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## 2 Allocation of and investment in the environment

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### **Abstract**

The paper explores the case for, and the different forms of, government intervention in the allocation of the environment. Market failures associated with public goods, common property resources, and external costs and benefits are examined. The relative effects and pros and cons of different interventions, namely the creation of property rights, rules and regulations, and market based taxes, subsidies and tradable permits, are explored under different information states of perfect knowledge, probabilistic information and uncertainty.

### **2.1 Introduction**

The environment provides benefits or utility to members of society as a provider of key production inputs, for example, agricultural land, minerals and energy; a place for disposal of wastes, for example, of domestic refuse, building materials and emissions from the combustion of fossil fuels; and the direct provision of environment amenity, for example, for recreation, clean air and water, and protection of flora, fauna and scenery. As is the general economic problem, wants of the environment exceed the limited supply, and allocation choices have to be made between the different uses at any point in time and of uses over time. Also, decisions to invest in protecting and augmenting environmental resources have to compete with other physical and human capital investment options for the limited supply of savings.

In many cases, well-functioning markets can be used, and are used, to allocate scarce environmental resources and to choose investment options. Markets work well where property rights provide for rival consumption and low costs of

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exclusion,<sup>1</sup> and competition prevails. Examples in place include the markets for most minerals and energy, agricultural and urban land, while markets are being developed for uses of consumable water and, in a few cases, for the least-cost supply of environment amenity.

In other cases, however, the allocation of and the investment in environmental resources, wastes and amenity encounter serious market failures. Important areas of market failure include the situations of public goods, where the environmental amenity services have non-rival and non-excludable properties; common pool resources, where the non-excludability property is important; and markets with external benefits and costs, where market buyers and sellers do not consider all the social costs and benefits of their production and consumption actions. The presence of a market failure provides a necessary but not a sufficient condition for government intervention to achieve a more socially efficient, and welfare-increasing, allocation of the environment and associated investment decisions. The nature of the market failure also guides the choice of the form and level of government intervention to improve efficiency.

Options for government intervention to correct market failures include the provision of better property rights; rules and regulations (sometimes referred to as ‘command and control’); market-based interventions using taxes, subsidies or tradable permits; and the provision of information (and usually information has public good properties which will be under-supplied by market forces) and jaw-boning. In Australia, and elsewhere, we find examples of the different policy intervention instruments, and how the relative pros and cons depend on the type of market failure and on the available information. This paper will focus on the normative and economic efficiency arguments for the level of and form of intervention to correct market failures.

While the focus of the paper is the criterion of efficiency, in practice consideration also has to be given to equity and political feasibility effects. Equity as a criterion, however, is given little consideration on the grounds that there are more direct and effective direct income transfer instruments to meet social equity goals than the instruments to correct market failures which affect product and input prices.<sup>2</sup> Another strand of the literature takes a positive mode of analysis and draws on the

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<sup>1</sup> The required property rights have the characteristics of: exclusiveness of the right; transferability; full appropriation of all the benefits and costs with ownership; and are durable and enforceable.

<sup>2</sup> More formally, we might invoke the first and second theorems of welfare economics.

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private theory of regulation, as opposed to the public interest theory used here, to explain the predominance of regulations in environment policy intervention.<sup>3</sup>

The rest of the paper is as follows. Section 2.2 sets out the underlying perfect knowledge and static models of market failure and their correction. A description of the different market correction intervention options in this simplified world is provided in Section 2.3, along with some caveats for second best and government failure. In the particular context of environmental external costs and benefits, Section 2.4 then considers how different forms or levels of imperfect and costly information alter the relative merits of the different government intervention options to correct an externality market failure. Section 2.5 concludes.

## **2.2 Market failure and the environment**

Here we present the public finance and environmental economics text book models of market failure (for example, Stiglitz 2000, and Perman et al. 2003), together with illustrative environment examples, for a public good, a common pool resource, and an externality. Other possible market failures associated with the exercise of market power and asymmetric information can be found in the allocation of the environment, but in the interests of space they will not be considered. While both partial-equilibrium and general-equilibrium models can be used, for the most part the key messages about the cause of market failure, the required correction for economic efficiency, and the nature of alternative corrective government interventions can be obtained from the simpler partial equilibrium model.

Public goods, as opposed to private goods for which markets work, have the combined properties of non-rival consumption and high costs of exclusion. Examples in the use of the environment include the preservation of flora, fauna and scenery. Often the amenity value includes not just contemporary consumption but also the option value of future consumption or just the knowledge of existence. With public goods, there is an incentive for individuals to free-ride, since

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<sup>3</sup> In practice, in almost all countries and examples of market failure with the allocation of environment resources we observe a much higher dependence on command-and-control interventions than on the market-type interventions proposed by economists and argued for in this paper. An alternative positivistic analysis of the supply and demand for intervention which places a high weight on equity effects and on political processes, for example, as discussed in Keohane et al. 1998, provides support for greater roles for the command-and-control interventions. While these models have been developed primarily for the USA context, and they place great importance on the independence of individual Congress representatives which seems less exercisable in the Australian political context of greater party power relative to individual independence, they suggest a valid alternative complementary paradigm for the study of policy in Australia.

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individuals gain the benefits anyway (because of non-rival consumption) and an individual cannot enforce a charge on other users (because of non-exclusion). As a result, with a market as the allocative mechanism too little of a public good is produced and consumed.

An efficient level of a public good, including the environment, defence and law enforcement, would seek a quantity which equates the sum of the individual marginal benefits with the marginal cost of supply (or, in a general equilibrium model, the sum of the marginal rates of substitutions across individuals with the marginal rate of transformation, and in both cases of the public good relative to other private goods).

Application of the efficiency principle to measure the efficient supply and consumption of an environmental public good, such as a national park or a share of water for the environment, would involve the collection of biological and physical information to estimate increments of the quantity of environmental services provided, and then some form of stated preference technique such as contingent valuation or choice-modelling to ascertain individual valuations of the incremental changes in environmental services. In practice, either with or without attempts to measure the social marginal valuation of public goods, political processes as a form of collective or social choice often make the actual decision.

In terms of policy instruments, governments generally would need to take an active role in securing and funding the efficient supply of a public good, including a share of the environment. The intervention could directly increase the supply or share of the public good, or it could operate indirectly by restricting the market-determined alternative private good use of a resource by using regulations, taxes or subsidies.

A second set of market failures in the allocation of the environment is referred to as the common-pool resource. Common-pool resources have the properties of rival consumption and very high costs of exclusion, although exclusion costs depend on technology and, often, on the state of government-provided property rights. Examples of natural resources, and some built resources, which are accessible to anyone with these common-pool properties include the British commons and grasslands before fencing, fisheries, public motorways, some forests and public parks, beaches, etc. In effect, the common-pool resource problem results in a type of external cost as additional users ignore that their consumption draws on the common-pool resource stock and increases the costs faced by all other users of the limited resource stock. From a society-efficiency perspective, the common-pool resource is overexploited and any economic surplus is driven to zero.

A society-efficient level of production and consumption of a common-pool resource would seek to equate the marginal social cost — which recognises both private

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costs and the spillover costs on other users — with the marginal benefit. Marginal social costs can be found from the individual firm marginal private cost curve, and treating this as the society-average cost curve. Perhaps ironically, one solution is to provide for monopoly ownership of the common-pool resource; this works because monopoly ownership converts the non-exclusive property of the common-pool resource under a competitive market structure to an exclusive property. Other policy interventions available to government to reduce overexploitation of a common-pool resource include rules and regulations to reduce consumption or the market-based mechanisms of taxes and tradable permits. In each case, the different sets of interventions might be applied directly on the quantity, or indirectly on closely correlated and sometimes easier to measure inputs and production methods.

The third set of situations where markets fail in the allocation of the environment is grouped under the heading of external costs and benefits. In effect, some of the costs and benefits to society are not recognised under existing market transactions between buyer and seller. Pollution associated with the disposal of wastes by households and businesses is the most important example. Other examples where external costs and benefits can arise include land-use choices, building and other structure designs. Within pollution examples, specific details can vary.<sup>4</sup> While such differences clearly are important in the determination of the details of the efficient allocation of resources and investment decisions, and in the specific design of the corrective policy intervention, the general guideline for economic efficiency is to choose decisions which equate marginal social cost with marginal social benefit.

Figure 2.1, which will be used again in the paper, provides one way of showing the externality problem. The horizontal axis shows the relevant measure of the pollution emission, for example the flow or stock of greenhouse-gas emissions. Output  $Q_{bau}$  is the emissions output, or business-as-usual decision under a market, where for valued private goods and services, such as electricity and transport involving the use of fossil fuels, marginal private benefits (MPB) are equated with marginal private costs (MPC) at a market price. The horizontal axis can also represent in a crude way a measure of output of these valued goods and services. The vertical axis shows costs per unit of emission. The increasing cost curve MEC for marginal external cost shows the marginal cost to society of extra pollution, a cost ignored by a market, essentially because there is no property right to pollute. The function

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<sup>4</sup> For example, we can distinguish between local, national and global pollution (for example particulates and local visibility, acid rain, and greenhouse gases associated with the combustion of fossil fuels); between pollution associated with a flow or a stock (for example most household wastes and heavy metals in sewage disposal); between cases where the external costs have a roughly equal incidence across jurisdiction effect or diffuse external costs by geographic area, whether the externalities relate to production and/or consumption decisions; and between point and non-point forms of pollution (see further, for example, Perman et al. 2003).

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increasing from  $Q_{bau}$  is called the marginal abatement cost (MAC). The MAC reflects the fact that as pollution is reduced, producers have to choose more costly production processes that incur less pollution; and/or buyers shift their consumption mix to less pollution-intensive products which are less effective substitutes; and/or society invests scarce resources in R&D to help achieve at lower cost the former two options. In a crude sense, the MAC reflects the difference between MPB and MPC for the desired goods and services as less pollution is emitted. The efficient level of pollution, at  $Q^*$ , and in turn the efficient choice of products and production processes with different pollution intensities, equates the MAC and MEC curves. This occurs also where  $MPC + MEC = MSC = MPB$  (which for completeness equals MSB), where MSC is marginal social cost and MSB is marginal social benefit for the private goods and services.

A number of additional observations can be drawn from figure 2.1. First, a measure of the efficiency gain in shifting from business as usual to the efficient allocation is given by the triangle of economic surplus area 'a'. Second, the optimal solution  $Q^*$  involves consideration not just of the technical effects of the externality, but also the relative marginal costs and benefits of the externality. Third, and related, seldom will the efficient solution be one of zero pollution. Fourth, both the MAC and MEC curves of figure 2.1 are almost certain to shift over time, both in their position and in their slopes or elasticities. Then, the efficient level of pollution will change over time, and so will also change the quantity of production and consumption, and the production methods, of the goods and services producing the externalities as by-products.

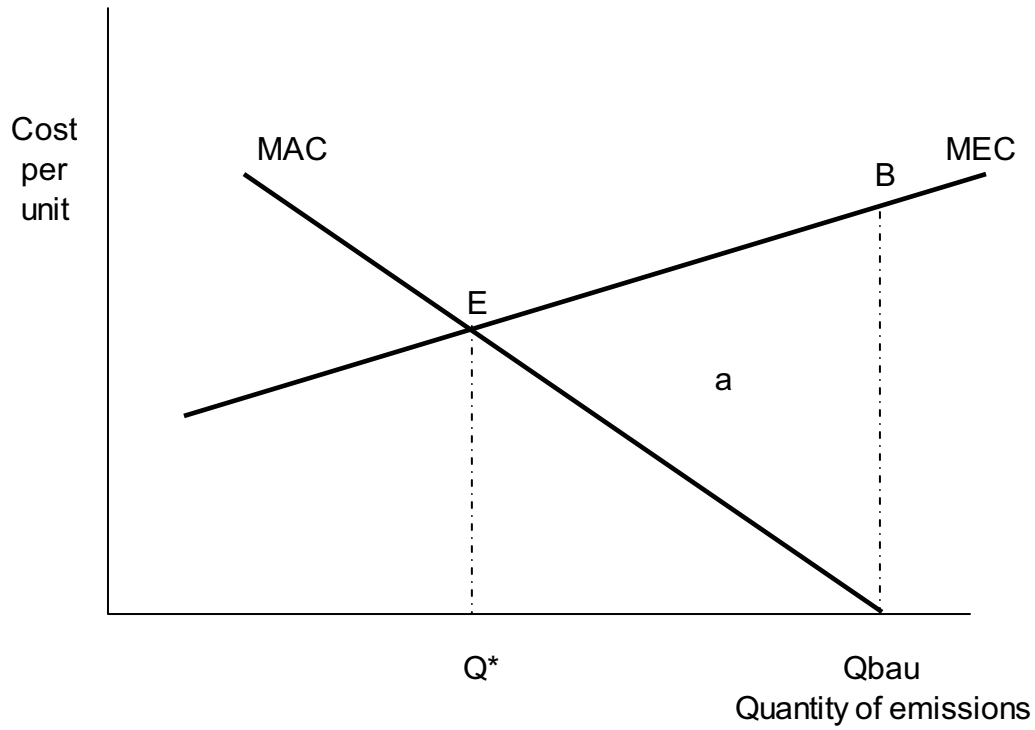
Many arms of government policy intervention are candidates to reduce the level of externalities from the current or business-as-usual level,  $Q_{bau}$ , to the socially efficient level,  $Q^*$ . These include establishing property rights (for example, to pollute); command-and-control regulations on the quantity of emissions, outputs or key inputs; market-based interventions, such as a tax, tradable permits or subsidies to reduce pollution; and moral suasion to reduce pollution. In all cases the regulation, tax, and so forth, should be directed at the size of the marginal external cost at the efficient output level.

Market failures that flow across countries involve additional policy challenges. Where the market failures affect households and businesses within a country, a national government has legal power to compel — although subject to various constitutional and democratic checks. By contrast, where the market failure crosses border boundaries — for example, for global pollution and some public goods — there is no effective international government. In these cases, a solution requires cooperative agreements among the governments of the different countries.

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Figure 2.1    **Externality correction**

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### 2.3    **Intervention with perfect knowledge**

Suppose initially that we have perfect knowledge of the science and economics of the relevant marginal benefit and cost functions, and so we know the efficient allocation of the environment as well as the current allocation with its market failures. Then, in figure 2.1, for a pollution externality, for example, government policy seeks an instrument to change the allocation from  $Q_{bau}$  to  $Q^*$ .

In principle, most of the potential instruments could be employed. A property right to pollute could be designed and managed. As argued in the Coase (1960) theorem, different initial allocations of the new property right, whether to the polluter or the polluted, would lead to an efficient allocation, if transaction costs are negligible. With many players, the low transactions cost pre-condition becomes untenable. A command-and-control strategy would simply require pollution at the efficient level of  $Q^*$ . Given the likelihood that there is a less-than-perfect correlation between the pollution externality (for example, greenhouse gas emissions), and the desired final good (for example, electricity), or a key input (for example, coal), or a production process (for example, heat exchange), it is preferable to regulate the indicator most

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highly correlated with the external cost product — namely the emission itself — rather than a final product, input or production process. If in reality measurement and monitoring costs are lower with the output, input or process indicators, such transaction cost savings might be traded off against errors in signalling the external cost.

Different market-based instruments could achieve the efficient allocation. A tax set at the marginal external cost, namely  $Q^*E$  of figure 2.1, would internalise the externality in the private costs. The shadow price, or opportunity cost, of a tradable permit set at the efficient level  $Q^*$  would have the same price and quantity effects as the externality tax. Or producers could be bribed with a subsidy equal to the tax per unit of emission to reduce emissions to the efficient level. As was the case with the command-and-control policy instruments, in general it is better directly to target the tax, tradable permit or subsidy on the pollution source rather than the indirect measures of related, but not perfectly correlated, outputs, inputs or production processes, unless there are large compensating savings in transaction costs.

In terms of redistribution effects, some to all of the costs imposed by governments to restrict pollution will be passed forward to consumers as higher prices under the different forms of corrective government intervention. With the exception of the subsidy, under other interventions the private opportunity cost of production of the externality-creating goods and services increases by the external cost to reflect its social cost. The more elastic is product supply relative to product demand, the higher is the share of the incremental cost passed on as a higher buyer price. Where the marginal cost function is perfectly elastic reflecting a constant returns-to-scale production technology, all of the cost increase will be borne by consumers.<sup>5</sup>

The distributional effects among producers and government will vary with the instrument used to reduce pollution. Where governments initially distribute newly-created property rights to pollute to producers, as is implicit with quotas or tradable permits, the producers (or more generally the other initial property-right recipients) receive a windfall surplus or rent. By contrast, if the permits are auctioned or a tax is imposed, government receives a windfall increase in revenue. A subsidy, by contrast, involves a loss of government revenue. Often regulations to restrict supply are seen by producer lobby groups as a way of creating rents and raising barriers to entry, so favouring the incumbent producers.

Households, and in some cases businesses also, are the beneficiaries of reduced pollution. Importantly, and as noted in the previous section, overcoming market

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<sup>5</sup> While this result assumes perfect competition, it also is a good approximation, for the different market structures of monopoly, monopolistic competition and some of the oligopoly models, see Freebairn (2008).



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failures is a positive-sum game where potentially, if not in practice, the losers can be more than compensated by the winners with some additional economic surplus left over.

So far this paper has proposed a set of interventions which assume that the rest of the economy is acting in a first-best way with no other market distortions. This is an extremely strong assumption and in practice it is an invalid simplification. Where there are distortions elsewhere in the economy — for example, other public goods, monopolistic behaviour, or market failures with other environment choices — adopting a market correction derived on the assumption of market perfection elsewhere will not be first-best. For example, if a product that involves external costs is also a monopoly, monopoly behaviour distorts the economy with too little production and consumption, but this may partly or more than fully reduce output as desired to counter excess production and consumption due to the externality. In principle, using a general equilibrium model, but also with much more information requirements, the appropriate correction in a second-best world can be derived. Recognising the limitations of information, Ng (initially in 1977 and in more recent texts such as 1990) argues that in most cases going for the first-best and ignoring other distortions (in what he terms the theory of third-best) will be close to the mark.

A related consideration is the transaction costs of intervention. Transaction costs include the costs of policy development, and then the costs of administering, monitoring and enforcing compliance with the policy intervention. A net efficiency gain requires that the additional transaction costs exceed the gains to society of the reduced extent of market failure.

In a realistic context of any modern economy and political processes for the determination of economic policy, against market failure has to be balanced government failure. As will be discussed in more detail below, information on the key parameters to correct market failure is imperfect, and costly to obtain. Inevitably the best-intentioned governments will not choose  $Q^*$  of figure 2.1, and possibly they will choose a much smaller level of pollution that incurs even larger efficiency costs than area 'a' generated by the market. The reality of our political processes is that producer lobby groups are more effective lobbyists and suppliers of information cast in their favour than consumers. The objective of politicians to seek re-election need not coincide with maximising economic efficiency, and bureaucrats in part have a selfish interest in interventions that build the size of the bureaucracy and their opportunities for promotion.

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## 2.4 Intervention with imperfect information

Reality is that knowledge about the required functions to choose the level of, and the form of, government policy interventions to correct for market failures — including allocation and investment decisions for the environment — is imperfect. Also, the relevant functions almost certainly change over time, and new information is collected and analysed with the passage of time. In this realistic context, we can draw some differences between the different policy instruments which were not found under the previous section's assumption of perfect knowledge. This section will consider different forms or levels of imperfect knowledge.

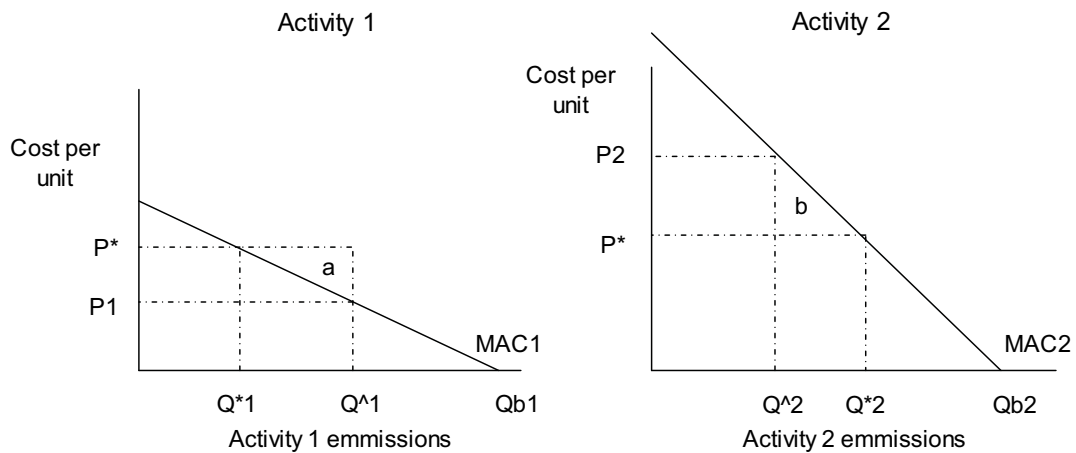
Consider first the case where policy makers have a good idea about the efficient allocation in aggregate, but not the details for individuals. For example, in figure 2.1, there is a good idea of the required reduction of the aggregate level of pollution from  $Q_{bau}$  to  $Q^*$ , or of the marginal external cost  $Q^*E$ ; but policy-makers have much less information for the MAC of the many individual households and businesses. In contrast, individuals have private information on cost-effective ways to reduce emissions.

To illustrate, in figure 2.2 we have two activities producing an external cost, and they have differently shaped MAC functions which are known (or knowable) to the firms but not to government; but government considers that the level of external cost production needs to be reduced  $x$  per cent, say a half of  $Q_{bau} = Q^*$ . A command-and-control regulation might set the same quota for both Activity 1 and Activity 2, namely output  $Q^1$  and  $Q^2$ . Note that at these levels, the MAC at the regulated levels varies between the two activities at  $P1$  and  $P2$ , respectively.

Market-based mechanisms offer cost-effective ways, and associated efficiency gains, in meeting the aggregate desired pollution levels. In figure 2.2, if the quotas were made marketable transferable permits, it would pay Activity 2 to purchase quota permits (to increase pollution) from Activity 1 (who then would further reduce pollution), until the MAC was equated across the activities at a market permit price of  $P^*$ . The same aggregate market level of emissions would be achieved with both parties gaining, namely area 'a' for Activity 1 and area 'b' for Activity 2, for a society efficiency gain of area 'a + b'.

That is, a tradable quota system is a cost effective way of allocating a limited resource, such as a common-pool fishery, or meeting a maximum pollution target, such as wastewater or greenhouse gas emissions. As an example, the tradable permit system introduced in the USA in the early 1990s to reduce emissions of sulphur causing acid rain arising from the combustion of coal in power stations was estimated to reduce the costs of emissions reduction by one-third to one-half of the

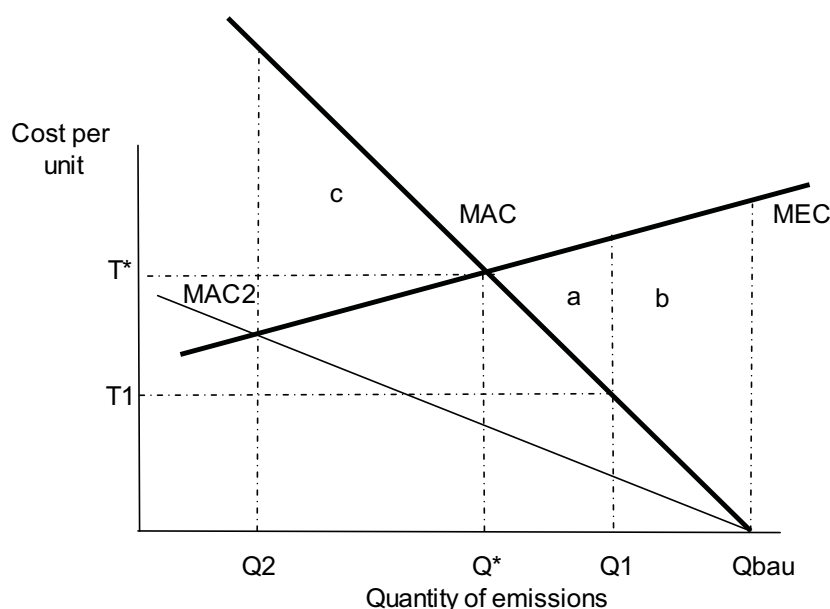
Figure 2.2 Least cost market instruments



costs under regulation (Shogren 1998). Alternatively, imposing a tax at rate  $P^*$  on the pollution maximises the pollution reduction for a given per-unit pollution charge. In addition, the tax or permit price provides continuing incentives to invest in R&D and to seek better and lower-cost ways of using the environment. The self-interest of different players in a market context has them revealing the private information which generally is not available to policy makers.

Information will often be imperfect for the aggregate functions, too. Then, policy intervention in the allocation of the environment generally will not be first-best, and in some cases it will be less effective than leaving allocations to the market. Consider figure 2.3 for a pollution externality. We start at  $Q_{bau}$ , for business as usual, with the true, but imperfectly known, MAC and MEC curves with a social optimum at  $Q^*$ . Suppose that, under imperfect knowledge, the policy-makers choose a tradable quota at  $Q_1$  or an emissions tax at  $T_1$ , which for simplicity are chosen to result in identical realised market outcomes. Relative to the no-intervention state, economic welfare is improved by the trapezoid area 'b', even though an additional potential first best efficiency gain of triangle area 'a' is missed. But under imperfect knowledge, it is also possible that the policy intervention case is less efficient than business as usual; and for illustration suppose that the estimate is  $MAC_2$  rather than the true MAC (and with MEC true), so that the area 'c' between MAC and MEC and quantity  $Q_2Q^*$  exceeds area 'a + b'.

Figure 2.3 Imperfect knowledge costs



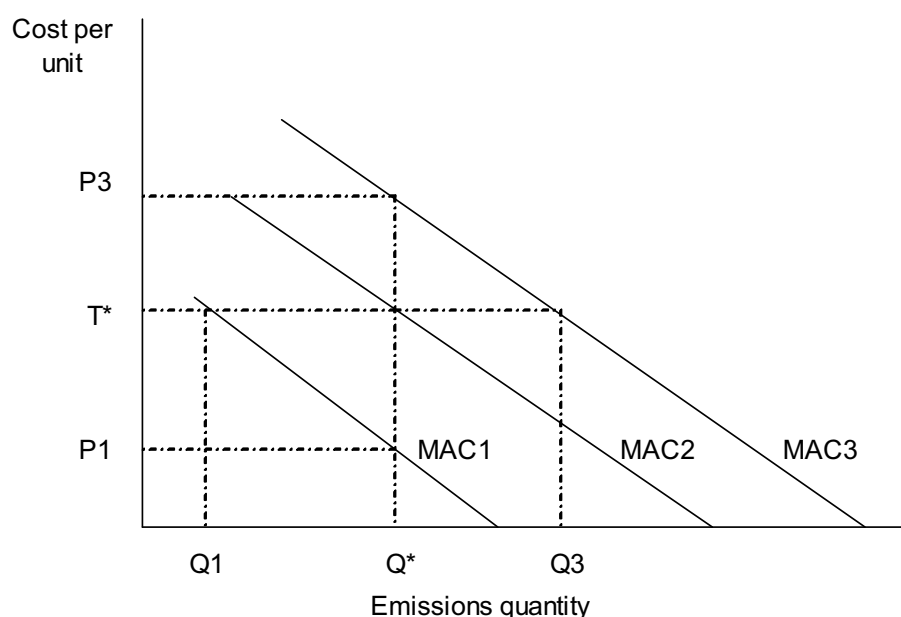
In the context of figure 2.3, and using Weitzman (1974), we can say something about the relative merits of choosing the tax instrument versus the tradable permit instrument under imperfect knowledge of the positions of the MAC and MEC curves; but with knowledge of their relative slopes, in terms of the relative sizes of the efficiency losses, namely the triangles ‘a’ and ‘c’. Where the MEC is flatter than the MAC, as illustrated in figure 2.3, comparable errors expressed as a percentage of  $T^*$  in the choice of the tax rate will result in smaller efficiency losses than comparable errors in the choice of the quota or cap  $Q^*$ ; with the reverse of a tradable quota favoured if the MAC is flatter than the MEC.

In most cases, the MAC (and in many cases also the MEC) curve will shift over time — for example, with economic growth, technology, tastes, climate and so forth. Also, the MAC will be more elastic with a longer length of run as there are more opportunities for substitution in production and consumption of the pollution-intensive inputs and outputs. In many cases, the long run will be decades given the long lives of equipment and buildings, and also with the endogeneity of investments in R&D.

Figure 2.4 shows an example of three different positions for the MAC function. Suppose that initially with MAC2 a tradable quota  $Q^*$  or a tax rate of  $T^*$  is chosen. Shifts in the MAC2 to MAC1 or MAC3 with a tradable permit result in stability of the emission at  $Q^*$ , but with volatility of the permit price of  $P1$ ,  $T^*$  and  $P3$ . By

contrast, with a tax, shifts in the MAC result in price stability at  $T^*$ , but with volatility of the emission levels of  $Q_1$ ,  $Q^*$  and  $Q_3$ . Which of these sets of volatility is least preferred will vary with circumstances, such as the relative shapes of the MAC and MEC curves already discussed, and on the relative effects of price volatility versus quantity volatility for the effectiveness of decision-making by households, businesses and governments.

Figure 2.4 Price versus quantity intervention



Economists, and others, often distinguish problems of imperfect knowledge between risk and uncertainty. Under risk, the different possible states can be specified, and there is general agreement about the probabilities for each state. With uncertainty, the possible states might not be known and there are diverse views on the probabilities of each state or, in the case of radical uncertainty, no probabilities can be attached.

For the case of risk, we replace the deterministic procedures of the perfect-knowledge model discussed above with expected outcomes for different actions if risk neutrality is assumed, or with expected utility comparisons if risk aversion is a more reasonable objective in choosing between different forms and levels of policy intervention.

Some cases of market failure with the allocation of the environment will not have sufficient information to form even a rough consensus probability distribution function with which to assess the effects of different policy interventions. Such

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uncertainty does not, of itself, nullify the statements of potential efficiency losses in the choice of level of intervention or the relative properties of the different instruments discussed above. But the reality of uncertainty has often given support to a number of regulatory interventions over market-based instruments, to different objectives such as sustainability and the precautionary principle, and to the more explicit and formal recognition of the need for flexibility to respond to new information.

There are different variants of the precautionary principle or option-value approach to government intervention in decisions affecting the environment under uncertainty (see, for example, Weier and Loke, 2007). One interpretation is that where there are actions with a reasonable likelihood of both large and irreversible damage, such actions should not be taken in the framework of a type of a lexicographic-objective function or of a maximin solution to a game-against-nature model of the decision problem. Regulations based on available scientific levels, on safeguards for biodiversity survival, on weak or strong sustainability, and on minimum health safeguards are examples of applications of the precautionary principle. Wills (2006) and others question why the action of ‘protect the environment’, rather than the action of ‘reduce the economic opportunity loss’, should necessarily be the worst or maximin state.

Often, complementary policy action involves further research, information collection and analysis to improve understanding, and then the option to revise decisions in the future in the light of the extra information, and investment in capacity to increase the resilience of the system to cope with possible adverse outcomes.

## **2.5 Conclusion**

A mixture of markets and of government intervention to correct for such market failures as public goods, common-property resources and externalities will be required to achieve an efficient allocation of the environment and for investment in its development. When government intervention is likely to improve upon market decisions, then in most cases market-based instruments such as taxes and tradable permits offer more cost-effective ways of changing allocations and investments, because they induce firms and households to reveal information not available to governments about their individual preferences and constraints.

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