital, and thus increase costs of goods and services and reduce after-tax returns (Bovenberg and de Mooij 1994; Bovenberg and van der Poeg 1994; Bovenberg and Goulder 1996, 1997; Goulder 1998; and Parry 1995, 1997). This tax interaction effect offsets some of the welfare gains attained by the revenue recycling effect. Theoretical models that combine both the tax interaction effect and the revenue recycling effect suggest that the tax interaction effect dominates. Hence, the revenue recycling effect will offset some, but not all of the costs of pollution control (Goulder 1998).

Because of the revenue recycling effect, the general equilibrium costs of environmental policy can be lower with the use of multiple policy instruments. In particular, the costs are

[8] The strong version of the double-dividend hypotheses asserts that the efficiency gains from reducing distortionary taxes can more than offset the actual costs of the pollution taxes themselves. Hence, pollution control policy with taxes (or auctioned permits) is costless in welfare terms. A weaker version of the double-dividend asserts that the efficiency gains from reducing distortionary taxes offsets part of the costs of pollution taxes.

lowest when policy makers use a revenue-neutral approach that *combines* a pollution tax with a proportionate cut in particularly distortionary taxes. The cost of this combined tax and tax-cut policy are lower than with the use of a single instrument, whether that single instrument be a pollution tax (with no revenue recycling) or a freely allocated permit system (Bovenberg and Goulder 1997; Goulder et al. 1997; Parry et al. 1999).[9]

In a second-best world, coordination of policies is required to attain an efficient outcome. As it turns out, the efficient coordination of policies in this case also involves the use of multiple policy instruments. In the next section, we demonstrate that this finding applies broadly to other cases of policy making in a second-best setting and that the need for coordinated response in a second-best world can often serve as an economic justification for the use of multiple policy instruments.

4 Second-best policy making with multiple constraints

One way to think about the second-best problem is that there are multiple constraints, any one of which causes the general equilibrium system to fail to reach a Pareto optimum. What are the interaction effects of these various constraints? To what extent does policy designed to address one constraint need to be coordinated or changed in light of the other constraints? In this section we focus on five pairs of constraints: (1) imperfect property rights and other externalities, (2) multiple externalities, (3) market power and externalities, (4) unobservable behavior and externalities, and (5) imperfect information and externalities. In each case, the constraints are market failures, but the general findings are likely to apply whenever there are multiple constraints, regardless of the nature of those constraints.

4.1 Imperfect property rights & other externalities

Most natural resource management problems are the direct results of poorly defined property rights. Open access fisheries are a classic example. If the oceans were privately held, the optimal management strategy would be to harvest fish until the marginal benefit of harvesting equals the marginal cost of harvesting (or net benefits are maximized).[10] But since no one owns the oceans, fishing continues as long as each fisher experiences a positive profit. Thus, fishing continues until total benefits of harvesting equal total costs (net benefits are zero), which generally results in higher initial harvest rates and lower long-run equilibrium stock and harvest rates. Many instruments for fisheries management are designed to address this imperfect property rights issue.

In multi-species fisheries, there is potentially a second market failure, namely a negative externality from fishing effort. There are two primary types of externalities that result from fishing activity. The first results from either incidental catch of non-targeted species or highgrading of targeted species.[11] High-profile examples of incidental catch include dolphins caught during the process of harvesting tuna, and turtles caught in the process of harvesting shrimp. The second type of externality results from degradation of habitat caused by fishing effort. For example, bottom-trawling fishing vessels can degrade habitat for benthic species.

[9] This finding has been demonstrated for several policy applications, including carbon dioxide and sulfur dioxide regulation. Goulder (1998) provides a summary of these findings.

[10] In the standard dynamic fisheries model, this point is where the growth rate of the value of the fish left in the ocean is exactly equal to the growth rate of the value of money (interest rate) (Conrad 1999:45).

[11] Highgrading occurs when fishers discard smaller fish so that they do not count against their quota. The survival rates of the discarded fish vary widely by species and fishing method (Squires et al. 1998).

Instruments currently employed to manage the excess fishing effort that results from open access fisheries include: fisheries closures, seasonal limits, licensing requirements, gear restrictions, landing fees, user fees, and individual transferable quota (ITQ) systems. Fee systems and ITQ systems can achieve cost-effective reductions in fishing effort (Conrad 1999: 52–53)[12] but employing ITQs to correct the property rights market failure can increase the incentives for incidental take and highgrading (Arnason 1994; Anderson 1994; Boyd and Dewees 1991; Sampson 1994; Vestergaard 1996). The typical ITQ system employed issues quotas for landed fish as opposed to quotas for fish that are caught. Under this type of ITQ system the net profit of a particular fish that is caught must be compared to the alternative benefit of discarding the fish and selling the quota. This alternative benefit will include the price of the quota less any cost of sorting and discarding lower valued fish. In comparison, in an open access fishery the incentive to discard simply compares the net profit from selling the fish to cost of sorting and discarding the fish (Arnason 1994; Anderson 1994). This *can* lead to an increased incentive for highgrading under an ITQ system.[13] Thus, imperfect property rights and externalities can be *jointly reinforcing* market failures. The optimal policy to correct the property rights problem can exacerbate the externality problem.

Does the mere existence of multiple market failures necessarily warrant the use of multiple policy instruments? The answer is no. Sometimes one instrument can be manipulated to address both market failures. Some of the externalities generated by ITQ systems can be corrected within the ITQ system. For example, when the incidental catch is also a species of market value and is regulated with an ITQ system, then banking and trading of quotas can help insure that fishers' quotas for different species match their catch (Squires et al. 1998). Similarly, an ITQ system can be designed over catch rather than landings, which would eliminate the increased incentive for highgrading (Arnason 1994).

It may not be feasible, however, to rely on a single instrument—an ITQ system—to correct for the externality in the case of highgrading or bycatch of ecologically but not economically valuable species or in cases where habitat externalities are significant. In such cases, additional policy instruments may be required to address the negative externalities. Some have suggested that combining ITQs with taxes on high grade fish or subsidies for low grade fish can correct the incentive problem (Anderson 1994). Alternatively, landing restrictions that requires a certain amount of low grade fish be landed for each high grade fish, could help ameliorate the incentive for high-grading (Anderson 1994).

The New Zealand fisheries management case (described in Sect. 2.3) highlights how traditional management instruments are often combined with an ITQ system. The important insight from the theory of the second-best as applied in this case is not necessarily the optimal number of instruments to be used, but rather that the existence of multiple market failures sometimes requires coordination of instruments to address these failures. However, no theoretical or empirical studies have examined the properties of fisheries management with alternative combinations of instruments.

4.2 Multiple externalities

Environmental externalities may interact with other types of externalities in ways that are jointly ameliorating or jointly reinforcing. A prime example is the interaction between positive

[12] Fishers who are more efficient tend to catch a higher share of the total allowable catch under an ITQ, and less efficient fishers are encourage to exit the fishery by selling their quotas.

[13] However, this result is not given as a corner solution, one with no discarding, is possible. In this case the open access and ITQ discarding rates would be the same. But for an interior solution, the discarding rate will be higher under the ITQ.

externalities (spillovers) from technological innovation and negative externalities from pollution. Policies that target only one of these externalities may have indirect effects on the other. Multiple policy instruments may be better suited to address the joint externality than one instrument alone. Indeed, this particular case of combined market failures provide a rationale for a portfolio of public policies that foster both emissions reductions and the development and adoption of environmentally beneficial technologies (Jaffe et al. 2005).

Research and development (R&D) activities can result in technological change that affects environmental quality. While it is frequently said that technological change improves the environment, in fact, technological change may be pollution-intensive or pollution-saving. Firms invest in R&D activity to maximize the expected returns of this activity. The returns to R&D investment, however, are highly uncertain, and often involve low probabilities of high payoffs. These two features of R&D investment can make it difficult to raise capital in traditional capital markets (Scherer and Harhoff 2000; Jaffe et al. 2003). In addition, if the outcome of R&D investment is advancement in general knowledge or technology, it may be difficult to exclude others from utilizing the results of R&D investments. These positive externalities of R&D efforts result in the under-provision of such investment (Arrow 1962; Spence 1984; Griliches 1979, 1992; Jaffe 1986, 1998).[14]

The interaction of the negative pollution and positive technology externality argues for policy coordination. For example, policies to reduce pollution should be designed in such a way as to promote, rather than hinder technological change (Jaffe et al. 2003). Market-based instruments, such as tradable permits and pollution taxes, increase the cost of pollution to firms and thereby create incentives for increased diffusion of existing pollution control technologies and may increase incentives for investment in innovation of new technologies. In contrast, technology-based standards inhibit innovation and diffusion of new technologies (Jaffe et al. 2004).

While the use of a single well-crafted environmental policy instrument may increase the incentives for technological change, evidence suggests that environmental policy alone does not create sufficient incentives to overcome completely the technological market failures (Jaffe et al. 2005). Combining environmental policies with policies to promote both innovation and diffusion of technology can enhance welfare. These additional policy instruments include promoting investment in technology in the public sector, changing the costs of R&D via tax incentives and subsidies, and changing the benefits of R&D through the use of patents (Jaffe et al. 2003). Again, the theory of the second-best suggests that coordination is required and that some combination of these instruments is likely to be optimal.

4.3 Market power and externalities

Environmental externalities and market power are another pair of jointly reinforcing market failures that can necessitate the use of multiple policy instruments. A firm exhibits market power if it holds such a large share of the overall market that its behavior as either a buyer or seller affects market price and there are barriers to entry that prevent additional firms from entering the industry. The combination of market power and negative externalities can yield problematic outcomes. In the case of a market with a negative externality, the socially

[14] It is worth noting that the fact that individual firms cannot fully appropriate the gains from research can theoretically lead to an oversupply of private R&D activity. This theoretical result stems from the fact that R&D is financed by the rents it produces, and hence investment in R&D effectively "steals" rents from competing firms by lowering the expected rents they will receive from their own investment (Mankiw and Whinston 1986). Empirically, this rent-stealing effect does not appear to be significant, but rather the data support the more traditional argument for under-provision of R&D (Griliches 1992).

optimal outcome results in less output being produced and being sold at a higher price than what would occur under perfect competition. But a monopolist in her efforts to maximize profits chooses to produce less and sell at a higher price than what would result under perfect competition. Thus market power may reduce the unwanted welfare effects of a negative externality (Lipsey and Lancaster 1956; Hammer 2000).[15] Policies implemented to rectify one market failure may affect the nature of policies required to rectify the other market failure.

The tradeoff between social welfare losses that result from decreases in production in markets with market power, and social welfare gains that result from those same decreases in production in markets with negative externalities are well-known. Does there exist an optimal number of firms such that these welfare losses and gains exactly offset one another (Cornes et al. 1986; Mason and Polasky 1997; Gopinath and Wu 1999)? The answer is that in general, there is an optimal number of firms that would lead – in theory – to welfare neutrality, suggesting that coordination of anti-trust and environmental policy could be welfare improving. But no studies have attempted to identify the instrument or set of instruments that would be likely to yield such a welfare-neutral second-best optimum.[16]

4.4 Unobservable behavior and externalities

Some environmental problems are characterized by regulators' inability to observe, measure, or monitor relevant behavior. For example, a regulator may wish to penalize improper disposal of a waste product, but improper disposal may be clandestine and difficult to detect. Likewise, emissions from mobile sources are costly to measure.

Under such circumstances, two-part instruments—instruments that combine a tax and a subsidy—can be equivalent to a Pigovian tax on the unobservable and unmeasurable activity (Fullerton and Wolverton 2000). Two-part instruments are generalizations of deposit-refund systems, where buyers pay a deposit on purchase and receive a refund of the deposit upon proper disposal (Sigman 1995).

The generalized two-part instrument does not require the tax and subsidy to be of the same magnitude or involve the same entities. In the case of recyclables, the efficient Pigouvian tax on improper disposal of recyclable material (for example, aluminum cans) can be replicated with a tax upon purchase of the cans (paid by the consumer) and a subsidy for recycling, which may be paid to the household or to a recycling company (Fullerton and Wolverton 2000). The use of such tax-subsidy combinations is not limited to waste disposal, but has potentially broad applications to any area where the key activity to be restricted is unobservable (Fullerton and Mohr 2002).

The optimal use of multiple instruments when undesirable behavior is unobservable is not restricted to two instruments nor to combinations of taxes and subsidies. In some cases, combinations of taxes on various inputs and outputs may be more efficient than a single tax. For example, mobile source emissions cannot be effectively taxed, due to the cost of measuring these emissions. Traditional approaches to mobile source regulation have focused on fuel efficiency restrictions and input taxes on gasoline. Given heterogeneity in preferences and driving styles, a combination of taxes on gasoline, engine size, and age of car can better

[15] This is not restricted to the static case. In the case of extraction of non-renewable resources, monopolists tend to extract more slowly over time, which is consistent (at least in terms of the direction if not the magnitude) with what would be socially optimal if there are negative externalities associated with the resource's extraction (Conrad 1999: 86–87).

[16] There is some legal scholarship on whether the courts should be allowed to consider welfare losses and gains from second-best situations in anti-trust cases (Hammer 2000)

approximate the Pigovian tax on emissions than the use of any of these taxes in isolation (Fullerton and West 2000).

Once again, in the presence of multiple externalities a coordinated policy that combines multiple instruments can be more efficient or cost-effective than the single first-best policy. This is an area that has received considerable attention from economists, who have identified optimal combinations of instruments, but outside of one policy area, namely waste management and the use of deposit-refund systems, these cost-effective combinations of instruments have not been widely used.

4.5 Imperfect information and externalities

The final combination of market failures that we examine is imperfect information combined with externalities. Consider the standard consumer utility maximization problem with multiple goods. Some of these goods may entail a negative externality in either production or consumption. Further assume that the consumer has preferences regarding the environmental impacts of specific consumption choices, but that the impacts of different consumption choices are not perfectly known. Two market failures are involved: there is production and consumption of goods that involves external costs; and there is imperfect information that impedes consumption choices.

How do these two market failures interact? In many cases, correcting the information problem can help reduce the externality problem. That is, the two market failures are jointly ameliorating.[17] To see how they might be jointly ameliorating, consider labeling programs, such as the EnergyGuide or Energy Star programs discussed in Sect. 2.1. These programs increase consumers' information about energy costs. For the purely private calculation about whether the additional costs of the good upfront are justified by the longer-term energy savings, labels can facilitate better decision-making. These decisions may in turn result in lower energy use. Empirical evidence on the effects of the Green Lights and Energy Star programs suggests that the programs have successfully lowered energy consumption (DeCanio 1998; DeCanio and Watkins 1998; Howarth et al. 2000).

A mix of instruments, in particular, some form of standards (which could be in the form of tradable permits or a tax) plus information disclosure requirements, can yield a more efficient solution in the presence of these potentially jointly ameliorating market failures. In practice, this coupling of instruments is frequently observed, but current practice appears to be to use one instrument to address one failure and another instrument to address the other failure without consideration of their potential interaction.

5 Second-best policy making with an exogenous constraint

There are several situations in which the existence of an exogenous constraint can lead to a second-best optimum that involves multiple policy instruments. We examine three cases: (1) uncertainty; (2) stakeholder support, and (3) administrative capacity constraints. In all three cases, a single policy instrument is desirable in the absence of the constraint, but multiple policy instruments may be the second-best solution in the presence of the constraint.

[17] The existence of markets for "green goods" which are jointly private consumption goods and public goods does not necessarily lead to environmental improvements, because private provision of the public good can be crowded out (Kotchen 2006). For an economy that is sufficiently large or where the public good (environmental quality) is a gross complement to private consumption, however, the existence of differentiated green products is likely to result in environmental improvement (Kotchen 2006).

5.1 Uncertainty

When government regulators are uncertain about pollution abatement costs, which is typically the case, how can the government seek to achieve the economically efficient degree of abatement? One approach, in theory, would be for the government to iteratively search for the optimum by successively announcing and revising its policies in the light of responses by firms. But much of the investment that firms carry out for pollution abatement takes years to accomplish and is essentially irreversible, convergence may be impossible because the optimal solution is itself changing over time, due to technological change and other factors.

Most analysis of policy choice under uncertainty has implicitly assumed that the government cannot alter a policy once it has been announced. This eliminates an iterative approach. What is the second-best policy in light of this political constraint? In comparing a choice between two distinct instruments—a price and quantity instrument—the optimal policy to choose *ex ante* is the instrument that is *expected* to exhibit the smaller degree of deadweight loss *ex post* (Weitzman 1974). Thus, the price instrument will be more efficient if the slope of the marginal abatement cost function is greater than the (absolute value of the) slope of the marginal benefit function (the inverse of the marginal damage function), and the quantity instrument will be more efficient if the slope of the marginal cost function is less than the slope of the marginal benefit function (Weitzman 1974).[18]

If we broaden government's choice set to include multiple instruments, then it turns out that under a range of realistic conditions the most efficient policy *ex ante* will combine a price and quantity instrument.[19] That is, a mixed system — involving charges (and possibly subsidies) and quantity restrictions via tradable permits will be preferable to either pollution charges or tradable permits used separately (Roberts and Spence 1976).[20]

The logic behind this theoretical result is as follows. Taxes (pollution charges) and permits (tradable permits) can be used to protect against the failings of the other. Permits can protect society from extremely high levels of pollution, whereas taxes can provide incentives to clean up more than required by permits if costs are low. This suggest a three-part policy mechanism: a fixed quantity of tradable emission (abatement) permits; a subsidy (per unit of emissions) paid by the government to any firm whose permit holdings exceed its emissions; and a tax (per unit of emissions) paid by firms if their emissions exceed their permit holdings (Roberts and Spence 1976).

This system has three key properties: first, it is efficient; second, it is superior to either a pure tax or pure permit system; and third, the system creates a piecewise linear penalty function faced by firms, which approximates the non-linear damage function assumed to be linked with pollution. So, under this system, emissions are limited cost-effectively through the tradable permit allocation. If abatement costs turn out to be less than anticipated, a residual incentive for additional abatement is provided by the subsidy.[21] On the other hand, if abatement costs turn out to be greater than anticipated, a "safety valve" from the restriction imposed by the permit allocation is provided by the possibility of a tax being paid for emissions exceeding permitted levels.

[18] Things also become more complex if there is uncertainty regarding both costs and benefits, and there is statistical dependence between the marginal benefit and marginal cost functions (Stavins 1996).

[19] This is frequently referred to as a hybrid instrument.

[20] Weitzman (1978) also examined the potential efficiency of hybrid instruments in the presence of uncertainty. In a related response to the dichotomous choice of a linear tax versus a permit system analyzed by Weitzman (1974) and others, Kaplow and Shavell (2002) argue for a non-linear tax.

[21] A hybrid policy that includes such a "price floor" through a government promise to buy back permits can foster dynamic inefficiencies (Baumol and Oates 1988).

The use of a combined tax and tradable permit system has been examined in recent years in the context of addressing global climate change (Jacoby and Ellerman 2004; Kopp et al. 2000; Pizer 1999, 2002; McKibbin and Wilcoxen 2002). The proposed systems combine an ordinary tradable permit system with a government promise to sell additional permits at a stated price, thereby creating a price (and cost) ceiling. These approaches have been labeled "safety-valve systems." This is a case where policy making in a second-best setting would recommend the use of multiple policy instruments. To date, despite substantial enthusiasm from economists, no such hybrid instrument has been implemented.

5.2 Stakeholder support

The choice of policy instrument can be limited by political participation constraints. The first-best policy may not be feasible because incidence of the policy's cost and benefits are such that key stakeholders are unwilling to provide sufficient political support.

Consider our previous example of a two-part hybrid policy combining an initial distribution of tradable permits with a provision that additional permits can be purchased at a specified "trigger" price (in essence, a tax). Empirically, such a policy may be only slightly more efficient than a pure tax regime, such as in the case of climate change (Pizer 2002), but it achieves its efficiency while preserving the political appeal of tradable permit systems (in which the permits are allocated without charge). In particular, the government authority has great flexibility to distribute the rents associated with the scarce emission permits as it chooses, and can thereby build a political constituency for the overall policy. Thus, such a two-part policy instrument can be motivated by a desire to generate stakeholder support.

There has been considerable attention given to the political attractions of a tradable permit system in which the permits are allocated without charge (Stavins 1989; Goulder et al. 1997; Parry and Williams 1999). It is well-known that when valuable permits are allocated gratis to those otherwise bearing the greatest cost burden, as with the SO_2 allowance trading program in the United States, political support for a program can be increased without an increase in the policy's social cost. Opposition to pollution taxes is great, because they fail to distribute such rents and because they force firms to pay not only the cost of abatement but also the tax penalty associated with residual emissions. Hybrid systems—tradable permits with a safety valve—have welfare properties equal to or better than a pure price-based mechanism (tax system) while retaining some of the politically desirable characteristics of a pure permit system (Pizer 2002).

The stakeholder support argument for hybrid policy instruments also operates in the presence of other distortionary taxes. A pollution tax may be efficient but politically unacceptable because of its adverse impacts on particular industries. These adverse impacts can be reduced or virtually eliminated by replacing the simple tax with an appropriate hybrid policy. For example, Goulder (2000) reports simulations of CO_2 abatement policies in which the efficiency costs of a standard carbon tax are greatly reduced by combining the carbon tax with industry-specific corporate tax cuts. This contrasts with a system of gratis tradable permits, which has considerably greater efficiency costs. Most striking is Goulder's finding that a permit system with only a small degree of gratis distribution is only slightly more costly than a standard carbon tax program, but can be designed to eliminate virtually all of the cost burden on the hardest hit sectors.

Stakeholder support constraints arise frequently in international environmental and resource policy. The constraint is often that the policy should be perceived to be equitable (Cazorla and Toman 2000). While definitions of what constitutes an equitable outcome vary (Cazorla and Toman 2000), perception of fairness is as important as efficiency or cost-effectiveness in many international negotiations. Unfortunately, there is often a tradeoff between cost-effectiveness (or efficiency) and distributional equity. In these circumstances, the second-best optimum may be to use a combination of instruments to better attain both goals.

A key example of how the stakeholder support constraint can affect policy choice arose in negotiations over developing country participation in the Kyoto Protocol. Economists have argued for developing country participation on cost-effectiveness grounds (Stavins 2001, 2005). But targets for developing countries, even if indexed by economic performance, are widely viewed by developing countries themselves as inequitable (Aldy et al. 2003). The policy eventually established in the Kyoto Protocol combined specific targets for developed countries with optional provisions in the form of the Clean Development Mechanism for developing countries.

5.3 Administrative capacity constraints

Sometimes the constraint that forces policy to deviate from it's first-best solution has to do with the administrative capacity of the state. A prime example of this comes from policies to regulate non-uniformly mixed pollution.

It is well known that cost-effectiveness can be achieved—in principle—with market-based systems, such as tradable emission permits, when pollutants are *uniformly mixed* in receiving airsheds or watersheds. With *non-uniformly mixed* pollutants, where location matters, things may become more complex. In theory, an "ambient tradable permit" system will be cost-effective in such circumstances (Montgomery 1972).

How might such an instrument be designed? In principle, if the government can define a vector of transfer coefficients for each pollutant emitting source, linking emissions from each source with concentrations (ambient conditions) at specified receptor locations, then a trading system can be designed that will achieve a cost-effective allocation of the abatement burden among sources (Tietenberg 1995). Although the design is relatively straight-forward, the implementation of such as system is not, and no such systems exist in practice. Under such a system, each emitter would need to obtain separate permits for each and every affected receptor. With a large number of receptor sites, the set of necessary transactions could be overwhelming.

A practical, second-best alternative may be to use multiple instruments. A market-based instrument—such as tradable emission permits or an emission tax (in the interest of cost-effectiveness)—can be combined with localized ambient standards to prevent concentrations from exceeding accepted levels in particular localities (so-called "hot spots"). This can be done by combining tradeable permits with: (1) ambient concentration limits (Krupnick et al. 1983; McGartland and Oates 1985), or (2) restrictions on both ambient concentrations and emissions (Atkinson and Tietenberg 1982).

There are several examples of the use of market-based instruments in concert with ambient air standards in the United States. One is the sulfur dioxide (SO_2) allowance-trading program carried out in the United States under the Clean Air Act amendments of 1990. This permit trading program exists in the context of ambient standards that limit local concentrations of sulfur dioxide and correlated pollutants. This combination of permits and standards promotes cost-effectiveness while preventing the existence of hot spots (Stavins 2003).

Under the Regional Clean Air Markets (RECLAIM) program in the Los Angeles metropolitan area, a tradable permit system for NO_x and SO_2 was combined with trading restrictions to reduce hot-spots. The Los Angeles basin was divided into two zones, inland and coastal. Inland facilities are allowed to purchase permits from any facility in the Los Angeles

Basin, but coastal facilities are allowed to purchase permits only from other coastal facilities (Harrison 1999).

Water quality regulation provides another example of how multiple policy instruments can lead to a better second-best outcome than a single policy instrument. In water quality regulation, not only do marginal abatement costs vary widely among pollution sources, but marginal damages can also vary widely, depending on source location, pollutant transport characteristics, weather, and other factors. Under these conditions, taxes targeted to address individual facilities' effects on ambient water quality are more cost-effective than quantity-based standards. But the typical proxy for site-specific taxes—a uniform tax—may actually be more costly than quantity-based standards if high abatement cost facilities are also high marginal damage facilities (Boyd 2003; Brown and Johnson 1984). This has been demonstrated empirically in the Delaware River basin the United States (Spofford 1983).

While multiple instruments are used in these policy situations, and this use may be justified on the bases of maximizing social welfare subject to exogenous constraints on administrative capacity, such cap-and-trade policies could benefit from further research on their second-best properties. For example, what is the optimal number of trading zones in a cap-and-trade within zone system? How should standards be set if standards will be combined with a cap-and-trade system? For water regulation, a hybrid approach, combining a quantity-based approach and a fee for exceeding the quantity limit may ameliorate the problems raised by uniform taxes or permit systems, but no such hybrid approach has been studied in this context.

6 Conclusion

We began by highlighting the frequency with which policy makers use multiple instruments to address environmental and natural resource problems, and we described three areas—energy efficiency, toxic chemical control, and fisheries management—where policy makers routinely use a mix of several instruments. Yet with few exceptions, economic research has focused on the economic properties of single policy instruments or comparative properties of individual instruments.

We find that under a fairly broad set of circumstances the use of multiple policy instruments *can* be justified on economic grounds. This justification comes from recognition that environmental policy is usually developed and executed in second-best settings. While some applications of second-best theory to environmental policy have been well examined, in particular, the interaction of environmental policy and pre-existing distortionary taxes, many other applications of second-best theory exist within the environmental domain. We highlighted several cases. A first group consisted of cases where an environmental market failure (imperfect property rights or negative externality) co-exists simultaneously with other market failures. A second group consisted of cases where environmental externalities exist in the presence of an additional (often political) constraint that cannot be removed.

The examination of policy making in these second-best settings reveals two commonalities. First, in the case of multiple market failures, coordination of policies to address the interaction of these failures will often be more efficient that policies that address these failures separately. Second, in all cases, the use of multiple policy instruments may be more efficient than the use of a single policy instrument.

Do these findings eliminate the apparent disconnect between the use of multiple policy instruments in practice and the relative paucity of economic research on multiple instruments? As with many economics questions, the answer is "both yes and no." It is true that the use of multiple policy instruments may be justified when one examines environmental policy in a second-best setting. But there is little research to suggest that the actual mix of instruments employed in practice is the economically efficient mix. Similarly, where there is good economic research to justify the use of multiple policy instruments—particularly research on hybrid instruments—there is little use in the policy world. Thus, the disconnect between instrument mixes used in practice and instrument mixes recommended by economists is only partially explained by the second-best nature of environmental problems. A particularly fruitful area for future research with direct policy implications will be to examine optimal instrument mixes in a second-best setting.

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