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POLLUTION TAX

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Abstract

This chapter aims to give a short but comprehensive overview of key literature on pollution taxes. It focuses on the introduction of the concept by Pigou in the 1920s and Coase's alternative 'property right' analysis of the pollution problem. Critiques of both approaches are subsequently discussed. The author then turns to some current views on the topic using tools such as game theory and public choice analysis. Finally a look is taken at different types of pollution taxes used today.
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1. Introduction

Environmental policy was designed to combat the increasing costs of human behavior to our natural environment. Environmental pollution is seen as the main cost to the environment. Pollution can be defined as the 'harm or damage done to animals/plants and their ecosystems' (Turner, Pearce and Bateman, 1994, p. 4). Governments have the option of protecting the environment by means of a 'direct regulatory' approach or a more 'economic' or market-oriented approach.

The 'command-and-control' approach uses standards in an attempt to alter behavior; the economic approach is based on the use of 'incentives', otherwise known as market-based instruments (MBI). The latter implies that a polluter should respond to economic signals once a market in 'pollution' is created. Possibly one of the most widely used methods of economic incentives to change behavior is taxation. The idea of environmental taxation can thus be translated as an attempt to alter polluting human behavior by imposing taxes that can be avoided, or diminished, by more environmentally friendly behavior.

The concept of pollution taxes was put forward almost 80 years ago but is still not universally accepted as an effective means to pollution abatement, in the camps of both lawyers and economists.

Some feel the solution to the problem of environmental degradation lies in economics, others feel law is the best instrument, a third group feels the problem will require a combined effort of law and economics.

This chapter will track the history of the pollution tax concept starting by discussing the Pigovian tradition, then concentrating on the subsequent issues and discussion involved.

2. Externalities - The Root of the Problem

The idea of pollution taxes finds its raison d'être in the existence of externalities. Pollution, as defined above as damage done to the natural environment, is seen as a classic example of externalities. Alfred Marshall (1936, p. 277) first wrote of what is now known as positive externalities as 'the external economies of production on a large scale' in 1910 in his work *Principles of Economics.*

Externalities are defined by Samuelson and Nordhaus (1995, p. 32) as follows: 'Externalities or "spillover effects" occur when firms or people impose costs or benefits on others outside the marketplace'; or as Begg, Fisher and Dornbush (1994, p. 52) put it in their basic *Economics* volume: 'An externality exists when the production or consumption of a good directly affects businesses or consumers not involved in buying and selling it and when those spillover effects are not fully reflected in market prices.'

Environmental externalities are generally negative and the consequence of the absence of markets (no exchange through supply and demand) and market prices (no payment required) for part of the natural environment. This presents an information gap for the economic agents who have no concept of the cost of their actions on the environment and thus the society. Pigou (1962) accepted this problem fully and even devoted a whole chapter to the 'hindrances to equality of return due to imperfect information'. His definition of externalities also included the concept of unintentional damage ('*incidentally* rendering services or disservices') conforming to the general idea that market imperfections such as a lack of information are responsible. As Pigou considered externalities to be market failures, he suggested tackling the problem with state intervention in the shape of taxes and subsidies. However, in the 1960s Coase argued that the problem of externalities could best be approached as a problem of poorly defined, or absent, property rights, and should be dealt with accordingly.

Solutions to the problem of externalities tend to be aimed at the compensation for, or the avoidance of, negative externalities, sometimes referred to as *external diseconomies.*

3. Pigou

3.1 Pigou's Original Writings

The British economist Arthur C. Pigou first developed the basis for the concept of a pollution tax or Pigovian tax, in *The Economics of Welfare* (1920). In this, Pigou (1962, p. 224) explains that in case the marginal *social* net product (including externalities) is different from the marginal *private* net product (net products are the results in the output of marginal resource increases), a tax or bounty (subsidy), depending on the sign of the difference, can be implemented to minimize the difference. There is only one tax or bounty for each externality that can lead to the optimum effect, that is, the equalization of the marginal private and social net product.

One could question whether Pigou originally meant this concept to be used as a means for environmental preservation. Pigou quite clearly answers this question himself by including the natural environment in his definition of possible social net products. In fact, he explains the principle of marginal *social* net product with the example of 'uncompensated damage done to surrounding woods by sparks from railway engines' (Pigou, 1962, p. 134).

However, this interpretation of Pigou's writing runs into problems, or rather contradictions, when reading on. The inclusion of the environment in the concept of social net product becomes unclear when one considers that Pigou explains the *value* of the marginal social net product on the following page as the 'sum of money which the marginal social net product is *worth in the market'* (Pigou, 1962, p. 135; own italics). As has already been discussed, the root for many environmental problems is exactly the absence of a pricing mechanism for the natural environment in today's markets.

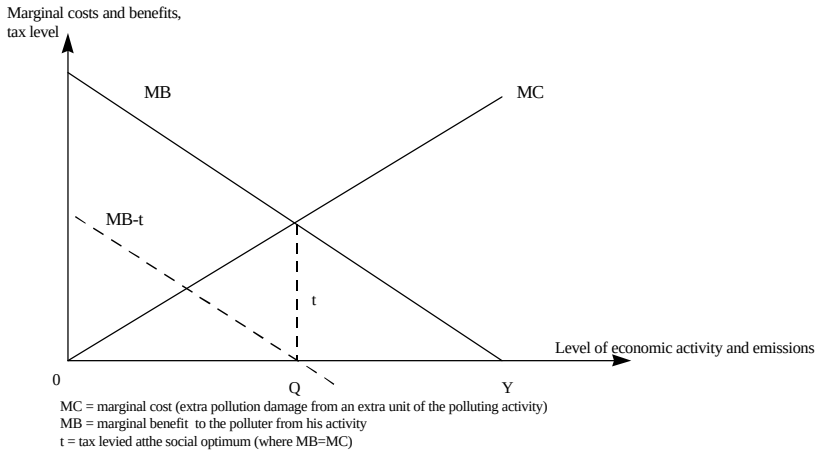
3.2 Current Interpretations of Pigou's Concept

The term pollution taxes, otherwise known as pollution charges, externality taxes or Pigovian taxes, by definition refers to a tax:

- used to correct the misallocation of resources when social costs are different from private costs; and
- based on the estimated damage.

This is graphically shown in Figure 1.

Figure 1 Optimal Pollution Tax



Assume the economic actor responsible for pollution in Figure 1 is a firm. The marginal benefits (MB) of the firm's activity decrease as the activity continues. However, as the firm is not confronted with the pollution in market prices, it is from a profit-maximizing perspective worthwhile to expand the activity so long as the marginal benefits are larger than zero (private optimum Y).

As the activity is responsible for pollution (expressed here in terms of marginal costs), the social optimum, which takes external costs into account, corresponds to a lower level of activity (Q). Marginal benefits are then equal to marginal costs. In order to confront the firm with this social optimum, and internalize the externalities, a tax can be introduced. A tax set at exactly the damage level (MC) at the social optimum, will in fact decrease the MB at each level of economic activity. The firm will now use the MB-*t* curve, instead of the MB curve, to decide on its optimal level of economic activity. As MB-*t* becomes equal to zero at level of activity Q, the firm will now see Q as its private optimum. The tax has thus succeeded in its purpose. The private optimum is now equal to the social optimum due to the implementation of an economic incentive.

Although this tax works perfect in theory, the practical implementation is very difficult due to a lack of complete information on damage levels (MC). Economists from the Austrian School have argued that the evaluation of costs is extremely difficult due to their subjective nature. Buchanan (Cordato, 1992, p. 6) defines costs as subjective because they 'only exist in the mind of

decision-maker or chooser' and are 'individual evaluations of enjoyment or utility anticipated'. He therefore concludes that costs can only be judged by the decision-maker since no one else can observe the 'subjective mental experience' surrounding cost evaluation.

Due to these practical problems, other taxes are now referred to as pollution taxes although they are not Pigovian taxes in the strict sense of the word. The term 'pollution charges' tends to be used for, and confused with, what are correctly called emission and product charges. Emission charges can be defined as 'fees collected by government, levied on each unit of pollutant emitted' (Tietenberg, 1996, p. 335). Product charges, on the other hand, are levied on each unit of a product harmful to the environment, for example, charges on fuels, detergents, and so on. Neither are defined to necessarily ensure that production is at the optimal level, that is, where marginal net private benefit equals marginal external cost, or where marginal abatement costs are equal to marginal benefits of reduced pollution, nor are they based on the estimated damage. They may not be pollution charges as originally defined by Pigou, but are considered to be legitimate interpretations of the Pigovian concept (see Section 5.3 and further), as they are taxes implemented to combat environmental pollution.

4. Coase

An introduction to the idea of (Pigovian) pollution taxes and consequent discussions in an Encyclopedia of Law and Economics must include Coase's main criticisms, and alternative solutions. As this is, however, also discussed at length in Chapters 0730 and 2300, the discussion here remains basic.

In the 1960s the concept of externality taxation was criticized by Ronald Coase who introduced an alternative approach, using a property rights theory. This theory may lead in some cases to the, at first sight contradictory, conclusion that once property rights have been correctly defined, it may be optimal to tax not the polluter but the victim of pollution. This is due to the fact that Coase addressed the *reciprocal* nature of the externality problem. For a negative externality to exist there must be at least two parties, one whose action (production or consumption) results in the externality (injurer) and one who is affected by the externality (victim). Due to the action, the injurer perceives a benefit (otherwise he would not do it) and the victim perceives a cost. Both parties attach values to their perceived costs and benefits. It seems obvious here that the injurer inflicts harm to the victim but at the same time it is also true to say that the injurer would suffer (lose benefits) if the victim were to prohibit or restrict the injurer's actions. Coase (1960, p. 2) therefore stated in his famous article 'The Problem of Social Cost' that the problem was 'to avoid the more serious harm'. In order to resolve the problem of externalities, the potential bargaining positions of both the victim and the injurer should, therefore, be analyzed, and could, in theory, lead to the restriction of the victim. Pigou,

however, placed the burden of liability solely on the polluter (that is, the polluting factory in his example).

Coase's ideas in 'The Problem of Social Cost' (1960) were later interpreted as 'the Coase Theorem' which was seen as propagating the use of property rights for internalizing externalities. The Coase Theorem can be interpreted as follows:

regardless of who holds the initial property rights, the bargaining process between polluter and those affected will bring about the most efficient solution, *assuming* transaction costs are zero.

However, Coase (1980) dissociated himself from this common interpretation of his ideas in the preface to his book, *The Firm, the Market and the Law.* He argued that in reality the presence of considerable transaction costs would often not enable bargaining to reach the optimum solution. The Normative Coase Theorem: 'Structure the law to remove the impediments to private agreements' (Cooter and Ulen, 1988, p. 101) can be seen to follow from this.

It is interesting to note, as Bromley (1991, pp. 62-64) does, that if property rights are clearly defined and there are no transaction costs (defined as ICE: Information, Contracting and Enforcement costs) there could be no (Pareto relevant - when the activity can be changed so that the victim can be made better of without the imposing party being made worse off) externalities. All possible gains from trade would have been bargained away. Consider the possible gains from trade (the beneficial effects of a certain action which normally only gives benefits to one party) to represent the externalities and the transaction costs to represent the bargaining process. A bargaining process will take place as long as there are possible gains from trade and no transaction costs. Bromley (1991, pp. 62-64) therefore feels the Coase theorem to be void as in his interpretation it only holds true in cases where there are no externalities in the first place. This interpretation is sensitive to the use of certain time horizons though. Bromley's statement can in any case only hold true in the long term. Short-lived externalities will always exist during the bargaining process.

In 'The Problem of Social Cost', Coase reproached Pigou because he felt environmental externalities were not the consequence of market failures but rather of a failure of regulation (see also Andersen, 1992). Coase referred to Pigou's example of the electricity sparks damaging the woods (see above) to justify this critique since under British law there was no right to compensation for damage from 'authorized' railways (Coase, 1960). He therefore felt that the interventionist approach taken by Pigou was not justified.

Coase (1960) also felt that Pigou's original text and the common interpretation lacked detail. He pointed out that Pigou never clarified how the tax receipts should be used. There is a clear difference between a simple tax on the polluter and regulation requiring the polluter to compensate the victim. Nonetheless, he continued, economists often see these two different solutions as being identical.

Spulber (1989, pp. 343-345) showed that private bargaining under complete information, absence of consumer income effects and independent of the assignment of property rights, induces an efficient emission level of pollution. However, other authors such as Hamilton, Sheshinsky and Slutsky (1989, pp. 453-471) have argued that a decentralized efficient solution to production externalities with free entry does not exist. In fact, standard monopoly inefficiency may result. Only if complete property rights exist (that is, the ability to control the right to pollute and the right to entry) and if the property rights holders bargain with all relevant consumers and producers, can bargaining provide an efficient output level. As this is highly unlikely they suggested an alternative solution using the property rights approach and Pigovian taxes when appropriate (see Section 5.5).

5. The 'Pollution Tax' Discussion Continued

5.1 Transferable Property Rights - Dales

Dales (1968) is best known for suggesting an actual market in property rights as the solution to pollution problems. This concept has its practical application in, for example, tradable emission permits.

Although Dales did not dismiss the idea of Pigovian taxes as such, he believed it impossible to obtain the information required to set taxes at the optimal level without wasting too many resources. This in turn would make the whole exercise inefficient. Dales (1968, p. 40) stated that 'it is the lack of information that is the crux of the matter'. He dismissed the use of cost-benefit analysis as the necessary information on costs and benefits could only be obtained when assuming a very simplistic, and therefore artificial world.

However, Dales also acknowledged the deficiencies of a transferable property right system and suggested that regulations, subsidies and excise taxation would be appropriate in case of multiple source pollution, as this could not be adequately handled with transferable property rights. Dales did therefore not completely dismiss Pigou's 'taxes and bounties'.

As transferable property rights cannot be classified as pollution taxes, they will not be discussed any further in this entry.

5.2 Pigovian Taxes and Monopolies - Buchanan's Critique

As Buchanan (Cordato, 1992, p. 6) defines costs and benefits as very subjective (see Section 3.2), he sincerely questions the idea of setting Pigovian taxes for the obvious reasons.

He further argues that Pigovian taxes (and subsidies) might increase misallocation in cases of monopoly. This cannot be seen as a critique of the early writings of Pigou, though, since Pigou (1962) specified quite clearly that

there are *optimal* taxes and bounty 'under conditions of simple competition'. Buchanan's criticism can therefore only be seen as dismissing the interpretation of Pigovian taxes as the ultimate solution in all circumstances and market forms. Baumol (1972) pointed out that as simple competition is close to reality in most cases anyway, Buchanan's critique is of no great importance. The existence of certain (natural) monopolies can, however, not be denied.

5.3 Baumol's 'Environmental Charges and Standards' Approach

Baumol (1972) accepted the basic idea of Pigovian taxes. He argued that Pigovian taxes on the 'generator of the externality' are most effective and that 'the conclusions of the Pigovian tradition are in fact impeccable'! He nonetheless recognized the difficulties of practical implementation as the main shortcoming of Pigovian taxes.

Instead of setting a tax rather arbitrarily in the hope of achieving a certain reduction of pollution, Baumol (1972) suggested to first set certain standards of pollution (emission, air and water quality, and so on) and then, through a process of trial and error, derive which levels of taxes have proved to give certain outputs. He thus suggested achieving 'selected standards of acceptability by experience'. He later referred to this as the 'environmental charges and standards approach' (see below). This approach aims to solve the implementation problem of Pigovian taxes.

5.4 Baumol and Oates - the Acceptability Standard further Developed - Emission Charges

Baumol and Oates further developed the environmental charges and standards approach in *The Theory of Environmental Policy* (1975).

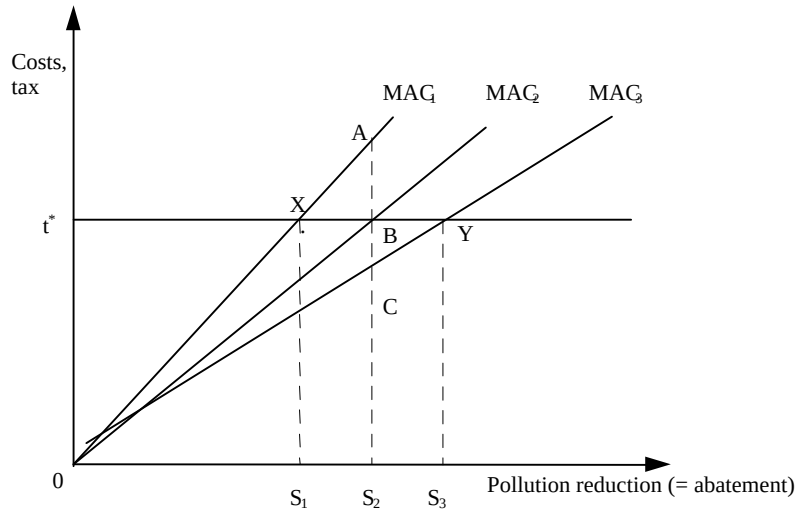
Taxes would be set to achieve a certain acceptable standard rather than being based on the 'unknown value of marginal damages'. Baumol and Oates (1975) further argued that such an approach would not result in Pareto optimality but that the 'use of unit taxes (or subsidies) to achieve specified quality standards ... is the least-cost method for the achievement of these targets'. 'An allocation is Pareto efficient for a given set of consumer tastes, resources and technology, if it is impossible to move to another allocation which would make some people better off and nobody worse off' (Begg, Fisher and Dornbusch, 1994).

As they were aware of the drawbacks of the use of acceptability standards, Baumol and Oates (1975) proposed to utilize these standards only in cases where 'there is reason to believe that the existing situation imposes a high level of social cost and that these costs can be significantly reduced by feasible decreases in the levels of certain externality-generating activities'.

The benefits of this approach are very well illustrated in Pearce and Turner (1990, p. 95) which gives the following example (illustrated in Figure 2).

Assume three companies' marginal abatement cost curves (MAC1, MAC2 and MAC3) which illustrate the extra cost of one extra effort of pollution abatement. It is possible to compare the total abatement costs (TAC) of a standard and a tax which both produce the same optimal pollution reduction level.

Figure 2: Charges and Acceptability Standards



Assume the desired pollution level has been set at S_2. This standard can be achieved in two ways:

a. Each firm has to abate pollution by S_2. Firm 1 will produce at A, firm 2 at B and firm 3 at C. Overall standard of abatement of $3S_2$. Total abatement costs: $TAC_1 = 0AS_2 + 0BS_2 + 0CS_2$
b. Tax t* is set. Firm 1 will produce at X, firm 2 at B and firm 3 at Y. Simply comparing the cost to the individual firms of the abatement costs and the tax can derive this. Again an overall standard of abatement of $3S_2$ is achieved; this time at $TAC_2 = 0XS_1 + 0BS_2 + 0YS_3$

It is clear that TAC_1 is greater than TAC_2 (the difference is $S_1XAS_2 - S_2CYS_3$ and S_1XAS_2 is greater than S_2CYS_3).

The tax policy referred to here is commonly known as emission charges. They are a way of achieving the desired pollution reduction at minimum cost of control. The idea behind this is that individual (profit-maximizing) firms will reduce pollution as long as this is cheaper than paying the government emission

charges. In economic terms this implies that a firm will reduce pollution, that is, manage pollution levels, as long as the marginal cost of this management is smaller than the emission charge levied on the firm's pollution.

The strength of emission charges therefore lies in the fact that the government can introduce incentive policies that will result in minimum costs of control without knowing the exact level of pollution damage. Bear in mind, however, that it is essential that the government apply the same emission charges to all firms.

The problem, of course, is once again at which level to set the emission charge. The costs of the firms to reduce pollution are unknown to the government. It is therefore impossible for the government to know which level of emission charges will result in the desired reduction of pollution as this depends on the firm's own technology and operation. The emission charges will therefore tend to be set on a trial-and-error basis, adjusting the charges periodically until a charge is set which results in the required pollution reduction.

As the firm's pollution management costs are dependent on the technologies used, a firm will invest in research and development to find more cost-effective technologies. However, as Tietenberg (1996, p. 336) explains, the firms will have an incentive to hide their new technologies from the government as the government will tend to tighten the standards as they learn of new, less polluting, technologies.

The main problem with this trial-and-error emission charge is that firms will have difficulties planning their investments. A new (tighter) emission charge may make their previously potentially profitable investments a recipe for disaster, so preparing a long-term investment plan will become more difficult as the firms are faced with more uncertainties.

5.5 Are the Pigovian Tradition and the Coase Theorem Contradictory?

At first sight, and considering the above discussions on the topic, the two theories on social cost - the Pigovian tradition and the property rights approach - seem totally different from each other and in fact quite opposite. However, some authors propose that these approaches can sometimes complement each other or that one policy can even be a special case of the other.

Bishop (1988, p. 194) in fact argued that: 'Pigovian analysis is a special case of the more general property rights approach'. He sees a Pigovian tax as a 'property rights solution' which 'concentrates on the income characteristic of property'. He explains this with an example of an air pollution tax. In this case the polluter is no longer the sole owner of the income derived from the air pollution (that is, the production which has this pollution as its externality) but has to share this property right with the government. The government then requests their share of the return on air in form of a tax. Concluding, Bishop

remarks that 'Pigovian taxes can be viewed as involving the assignment of property rights via the constitution'.

Hamilton, Sheshinsky and Slutsky (1989, pp. 453-471) further examined Coase's externalities approach (as seen above in Section 5) and developed further ideas on the application possibilities. They started from the idea that the Pigovian and property rights approach complement each other. The Pigovian approach could be used when bargaining is too costly or infeasible. However, their main finding was that decentralized bargaining cannot be efficient in cases of production externalities with free entry for new actors, unless this is done as economy-wide negotiations. In cases of limited property rights (for example due to a liability rule which induces people to step in and claim compensation), their solution is to introduce some government intervention in the sense of a tax system - this even in cases where bargaining is possible! An efficient outcome will only be achieved through a non-linear tax scheme; the combination of a tax on company output if and only if this is in excess of the efficient level of production, and a franchise fee to tax away profits. The latter should discourage new entries. Note that such a tax should not raise revenues in equilibrium, as the franchise fee would be given as a lump sum to consumers. The authors conclude that 'it is better to limit property rights and discourage bargaining than to try and make them as complete as possible and encourage bargaining'. The authors also conclude that, as ever, the efficiency of this system depends on the ability for the government to estimate the optimal taxes.

When comparing the alternatives, some authors found that both Pigou and Coase's alternatives had their costs and benefits and that in the real world, neither were perfect. Starret and Zeckhauser (1974, p. 66) compared artificial markets (that is, the property rights approach) and taxing schemes, and came to the conclusion that neither provide easy answers in a complex real world situation. However, whereas they concluded that 'an equilibrium may not even exist with artificial-markets setups', the problem with taxation solutions was rather a problem of multiple equilibria, that is, apparent different optimal pollution taxes, and the problem of detecting the one efficient tax.

6. Current Views on Pigovian (and Related) Taxes

6.1 Are Pollution Taxes in Accordance with the Polluter Pays Principle?

In 1972 the OECD adopted the Polluter Pays Principle (PPP) aiming to use this principle as an instrument for internalizing environmental costs. It therefore links in well with the initial ideas of Pigou.

The PPP is now a commonly used term. One has to be careful, though, when interpreting the meaning. As Bugge (1996) argued the polluter pays principle can be read as having four main meanings:

1. the PPP as an economic principle; *a principle of efficiency;*
2. the PPP as a legal principle; a *principle of just distribution of costs*;
3. the PPP as a *principle of international harmonization of national environmental policy*; and
4. the PPP as *principle of allocation of costs between states.*

Pollution charges as discussed here primarily relate to the principle of economic efficiency; reducing pollution insofar as this can be achieved by internalizing social cost of pollution. However, the pollution charges could also be seen in the context of the PPP as a legal principle as its aims to efficiently redistribute costs of externalities and abatement efforts.

One could assume, as in the interpretation of Coase's writing, that compensating the victims of pollution or taxing those affected (for example, when it is felt that they were the parties who could have prevented the damage from occurring most efficiently) would have the same result as taxing the polluters. Baumol (1972), however, claimed that optimal resource allocation could only be achieved by 'a Pigovian tax (subsidy) upon the generator of the externality'. This idea corresponds fully with the PPP principle and at the same time dismisses the common interpretation of the Coase theorem. However, Baumol (1972) only intended his critique on Coase's ideas in cases of large numbers and does not consider the 'small number' case where negotiation is easily possible.

6.2 Environmental Taxes - a Revenue-Generating Instrument?

Every type of pollution taxation raises revenue for the enforcing government. Although one could argue that for some taxes, such as product taxes, the ultimate goal is to minimize the use of the polluting product, the revenue-generating aspect remains appealing to governments. In fact this aspect can cause problems when considering the real reasons for implementing and continuing pollution charges.

This problem can easily be compared to that of, for example, cigarette (excise) taxation. Governments declare that raising excise taxes on cigarettes is necessary because the government wishes to discourage its citizens from smoking as this is damaging to their health. This is what can be referred to as the paternalistic objective. However, the excise tax revenues are also a welcome income for the Treasury. How can a government therefore satisfy two goals, discourage smoking and raise revenue, with one instrument, namely excise taxation? Indeed, were the health objectives to be successful, less cigarettes would be smoked and the revenue would fall; alternatively, to raise sufficient revenues enough cigarettes are to be sold. A balancing of goals is possible - decreased smoking at a certain revenue level - though will not optimize (maximize) either goal. This problem refers back to the issue raised by Tinbergen (1952, p. 39) in his *On the Theory of Economic Policy*; that one can only fulfil one goal efficiently when using just one policy instrument.

The same problem will occur when governments start relying on the revenues of the implemented 'green' taxes. While the goal is to reduce environmental pollution, generation of revenues becomes an 'induced' secondary (or primary in the worst-case scenario) goal the longer the tax is levied. In fact opposite assumptions concerning elasticities are required. A 'justified' environmental tax requires high elasticity of the taxed behavior. For example, an energy tax aims to reduce the use of a certain energy source. In other words, the tax will raise energy prices which should consequently reduce the demand (because people have started using less energy or are using alternative, less polluting, energy sources) and thus the tax revenues will fall. The demand therefore has to be elastic. However, if governments wish to use the pollution tax as a revenue-generating instrument, the tax base has to remain sufficiently large. This implies that in order to raise revenues on a continuing base without having to keep increasing the tax rate, demand should be fairly inelastic.

This whole issue can be avoided by earmarking revenues for specific projects, such as clean-up projects, funding awareness campaigns and so on. However, earmarking is generally avoided as a budgeting procedure as it does not allow for unexpected changes in revenues and required finances, nor does it allow for flexibility in public finances.

An alternative is the use of the revenues of green taxes to compensate for the reduction in Treasury revenues of other taxes. This is commonly referred to as the 'double dividend' aspect of pollution taxes. The double dividend idea implies that new environmental taxes can not only reduce environmental damage but can also reduce the need for other revenue-generating distortionary taxes such as levies on income. As all the new tax revenues are thus returned to taxpayers, the double dividend idea is linked to the 'revenue recycling' idea. Appealing as this idea might be to governments, questions are being raised as to the validity of this proposition. This primarily concerns the idea that as environmental taxes correct distortions (externalities) they cannot be distortionary themselves. However, if, for example, these taxes are indirect taxes (such as a carbon tax would be), they will influence the real after-tax wage and can therefore not be considered non-distortionary (O'Riordan, 1997, pp. 106-120). In fact Bovenberg and Van der Ploeg (1994) consider, contrary to what proponents of environmental taxation feel, that employment will decline even if the double dividend idea of compensating the taxes with a lower tax on wages were implemented.

Four main alternative uses for the pollution tax revenues can then be distinguished (OECD, 1991, p. 11):

1. Earmarking funds for polluters who reach the desired pollution abatement standard as long as the charges can not ensure a reduction to this level. The funds should be distributed so as to ensure the bridging of the gap between

the actual and the required level of pollution. This technique is sometimes used in the water sector.
2. Funds can also be earmarked to finance specific environmental projects and services, for example clean-up operations.
3. The revenues can also be poured into the general budget. This implies that specific revenues will not be used for specific uses (non-earmarking).

A fourth alternative is to pour the revenues into the general budget but only if combined with a reduction in other taxes (see above). For example, many governments have played with the idea of combining the implementation of an energy tax with a reduction of the tax on labor.

6.3 Do 'Green' Taxes Give Rise to the Same Adverse Effects as Other Taxes Do?

There is vast and extensive literature on the advantages and disadvantages of taxation. Taxes are often regarded to be inefficient as a policy tool because of the distortion created in the economic decision-making process. However, in the case of pollution taxes, the shift in consumer and producer behavior is exactly the desired output. One therefore tends to speak of tax 'incentives'. For example, an energy tax is used to incorporate the environmental cost of energy in consumer's energy choices.

Nonetheless, pollution charges can have a negative impact on certain aspects of the economy, comparable with those seen with other types of taxes and regulation.

6.3.1 Adverse Competitive Consequences of Non-Global Pollution Charges If only one country's government imposes environmental taxes one could wonder what would happen to the competitiveness of the industries affected in that country. Consider a country's chemical plants are subject to environmental charges, which they pass on to their consumers by raising their prices. These goods might be faced with a falling demand, since on the international market there are now cheaper comparable products available. Another consequence could well be that multinationals decide to relocate their plants to other countries without these environmental charges. The relocation of the most polluting industries can be seen as a clear sign that this country now has a comparative disadvantage. Bovenberg and Van der Ploeg (1994) feel that greener preferences in public finances (that is, environmental taxation) will ordinarily result in capital flight. This can be compared to the consequences of non-global social security contributions and differing social regulations concerning wages. The relocation of labor-intensive industries to developing countries has drawn widespread attention and concern.

However, Porter (1990) sees stringent standards among other environmental impacts as contributing to creating and upgrading competitive advantages, as

it forms an incentive for companies to improve, for example, quality and the use of new technologies. When Porter uses the word 'standards' in this context, this can be interpreted as more stringent environmental regulation of any form.

Wolken and Koopmans (1992) used Porters' theory on the importance of rapid national adjustments to society's new (environmental) requirements, to show that the sooner a country introduces *national* policies to protect the environment, the more competitive that countries' industries will be when *international* environmental regulation will be implemented. Stringent national environmental regulation can thus be seen as only a temporary comparative disadvantage. They therefore even referred to, for example, the 'reinforced national advantage' of Sweden because of its 'environmental sensitivity'.

A clear line was taken at the round table on 'The Role and Enforcement of competition policy in regulated sectors' (21 October 1994, OECD) by the Dutch delegation. They presented a paper which declared that the effectiveness of market-oriented instruments, such as pollution charges, in environmental regulation could be reduced if the competition policy is not strict enough. Indeed, firms will feel less need to improve their environmental performance if they can form cartels or even monopolies, as they can just pass the taxes on to the consumers who would not be able to shift to substitute products. The tax would therefore be paid by the consumers and would form a revenue source for the government, but form no incentive for the firms to clean up their act.

At the same time, though, the optimal output for monopoly firms should in theory fall, which is partly the aim of the pollution charges in the first place. Monopolies' optima lie at a lower production and output level than is the case in perfect competition. The prices they charge are higher.

Concluding, Turner, Pearce and Bateman (1994, p. 178) feel that many environmental taxes can only be implemented on a significant scale for global problems (ozone layer, greenhouse effect, and so on) if they are the result of concerted action by many countries. However, this form of international agreement introduces the threat of a 'free-rider effect', since every country has an incentive not to sign the agreement whilst profiting from the global environmental improvement resulting from other countries' commitment.

In short, international agreements may be required to implement an environmental regulation, which is deemed too risky on competitive grounds by national governments. Those countries taking the risk, though, may in the long run, be rewarded with a competitive advantage instead of a competitive disadvantage.

6.4 Pollution Charges and Uncertainty

Increased importance is being given in the literature to the effect of '*uncertainty*' on pollution taxes. Uncertainty can be defined in situations where

probabilities cannot be assigned to possible consequences. It impacts on both macroeconomic and microeconomic variables. Uncertainty is especially important with effect to discounting of environmental effects, uncertainty of future preferences and developments, and also uncertainty concerning the damage function (relationship between polluting activity and emissions and pollution). It is therefore unlikely that a government faced with uncertainty will implement policies that achieve optimal outcomes.

Melese and Michel (1991, pp. 140-153) point to the fact that the threat of future tax changes can influence the (present) behavior of economic agents in a negative, lasting and important manner. They refer to the writings of Adam Smith (1776) who called uncertainty in taxation a 'great evil' in his *Wealth of Nations* and built a model examining the consequences to firms' behavior of 'perceived future changes in the probability of tax reform and the expected profitability under the new tax structure'. The results of the analysis were that the firms alter their behavior in an attempt to shift the burden. Taking into account, in turn, the uncertainty surrounding these behavioral changes, the task of setting the optimal taxation level becomes ever more difficult as the production function changes.

6.5 Pollution Taxes and Strategic Behavior - the Use of Game Theory with Relation to Pollution Taxes

The above issue of the link between uncertainty and the responsive behavioral changes is in close relation to the study of strategic behavior and pollution charges. Economists use *game theory* to analyze strategic behavior. This is the behavior of at least two economic agents whose payoffs are interdependent and who take the expected behavior of the others into account when deciding on their actions.

Samuelson and Nordhaus (1995, p. 193) speak of 'the pollution game'. This game shows that in an unregulated market each firm prefers to maximize profits, that is, pollute, rather than install pollution abatement equipment when they are not sure (due to non-communication, non-cooperation) whether their competitors will be installing costly abatement equipment. This is even the case when firms suspect installing abatement equipment might provide them with advantages in the long run (see Porter's theory in Section 6.3.1 above). This leads to a (Nash-) equilibrium where both parties are responsible for high pollution as a result of non-cooperative behavior. This is referred to as the 'deadly pollution game'.

As mentioned before (see Section 4), under the Coase theorem this problem would be dealt with by a private bargaining system. This would in fact make the regulator obsolete (assuming there are well-defined property rights and zero transaction costs). The alternative was the Pigovian tax levied on the polluter.

However, there have since been several studies in the field of game theory that tackle the issue differently.

Leung (1992), for example, suggested a pollution tax scheme which would tax both the injurer and the victim. Assume a situation where the polluter and victim have full information about each other's taste and technology, but the regulator is faced with a lack of information. The question is then how to reach an (economically) efficient pollution level. This scheme should help the uninformed regulator in case of a sequential game and would lead to a first-best output. The polluter is taxed to redistribute revenues amongst polluter and victim, whilst the victim is taxed to avoid exaggeration of the damage claims by the latter.

Other authors discuss different possibilities under simultaneous or sequential games. This would, however, lead us too far in this chapter - the discussion becomes rather complicated and mathematical - which merely aims to give a general overview of the literature and discussions.

6.6 Increased Importance of Valuation Techniques

Valuation techniques become important because pollution taxes, as theoretically described by Pigou, are impossible to devise in reality. Lack of information makes it impossible to set a tax on the optimal level (see above). The optimum level is where (see above) the marginal cost of abatement equals the marginal reduction in pollution. Whereas it is (sometimes) possible to estimate a company's marginal abatement costs, it is fair to say that the marginal benefit of reduced pollution is much more difficult to calculate. These difficulties arise in part from the subjectivity of costs and benefits (see Section 3.2). Many valuation techniques have been devised but none are ideal.

As the optimum Pigovian tax is fairly impossible to set, it is of extreme importance to set as efficient a tax as possible. Economists have developed a wide array of techniques for valuing the environment, mostly derived from so-called cost-benefit analysis. A short overview of cost-benefit analysis can be found in Chapter 2300, Environmental Regulation: General.

The most used valuation techniques are the contingent valuation technique, an expressed preference method which makes use of surveys to reveal people's willingness to pay (WTP), and the revealed preference methods such as hedonic pricing method (using prices in related markets, for example real-estate) and the travel cost method.

These techniques are essential for valuing the damage done to the natural environment, itself a prerequisite for the optimal Pigovian tax, which should be based on the 'estimated damage'. However, these estimates will inevitably be plagued with a certain degree of uncertainty, a problem, discussed in short in Section 6.4 above.

6.7 Pollution Charges from a Public Choice Point of View

Pollution charges are a policy instrument, and when implemented by democratic governments can be analyzed from a public choice (see Chapter 0610) point of view. Who has an interest in seeing pollution charges being implemented, which parties feel pollution charges are inappropriate, and what specifications are requested by alternative economic agents? These are all questions which can help understand why or why not pollution charges are being implemented, and why they are used for specific target groups and products and not for others.

Whereas economists of different backgrounds agree on the (efficiency) superiority of pollution charges in comparison with command-and-control policies, many governments have so far preferred the latter. As in all public choice theories it is possible to relate this to the interests of those affected by the environmental externalities and those potentially affected by the pollution charges.

Buchanan and Tullock (1975, pp. 139-147) feel direct regulation is (was) often preferred because 'penalty taxes' were not acceptable to those primarily affected. As long as individuals cannot expect returns from the tax revenues in the form of 'cash subsidies, public good benefits or reductions in other taxes', they will prefer direct regulation to taxes as their loss in 'consumer surplus' under this alternative is smaller. Democratic governments will therefore implement regulations as their decisions on the implementation of policy instruments are influenced by the 'preferences of those subject to them'.

In retrospect it has become apparent that governments have tried to 'sell' the pollution taxes by pointing out what can be done with the earmarked revenues; provide public benefits such as clean-up operations or support to environmental causes, or a reduction in other taxes such as income taxes. Buchanan and Tullock's reasoning may therefore no longer be valid.

Wilson (1980) developed his 'regulation' theory in which he no longer followed the classic public choice idea of 'capture' by regulated interest, but simply looked at the costs and benefits of regulation (as perceived by affected parties) in a classic law and economics way. Andersen (1994) used Wilson's regulation theory to analyze how costs and benefits of regulations affect the choice of policy instruments.

Environmental regulation can, then, according to Andersen using Wilson's theory, be classified as being part of the 'entrepreneurial regulation' classification (a classification designed by Wilson, 1980, pp. 367-370) which implies that costs are concentrated and benefits are spread. Whereas under the classical assumptions that regulations will only be passed in the interest of the regulated, Wilson explains that the 'new social regulations' are supported by the 'entrepreneurs', who lobby to have these regulations put on the political agenda. Whether these entrepreneurs are successful in outweighing the influence of affected parties largely depends on their support from 'non-affected third

parties, such as media, influential writers, and so on'. The problem is that the lobby is mainly concerned that some action is taken, against, for example, air pollution. They are less interested in which policy instrument is being used as they have inadequate information to assess which policy is to be preferred. Those who will be affected by the policy, however, such as private firms, for example, have more interest in making sure certain policy instruments are used or not. They have specific cost information, which cannot be estimated by the lobby. The latter cannot, therefore, provide reasons to policymakers why a specific instrument should or should not be implemented. The target groups mostly perceive economic instruments, such as pollution taxes, to impose much greater costs on them than command-and-control policy through standards and voluntary agreements. The lobbiest will tend to accept any policy instruments as long as the 'polluters' have to comply with a general criterion.

7. Pollution Taxes in Practice

7.1 Economic Incentives

One of the practical problems with estimating the efficient level of environmental damage, required to set a Pigovian tax, was tackled by Kohn (1986, pp. 625-630) when he suggested the introduction of a *non-linear per unit tax* to reach a long-run social optimum. This was to surpass the problem of non-linear abatement cost curves. Carlton and Loury (1980, pp. 559-566) used a model to show that a Pigovian (per unit) tax will not produce the socially optimal output as it will uniformly raise a firm's average cost curve. This would result in the firm minimizing its costs at the same output level as before the tax was implemented. Their solution is to supplement the Pigovian tax with a lump-sum tax subsidy scheme for participating firms. This should also give an incentive for efficient entry into the industry.

The realization that many of the economic instruments proclaimed by the economists of the first hour did not take into account the practical implementation difficulties which would jeopardize the efficiency of the instruments, is reflected in the many alternative, more practical, solutions that have since been developed (OECD, 1994).

7.1.1 Emission Charges (Effluent Charges) Emission charges are implemented by governments to be paid on emissions into the environment and are based on the quantity and/or quality of the pollution discharged.

When the charges are levied to fund the public treatment of effluents they are called 'user charges'. The charge may then be uniform or dependent on use.

The OECD (1994) distinguishes three types of emission charges classified by the charge base:

a. actual source emissions (the emission are actually metered);
b. a proxy of source emissions (the estimated emissions are based on pre specified characteristics serving as proxies, for example, water consumption serving as a proxy for wastewater emissions);
c. a flat rate (each source, being a company or a household pays a fixed amount unrelated to the actual pollution caused by this source).

It is obvious that these are, in descending order, less and less true to the original idea of Pigou where the tax would be based on the marginal damage.

One of the main problems with emission charges is one of implementation. Emissions below the officially permitted levels are exempt from taxation. This prohibits the dynamic benefits of a tax system (as opposed to a command and control system) to create results. At this cut-off point (the maximum allowed level of pollution) the firms will also stop comparing marginal benefits against marginal cost of pollution, so unless the government has been able to set the standard at the exact efficient level of pollution (where marginal costs equal marginal damages), this approach will prove to provide inefficient results. Moreover, as many firms will have differing marginal abatement costs, it is impossible for the government to set a uniform level of production that would be efficient for every firm.

7.1.2 Product Charges (Taxes) Product charges or taxes are levied on each unit of a product, which is harmful to the environment. Whether a product is to be taxed depends on:

- whether any of the different stages of its product life is deemed to be polluting. A life-cycle analysis can detect whether the product is polluting in any aspect of its manufacturing or consumption phase or after disposal (from *cradle to grave*);
- the damaging effect of a product component or the product itself. The tax itself will have this as its base. For example, a charge on the lead content of gasoline or a gasoline charges.

Product charges can thus generate government revenues. The danger here is that the revenue-raising aspect may become the prime goal. This can be prevented though as, in practice, product charges can be implemented under the form of tax differentiation. The more 'environmentally friendly' product becomes cheaper due to the tax differentiation. This was used with success, for example, in several European countries as an incentive to boost the sales of unleaded petrol. Whereas product charges may have a revenue-raising goal, tax differentiation operates in a budget neutral manner. In fact it may even lead to a drop in tax revenues, depending on the exact implementation.

Although so-called '*input or resource taxes*' are sometimes seen as a separate environmental tax category, they can be classified under product taxes if the 'product' (or characteristic of a product) taxed is a natural input/resource.

7.1.3 Administrative Charges Administrative charges are fees that should be paid to cover the expenses made by the controlling authorities for control and authorization and related administration. A tax dependent on the domestic consumption of water, or charges implemented for the removal and disposal of waste fall under this category.

However, as these charges are not directly related to pollution levels, and are thus far removed form Pigovian taxes, they will not be discussed any further in this chapter.

7.1.4 Transferable Property Rights Whereas the idea of transferable property rights may well stem from that of pollution charges (see Section 5.1), the outcome - emissions trading - can no longer be seen as a pollution tax and therefore also falls outside the scope of this chapter. Transferable property rights are discussed at further length in Chapter 2300.

Practical experience with the permit trading system can primarily be found in the USA, where they exist, for example, under the Clean Air Acts (1970 and 1991).

7.2 Are Pollution Taxes as Studied and Implemented Today Efficient?
Throughout this contribution, the development of pollution taxes and its many related problems have been discussed. The question now remains whether the current translation of Pigou's ideas on tackling the pollution problems, that is, the emissions and product charges discussed above, provides an efficient instrument.

Evaluating the efficiency of an instrument is not a simple task. Most instruments will have their own advantages and disadvantages compared to other, alternative, instruments. The efficiency can be evaluated in terms of costs to governments, households and firms, but the costs to environment remain difficult to assess in purely financial terms.

Some clear advantages of pollution taxes can be pointed out (though not expressed in easily comparable units such as money):

- pollution taxes leave the choice of pollution-abating policy to the individual firms. Some firms may use clean-up technologies, others may prefer to control their output of emissions or their input of raw materials. This allows a *least-cost abatement* as the firms themselves are best-placed to estimate the different costs of abatement possibilities and firms are confronted with differing individual clean-up costs;

- where non-point sources of pollution cannot be controlled by standards or permits, it is often possible to tax proxies such as consumer products;
- taxes are a dynamic instrument (as opposed to a fixed license) and as such give a constant incentive (if implemented correctly, see Section 7.1.1 above) to reduce emissions;
- firms subject to pollution taxes which are not, or cannot be, passed on to customers are provided with an incentive to develop cleaner technologies which will reduce the price of pollution - this is therefore also beneficial to the long-run resource conservation;
- firms who pass their costs on to customers will in the long run be confronted with a falling demand for their products provided there are cheaper, less-polluting, substitutes available. As consumers favor the more environmentally friendly, and less wasteful products, the use (and abuse) of natural resources will be minimized as all firms will aim to alter their products and production processes to meet the altering demand; and
- taxes provide revenues for the controlling government, which may choose to use this to further protect and clean up the natural environment.

From the last remark it becomes once again apparent that the efficiency of pollution taxes is linked very closely to the price elasticity of the polluting product or services and the availability of less-polluting alternative products or services (see Section 6.2. above). Raising taxes on price-inelastic products (that is, the demand is fairly independent of the price changes) may raise a lot of tax revenues, but is of little incentive to changing behavior. Taxes on price-elastic products, on the other hand, may not in the long run raise much revenue but can be responsible for a shift in consumer buying behavior (provided there are cheaper more environmentally friendly substitutes available).

The above efficiency arguments in favor of pollution taxes has to be seen, however, in the light of the many practical implementation problems with finding the right (efficient) tax level. Many alternatives to the optimal Pigovian tax have therefore been suggested. This has been discussed at length throughout this paper. The main drawbacks of practical implementation are summarized again next.

8. Conclusions and Recommendations for Further Research

The theoretical concept of pollution taxes as first introduced by Arthur C. Pigou has drawn widespread attention. It is neither possible nor desirable to summarize more than half a century's literature on a subject as vast as this in a short encyclopedic entry. The distributional effects and labor market distortions due to pollution taxes have, for example, not been discussed, and

neither has intergenerational distribution due to the implementation of pollution taxes. The bibliography does, however, include sources on these and other topics that have not been discussed in this entry. This entry has primarily focussed on the original writings of Pigou and Coase, seen within the context of law and economics analysis. Public choice aspects of the issue have therefore also been mentioned.

It is not only (environmental) economists who have been drawn to the area of pollution taxes, policymakers looking for efficient environmental regulation (see Chapter 2300) have also shown great interest in this subject area.

In theory pollution taxes have many advantages when compared to command-and-control policies. They allow least-cost abatement, are generally more dynamic and provide incentives for producers ànd consumers alike. The main draw-backs lie with the practical implementation:

- Pigovian taxes are close to impossible to implement effectively as the efficient level of taxation is dependent on estimated damage costs.
- Even if the main goal of a tax is environmental improvement, the effect will often depend on the availability of alternatives and the price sensitivity of consumer demand. If demand is inelastic, that is, the tax does not change consumer behavior but consumers simply pay a higher price for the good, the tax will have little effect on the environment, and government may in the end use pollution taxes as merely a revenue-generating instrument.
- Governments are often hesitant to implement environmental charges as they fear this may damage the competitive position of domestic industries *vis-à-vis* international competitors. This holds true for any type of nationally implemented environmental regulation.

The most important challenge for research on pollution taxes lies in the field of implementation. How can theoretical systems be transposed to the real world and provide tangible results?

New research into the theory of pollution taxes is also required. What may once have been seen as nothing but a mere theoretical exercise, may one day effectively be implemented. For example, the theoretical idea of tradeable pollution rights first introduced by Dales and now effectively implemented in the USA under the Clean Air Act.

As it has become clear that the manner of implementation by policymakers is as important to the success of a pollution tax as the original theoretical concept, an analysis of pollution tax schemes using a law and economics perspective, including a public choice approach, is recommended.

Bibliography on Pollution Tax (2500)

Andersen Mikael S. (1992), *Governance by Green Taxes. Making Pollution Prevention Pay*, Manchester, Manchester University Press.

Andersen Mikael S. (1994), *The Use of Economic Instruments for Environmental Policy: A Half Hearted Affair*, Seminar Papers on Instruments to promote Sustainable Patterns of Consumption and Production.

Anonymous (1995), *Environmental Taxes and Charges*, IFA Congress Seminar Series.

Barnes, David W. and Stout, Lynn A. (1992), *Economics of Property Rights and Nuisance Law*, St Paul, MN, West Publishing.

Baumol, William J. (1972),'On Taxation and the Control of Externalities', **june** *American Economic Review*, 307-322.

Baumol, William J. (1991), 'Toward Enhancement of the Contribution of Theory to Environmental Policy', **1(4)** *Environmental and Resource Economics*, 333-352.

Baumol, William J. and Oates, Wallace E. (1975), *The Theory of Environmental Policy. Externalities, Public Outlays and the Quality of Life*, New Jersey, Prentice-Hall, 272 p.

Beckerman, Wilfred (1990), *Market Pricing, Government Regulation and Environmental Policy*, Hobart Paper 66.

Begg, David K., Fisher, Stanley and Dornbusch, Rudiger (1994), *Economics* (5th edn), London, McGraw Hill, 666 p.

Benson, Bruce L. (1984),'Spatial Price Theory and an Efficient Congestion Toll Established by the Free Marke', **22** *Economic Inquiry*, 244-252. Reprinted in Greenhut, Melvin L. and Norman, George (eds) (1995), *The Economics of Location*, Vol. II, London, Edward Elgar Publishing, 172-180.

Benson, Bruce L. (1985), 'Free Market Congestion Tolls: A Correction', **23** *Economic Inquiry*, 361-362.

Bishop, John A. (1988), 'Pigovian Taxes and 'Full' Property Rights', **14** *Eastern Economic Journal*, 193-196.

Bongaerts, Jan C., Meyerhoff, Jürgen, Thomasberger, Claus and Wittke, Anja (1989), *Lösungsansätze für ein Ganzheitliches System von Umweltsteuern und Sonderabgaben in der Bundesrepu blik Deutschland* (A Solution for a Total Environmental System and Special Taxes in the Federal Republic of Germany), Berlin, Schriftenreihe des Instituts für Oekologische Wirtschaftsforschung Nr. 31.

Bonus, Holger (1975), 'Steuern als Instrumente des Umweltschutzes - Weitere Bemerkungen zu Richard Zwintz (Taxes as an Instrument of Environmental Protection)', **131(3)** *Zeitschrift für die Gesamte Staatswissenschaft*, 540-549.

Bovenberg, A. Lans (1994), *Optimal Environmental Taxation in the Presence of other Taxes, General Equilibrium Analyses*, Cambridge, National Bureau of Economic Research Summer Institute.

Bovenberg, A. Lans (1995), *Environmental Policy, Distortionary Labour Taxation and Employment: Pollution Taxes and the Double Dividend*, Fondazione Eni Enrico Mattei, Economics, Energy and the Environment.

Bovenberg, A. Lans and De Mooij R.A. (1994), 'Environmental Taxes and Labour-Market Distortions', **10(4)** *European Journal of Political Economy*, 655-685.

Bovenberg, A. Lans and Goulder, Lawrence H. (1995), *Costs of Environmentally Motivated Taxes in the Presence of Other Taxes: General Equilibrium Analyses*, Fondazione Eni Enrico Mattei, Economics, Energy and the Environment.

Bovenberg, A. Lans and Heijdra, Ben J. (1996), *Environmental Tax Policy and Intergenerational Distribution*, Research Memorandum, 9605.
Bovenberg, A. Lans and Van der Ploeg, Frederick (1994), 'Green Policies and Public Finance in a Small Open Economy', **96(3)** *Scandinavian Journal of Economics*, 343-363.
Bovenberg, A. Lans and Van Der Ploeg, Frederick (1995), *Optimal Taxation, Public Goods and Environmental Policy with Involuntary Unemployment*, nota di lavoro, 44.95.
Bowles, Roger A. and Jones, Philip (1993), 'Nonpayment of Poll Tax: An Exploratory Analysis of Tax Resistance', **13** *International Review of Law and Economics*, 445-455.
Braulke, M. and Endres, Alfred (1985), 'On the Economics of Affluent Charges', **18** *Canadian Journal of Economics*, 891-897.
Brito, Dagobert L. and Intriligator, Michael D. (1987), 'Stock Externalities, Pigovian Taxation and Dynamic Stability', **33** *Journal of Public Economics*, 59-72.
Bromley, Daniel W. (1991), *Environment and Economy. Property Rights and Public Policy*, Oxford, Basil Blackwell, 247 p.
Brooks, Michael A. and Endres, Alfred (1987), 'Rent Seeking and Pollution Taxation and Dynamic Stability', **54** *Southern Economic Journal*, 335-342.
Brooks, Michael A. and Heijdra, Ben J. (1987), 'Rent Seeking and Pollution Taxation: An Extension', **54** *Southern Economic Journal*, 335-342.
Brown, Gardner M., Jr and Johnson, Ralph W. (1984), 'Pollution Control by Effluent Charges: It Works in the Federal Republic of Germany, Why Not in the U.S.?', **24** *Natural Resources Journal*, 929-966.
Brown, John Prather and Holahan, William L. (1980), 'Taxes and Legal Rules for the Control of Externalities when there are Strategic Responses', **9** *Journal of Legal Studies*, 165-178.
Buchanan, James M. (1959), 'Positive Economics, Welfare Economics, and Political Economy', **2** *Journal of Law and Economics*, 124-138.
Buchanan, James M. and Stubblebine, W. Craig (1972), 'Pareto-Optimality and Gains from Trade: A Comment', **39** *Economica*, 203-205.
Buchanan, James M. and Tullock, Gordon (1975), 'Polluter's Profits and Political Response: Direct Control versus Taxes', **65** *American Economic Review*, 139-147.
Bugge Hans Chr. (1996), 'The Principles of 'Polluter-Pays' in Economics and Law', in Eide, Erling and Van Der Bergh, Roger (eds), *Law and Economics of The Environment*, Oslo, 53-90.
Calabresi, Guido (1991), 'The Pointlessness of Pareto: Carrying Coase Further', **100** *Yale Law Journal*, 1211-1237.
Carlson, J. Lon and Bausell, Charles W., Jr (1987), 'Financing Superfund: An Evaluation of Alternative Tax Mechanisms', **27** *Natural Resources Journal*, 103-122.
Carlton, Dennis W. and Loury, Glenn C. (1980), 'The Limitation of Pigovian Taxes as a Long-run Remedy for Externalities', **XCV** *Quarterly Journal of Economics*, 559-567.
Carlton, Dennis W. and Loury, Glenn C. (1986), 'The Limitation of Pigovian Taxes as a Long-run Remedy for Externalities: An Extension of Results', **101** *Quarterly Journal of Economics*, 630-635.
Carraro, Carlo and Soubeyran, Antoine (1993), *Environmental Taxation, Market Share, and Profits in Oligopoly*, Nota di Lavoro, 70-93.
Carraro, Carlo and Soubeyran, Antoine (1995), *Environmental Taxation and Employment: in a Multi-Sector General Equilibrium Model*, Nota di Lavoro, 35-95.

Carraro, Carlo and Topa, Giorgio (1993), *Taxation and the Environmental Innovation*, Fondazione Eni Enrico Mattei, Economics, Energy and the Environment.

Carraro, Carlo, Galeottii, Marzio and Gallo, Massimo (1995), *Environmental Taxation and Unemployment: some Evidence on the Double Divided Hypothesis in Europe*, Nota di Lavoro, 34-95.

Coase, Ronald H. (1960), 'The Problem of Social Cost', **3** *Journal of Law and Economics*, 1-44.

Coase, Ronald H. (1988), *The Firm, The Market, and the Law*, Chicago, University of Chicago Press.

Coelho Philip R.P. (1976), 'Pollution, Direct Controls, Regulation and the Size of the Firm: Comment', **56** *American Economic Review*, 976-978.

Commons Michael (1995), *Sustainability and Policy. Limits to Economics*, Cambridge, Cambridge University Press, 348 p.

Conrad, Klaus (1990), 'Taxes on Emissions, Conjectural Variations and Overinvestment in Abatement Capital', **146** *Journal of Institutional and Theoretical Economics*, 281-297.

Conrad, Klaus (1995), *Choosing Emission Taxes under International Price Competition*, Nota di Lavoro, 18-95.

Cooter, Robert and Ulen, Thomas S. (1988), *Law and Economics*, New York, HarperCollins Publishers, 644 p.

Cordato, Roy E. (1992), *Welfare Economics and Externalities in an Open Ended Universe. A Modern Austrian Perspective*, Boston, Kluwer Academic Publishers, 140 p.

Cremer, H. and Thisse Jacques-François (1994), *On the Taxation of Polluting Products in a Differentiated Industry*, Nota di Lavoro, 31-94.

Cropper, Maureen L., Aede Sema K. and Portney, Paul R. (1992), 'Rates of Time Preference for Saving Lives', **5** *American Economic Review. Papers and Proceedings*, 469-477.

Dales, John H. (1968), *Pollution Property and Prices. An Essay in Policy Making and Economics*, Toronto, University of Toronto Press, 111 p.

De Clercq, Marc (1983), *Economische Aspecten van het Vervuilingsbeleid (Economic Aspects of Pollution Policy)*, Leiden, Spruyt, van Mantgen & Does, 301 p.

De Meza, David (1988), 'The Efficacy of Effluent Charges', **21** *Canadian Journal of Economics*, 182-186.

De Sousa Ramos F. (1994), *Pigovian Taxes, Tradeable Permits and a Dynamic Process for an Economy with Pollution*, Louvain la Neuve, ULC Centre for Operations Research and Econometrics, 15 p.

De Vries J.L., Van der Burg, T. and Rouw, M. (1993), 'Ruimte voor Nationaal Milieubeleid', *ESB*, 224-227.

Desaigues, Brigitte and Rabl, Ari (1994), 'Preferences Individuelles et Calcul de la Taxe Ooptimale (Individual Preferences and Calculation of Optimal Tax)', **45(3)** *Revue Économique*, 917-929.

Dewees, Donald N. (1983), 'Instrument Choice in Environmental Policy', **21** *Economic Inquiry*, 53-71.

Dore M.H.I. (1992), 'On the Taxation of Exhaustible Resources under Monopolistic Competition', **20(2)** *Atlantic Economic Journal*, 11-20.

Ekins Paul (1996), *Environmental Taxes Charges: Experiences and Plans: Report of the European Workshop held at the Foundation, Dublin*, Luxembourg, Europ- Publications, 34 p.

Endres, Alfred (1983), 'Do Effluent Charges (Always) Reduce Environmental Damage?', **35** *Oxford Economic Papers*, 254-261.

Endres, Alfred (1985), 'Effluent Charges and Environmental Damage: Comment', **37** *Oxford Economic Papers*, 703-704.

Ethridge, D. (1972), 'User Charges as a Means for Pollution Control: the Case of Sewer Surcharges', **3** *Bell Journal of Economics*, 346-353.

European Environment Agency (1997), 'Environmental Taxes: Implementation and Environmental Effectiveness', in X (ed.), *Environmental Issues. Series No. 1*, Office for Official Publications of the European Communities, Luxembourg.

Frankel, Marvin (1987), 'Taxes, Pollution, and Optimal Abatement in an Urban Economy', **22(2)** *Journal of Urban Economics*, 117-135.

Frech, H. Edward III (1979), 'The Extended Coase Theorem and Long Run Equilibrium: The Non-Equivalence of Liability Rules and Property Rights', **27(1)** *Economic Inquiry*, 254-268.

Germain, Marc (1989), 'Externalités, taxation et traitement de la pollution dans le cadre d'un duopole de Cournot (Externalities, Taxation and Dealing with Pollution in the Case of a Cournot Duopoly)', **55** *Recherches Economiques de Louvain*, 273-292.

Grabitz, Eberhard and Zacker, Christian (1989), 'Scope for Action by the EC Member States for the Improvement of Environmental Protection Under EEC Law: The Example of Environmental Taxes and Subsidies', **26** *Common Market Law Review*, 423-447.

Grafton R.Q. and Devlin, Rose Anne (1996), 'Paying for Pollution, Permits and Charges', **98(2)** *Scandinavian Journal of Economics*, 275-288.

Groenen W.C.C., Pommer E.J., Ras M. and Blank J.L.T. (1993), 'Gedrags-en Inkomenseffecten van Milieuheffingen (Behavioural and Income Effects from Environmental Taxation)', **11** *Economisch-Statistische Berichten*, 1028-1032.

Grossman, Gene M. and Krueger Alan B. (1995), 'Economic Growth and the Environment', **60(2)** *Quarterly Journal of Economics*, 353-377.

Haddock, David D., McChesney, Fred S. and Spiegel, Menahem (1990), 'An Ordinary Economic Rationale for Extraordinary Legal Sanctions', **78** *California Law Review*, 1-51.

Hahn, Robert W. and Stavins, Robert N. (1992), 'Economic Incentives for Environmental protection: Integrating Theory and Practice', **82(2)** *American Economic Review*, 464-468.

Hamilton, Jonathan H., Sheshinski, Eytan and Slutsky, Steven M. (1989), 'Production Externalities and Long run Equilibria: Bargaining and Pigovian Taxation', **27(3)** *Economic Inquiry*, 453-471.

Helfand, Gloria E. and Rubin, Jonathan (1994), 'Spending versus Concentrating Damages: Environmental Policy in the Presence of Nonconvexities', **27(1)** *Journal of Environmental Economics and Management*, 84-91.

Hoel, Michal (1994), *International Co-ordination of Environmental Taxes*, Fondazione Eni Enrico Mattei, Economics, Energy and the Environment.

Hrubovcak, James, Leblanc, Michael and Miranowski, John (1990), 'Limitations in Evaluating Environmental and Agricultural Policy Coordination Benefits', **80** *American Economic Review. Papers and Proceedings*, 208-212.

Hung, N.M. (1994), 'Taxing Pollution in an International Duopoly Context', **44(3)** *Economics Letters*, 339-343.

Jenkins, G.P. and Lemach Rnajit (1994), *Green Taxes and Incentive Policies: an International Perspective*, San Francisco, Kluwer Academics, ICEG, 260 p.

Johnson, Peter, McKay, S.R. and Smith S. (1990), *The Distributional Consequences of Environmental Taxes*, Commentary, 23 ff.
Kaplow, Louis and Shavell, Steven (1996), 'Property Rules versus Liability Rules: An Economic Analysis', **109** *Harvard Law Review*, 713-790.
Katsoulacos, Y. and Xepapadeas Anastansios (1994), *Emission Taxes and Market Structure*, Nota di Lavoro, 23-94.
Klepper, Gernot (1994), *Trade Implications of Environmental Taxes*, Kiel, Kiel Instute of World Economics.
Kohn, Robert E (1986)., 'The Limitations of Pigouvian Taxes as a Long-run Remedy for Externalities: Comment, **101** *Quarterly Journal of Economics*, 625-630.
Kort, P. M., Verheyen P. and Feenstra T. (1995), *Standards Versus Taxes in a Duopolic Model of Trade*, Nota di Lavoro, 62.95.
Lee, Dwight R. and Misiolek, Walter S. (1986), 'Substituting Pollution Taxation for General Taxation: Some Implications for Efficiency in Pollutions Taxation', **13** *Journal of Environmental Economics and Management*, 338-347.
Leung, Michael C.M. (1992), 'Pollution, Taxation, and Strategic Behaviour', **40(2)** *Economics Letters*, 251-255.
Määttä, Kalle (1997), *Environmental Taxes. From an Economic Idea to a Legal Institution*, Helsinki, Finnish Lawyer's Publishing.
Markusen, James R., Morey, Edward R. and Olewiler, Nancy (1995), 'Competition in Regional Environmental Policies when Plant Locations are Endogenous', **56(1)** *Journal of Public Economics*, 55-77.
Marshall, Alfred (1936), *Principles of Economics. An Introductory Volume*, London, Macmillan, 871 p.
McGee, Robert W. and Block, Walter E. (1994), 'Pollution Trading Permits as a Form of Market Socialism and the Search for a Real Market Solution to Environmental Pollution', **6(1)** *Fordham Environmental Law Journal*, 51-77.
Medema, Steven G. (1994), 'The legacy of Ronald Coase in Economic Analysis', in X (ed.), *Intellectual Legacies in Modern Economics*, Aldershot, Edward Elgar.
Medema, Steven G. and Coase, Ronald H. (1994), *Contemporary Economist*, Houndmills, Macmillan, 205 p.
Melese F. and Michel P. (1991), 'Uncertainty in Tax Reform: The Case of an Extractive Firm', **21** *Journal of Environmental Economics and Management*, 140-153.
Misiolek, Walter S. (1988), 'Pollution Control Through Price Incentives: The Role of Rent Seeking', **15** *Journal of Environmental Economics and Management*, 1-8.
Moores Rowland Europe (1990), *Comparative Study of Different Systems of Environmental Taxes*, Brussels, Moores Rowland.
National Research Council (NRC) (1990), *Valuing Health Risks, Costs, and Benefits for Environmental Decision Making. Report of A Conference*, Washington, National Academy Press.
Nielsen, Soren Bo, Pedersen, Lars Haagen and Sorensen, Peter Birch (1995), 'Environmental Policy, Pollution, Unemployment, and Endogenous Growth', **2(2)** *International Tax and Public Finance*, 185-205.
Nikolai, Loren A., Elam, Rick and Bozeman, Barry (1979), 'Financial Statement Modeling: Analyzing the Pollution Control Tax Incentive', **5(2)** *Policy Analysis*, 243-254.
Nordhaus, William D. (1993), 'Optimal Greenhouse-Gas Reductions and Tax Policy in the Dice Model', **1** *American Economic Review. Papers and Proceedings*, 313-317.

Nordic Council of Ministers (1994), *The Use of Economic Instruments in Nordic Environmental Policy*, *Tema Nord Environment*, Copenhagen, Nordic Council of Ministers, 95 p.
Nordic Council of Ministers (1996), *The Use of Economic Instruments in Nordic Environmental Policy*, TemaNord Environment, Copenhagen, Nordic Council of Ministers.
O'Riordan T. (1997), *Ecotaxation*, London, Earthscan Publications, 338 p.
OECD (1980), *Pollution Charges in Practice*, Paris, OECD, 118 p.
OECD (1991), *Environmental Policy: How to Apply Economic Instruments*, Paris, OECD, 130 p.
OECD (1994), *Managing the Environment. The Role of Economic Instruments*, Paris, OECD, 191 p.
OECD (1995), *Environmental Taxes in OECD Countries*, Paris, OECD, 191 p.
OECD (1996a), *Competition Policy and the Environment. Contribution from the Netherlands*, OCDE/GD/96/22, OECD on-line document, http://www.oecd.org/daf/ccp/envr07.htm..
OECD (1996b), *Implementation Strategies for Environmental Taxes*, Paris, OECD, 94 p.
OECD (1996c), *Environmental Taxes in OECD Countries*, Paris, OECD, 99 p.
Oskam, E.A., Van Der Wijst, C.A and Duursma, S.T. (1993), *Naar een Europese Regulerende Energieheffing*, ESB.
Parry, Ian W.H. (1995), 'Optimal Pollution Taxes and Endogenous Technological Progress', **17(1)** *Resource and Energy Economics*, 69-85.
Paulus, A. (1995), *The Feasibility of Ecological Taxation, Law and Economics*, Antwerpen, Maklu, 373 p.
Pearce, David W. and Turner, K.R. (1990), *Economics of Natural Resources and the Environment*, London, Harvester Wheatsheaf, 378 p.
Pearson, Mark and Smith, Stephen (1990), *Taxation and Environmental Policy: Some Initial Evidence*.
Pigou, A.C. (1920), *The Economics of Welfare*, London, Macmillan.
Pigou, A.C. (1962), *The Economics of Welfare*, London, Macmillan, 876 p.
Polinsky, A. Mitchell (1979), 'Controlling Externalities and Protecting Entitlements: Property Right, Liability Rule, and Tax-Subsidy Approaches', **8** *Journal of Legal Studies*, 1-48.
Porter M. (1990), *The Competitive Advantage of Nations*, London, Macmillan.
Rapanos V.T. (1995), 'The Effects of Environmental Taxes on Income Distribution', **11(3)** *European Journal of Political Economy*, 487-503.
Rose-Ackerman, Susan (1975), 'Effluent Charges: A Critique', **6** *Canadian Journal of Economics*, 512-527.
Rose-Ackerman, Susan (1977), 'Market Models for Pollution Control: Their Strengths and Weaknesses', in Brown, G., Kneese, A. and Rose-Ackerman, Susan (eds), *Public Policy*, 383-406.
Rose-Ackerman, Susan (1992), 'Assessing the State of the Art: Environmental Liability Law', in Tietenberg, T. (ed.), Aldershot, Edward Elgar, 223-243.
Rothbard, Murray N. (1982), 'Law, Property Rights and Air Pollution', **2(1)** *Cato Journal*, 55-99.
Samuels, Warren J., Medema, Steven G. and Schmid, A. Allan (1996), *The Economy as a Process of Evaluation*, Cheltenham, Edward Elgar.

Samuelson, Paul A. and Nordhaus, William D. (1995), *Economics* (15th edn), New York, McGraw-Hill, 789 p.
Shibata, Hirofumi (1972), 'Pareto-optimality and Trade and the Pigovian Tax', **39** *Economica*, 190-202.
Shibata, Hirofumi (1974), 'Pareto-optimality and Gains-from-trade: a Further Elucidation', **41** *Economica*, 71-78.
Skogh, Göran and Lidgren, K. (1996), 'Extended Producers Responsibility. Recycling Liability and Guarantee Funds', **79** *Geneva Papers on Risk and Insurance*, 170-181.
Sleszynski Jerzy (1996), 'Economic Instruments in Environmental Policy: A Profile of Poland', **6(4)** *European Environment Review*, 136-134.
Smith, Adam (1776), *The Wealth of Nations* (Cannan, E. (ed. 1976)), Oxford, Clarendon.
Smith, J.B. and Sims, W.A. (1985), 'The Impact of Pollution Charges on Productivity Growth in Canadian Brewing', **16** *Rand Journal of Economics*, 410-423.
Smith, Stephen (1995), *Green Taxes and Charges: Policy and Practice in Britain and Germany*, London, Institute for Fiscal Studies, 137 p.
Spulber, Daniel F. (1989), *Regulation and Market*, Cambridge, MA, MIT Press, 688 p.
Starret, David A. and Zeckhauser, Richard (1974), 'Treating External Diseconomies - Markets or Taxes?', in Pratt, J.W. (ed.), *Statistical and Mathematical Aspects of Pollution*, New York, Dekker, 65-84.
Svendsen, Gert Tinggaard (1993), 'Fordele ved et marked for CO_2 -kvoter (Advantages in CO_2 Emissions Trading)', **7** *Samfunds¢konomen*, 5-9.
Svendsen, Gert Tinggaard (1994), 'Kvoter og Syreregn (Quotas and Acid Rain)', **3** *Okonomi & politik*, 33-39.
Svendsen, Gert Tinggaard (1994), 'Globalt CO_2-marked', **1** *Fremtidsorientering*, 35-36.
Tahvonen, Olli (1995), 'International CO_2 Taxation and the Dynamics of Fossil Fuel Markets', **2(2)** *International Tax and Public Finance*, 261-278.
Thomas, Alban (1995), 'Regulating Pollution under Asymmetric Information: The Case of Industrial Wastewater Treatment', **28(3)** *Journal of Environmental Economics and Management*, 357-373.
Tietenberg, Thomas (1996), *Environmental and Natural Resource Economics* (4th edn), New York, HarperCollins Publishers, 614 p.
Tinbergen, J. (1952), *On the Theory of Economic Policy*, Amsterdam, North Holland, 78 p.
Turner, K.R., Pearce, David W. and Bateman I. (1994), *Environmental Economics. An Elementary Introduction*, London, Harvester Wheatsheaf, 328 p.
Viscusi, W. Kip, Magat, Wesley A., Carlin A. and Dreyfus, Mark K. (1994), 'Environmentally Responsible Energy Pricing', **15** *Energy Journal*, 23-42.
Von Weizsäcker Ernst U. and Jesinghaus Jochen (1992), *Ecological Tax Reform. A Policy Proposal for Sustainable Development*, London and New Jersey, Zed Books, 90 p.
Wang, Lih Jau (1995), 'Environmental Capital Flight and Pollution Tax', **5(3)** *Environmental and Resource Economics*, 273-286.
Welsch, Heinz (1995), *Joint vs. Unilateral Carbon/Energy Taxation in a Two-region General Equilibrium Model for the European Community*, Nota di Lavoro, 36.95.
Wenders, John T. (1973), 'Corrective Taxes and Pollution Abatement', **16** *Journal of Law and Economics*, 365-368.
White, Michelle J. (1979), 'Suburban Growth Controls: Liability Rules and Pigovian Taxes', **8** *Journal of Legal Studies*, 207-230.

White, Michelle J. and Wittman, Donald A. (1983), 'A Comparison of Taxes, Regulation, and Liability Rules under Imperfect Information', **12** *Journal of Legal Studies*, 413-425.
Wilson, James Q. (1980), *The Politics of Regulation*, Basic Books, 468 p.
Wittman, Donald A. (1985), 'Pigovian Taxes which Work in the Small Number Case', **12** *Journal of Environmental Economics and Management*, 144-154.
Wittman, Donald A. and White M. (1981), 'Optimal Spatial Location Under Pollution: Liability Rules and Zoning', **10** *Journal of Legal Studies*, 249-268.
Wittman, Donald A. and White, Michelle J. (1983a), 'A Comparison of Regulation and Liability Rules Under Imperfect Information', **12** *Journal of Legal Studies*, 413-426.
Wittman, Donald A. and White, Michelle J. (1983b), 'Pollution Taxes and Optimal Spatial Location', **50** *Economica*, 297-311.
Wolken, John D. and Koopmans C.C. (1992), 'Aanpassen of Achterblijven (Adjust of Lag Behind)', **9** *Economisch-Statistische Berichten*, 861-863.
Yohe, Gary W. (1989), 'More on the Properties of a Tax cum Subsidy Pollution Control Strategy', **31** *Economic Letters*, 193-198.