Tomasz Zylicz, "Goals and Principles of Environmental Policy", *International Review of Environmental and Resource Economics*, Vol. 3, No 4, 2010, pp. 299-334
[http://dx.doi.org/10.1561/101.00000028]

Goals and Principles of Environmental Policy

Abstract

This paper looks at how contemporary environmental (including climate) policy problems are phrased in terms of effectiveness, efficiency, and equity. The latter three concepts have served as foci of theoretical discussions among economists who analyze these issues and identify criteria that determine relevant regulations and programmes adopted by governments. The paper starts with a discussion of Pigouvian taxation as model instrument used in order to solve policy problems. It analyzes to what extent and under what circumstances alternative instruments – such as e.g. marketable pollution permits – can achieve environmental and climate goals while serving other purposes too. Coase theorem is used as a reference for discussing what government interventions are indeed indispensable to achieve both explicit and tacit policy goals. Popular principles and practically applied 'rules of thumb' – such as e.g. the *Polluter Pays Principle* – are then reviewed. The next part is devoted to examining market structures as they influence environmental outcomes of economic activities. This is followed by a discussion of Environmental Tax Reforms which seem to inspire much of the economic thinking about contemporary policies. An outlook for the 21st century concludes the paper.

Keywords: effectiveness, efficiency, equity, environmental policy, climate policy, Pigouvian taxes, Coase theorem, Environmental Tax Reform

JEL codes: H23, H43, Q52, Q54, Q58

1. Theoretical foundations of environmental policy

Environmental policy can be traced back to ancient times. Nevertheless, it would be difficult to identify its mature formulations earlier than in the 1960s. The United Nations report of 1969 – the so-called *U Thant Report*[1] – is probably the earliest comprehensive exposition of the need to look at the natural environment as a policy problem. The report outlined the seriousness of the global predicament without, however, specific guidelines on how the problem can be handled. In response to the *U Thant Report*, a number of initiatives evolved. The most remarkable one was the United Nations conference on the human environment in Stockholm in 1972. As a result of the conference, many governments established departments in charge of environmental protection. The conference produced a number of documents, many of which provided important inputs for subsequent endeavours. In particular, it formulated 'Principle 11' stating that:

> *The environmental policies of all States should enhance and not adversely affect the present or future development potential of developing countries, nor should they hamper the attainment of better living conditions for all, and appropriate steps should*

> *be taken by States and international organizations with a view to reaching agreement on meeting the possible national and international economic consequences resulting from the application of environmental measures.* [United Nations 1972]

This can be seen as a prototype for future statements leading to the *sustainable development* paradigm. More importantly, however, it also included 'Principle 23' which alludes to economic analyses as a foundation for environmental policies:

> *Without prejudice to such criteria as may be agreed upon by the international community, or to standards which will have to be determined nationally, it will be essential in all cases to consider the systems of values prevailing in each country, and the extent of the applicability of standards which are valid for the most advanced countries but which may be inappropriate and of unwarranted social cost for the developing countries.* [United Nations 1972]

Of course, principles discussed at the United Nations conference in Stockholm where not discovered there. They were present in economics for some years already. H. A. Thomas Jr [1963] was perhaps the first economist to clearly explain that environmental standards depend on costs and benefits they correspond to. Thomas explained that e.g. potable water standards cannot be seen as 'objective' or 'scientifically justified'. They depend on both costs and benefits that society faces when contemplating whether to sharpen or relax a given standard. In particular, he observed that the standard may depend on how the society views the value of a statistical life *vis à vis* other goods. This has proved to be a delicate issue, especially with respect to international division of labour[2], but it captures the essence of goals in environmental policy: to maximize social benefits net of costs, despite the fact that neither the former nor the latter are easy to be quantified.

It is commonly accepted that Baumol and Oates [1975] provided the 'classical' textbook of environmental policy. Even though their book was several times revised, from the very first edition it offered a universally adopted perspective on environmental policies. According to Baumol and Oates, environmental policy should be efficient. In other words, it should maximize the surplus of *total social benefits* (TSB) over *total social costs* (TSC): TSB-TSC. Assuming further that benefits are concave with respect to some variable characterizing the policy, and the costs are convex, then the *First Order Conditions* for maximization require[3] that the relevant derivative vanishes, i.e. that MSB=MSC (where MSB=TSB', and MSC=TSC'). Comparing TSB with TSC provides a base for Cost-Benefit Analysis, an approach that is contested but nevertheless indispensable as a tool for arriving at sound policy conclusions [Arrow *et al.* 1996]. Ability to compare various policy outcomes is also inevitable given the fact that policy makers and their constituencies are concerned with multiple aspects of what they do [Braathen 2007].

Thus efficiency emerges as the key principle of environmental policy. In practice, however, it is difficult to be assessed, since neither benefits nor costs allow for easy estimation methods.[4] In parallel, there also evolved other approaches to environmental policy. Effectiveness – identified with achieving an effect – is perhaps a concept which is understood more widely than efficiency. Moreover, effectiveness does not call for quantification of benefits and costs which is considered controversial, especially if one attaches price tags, as required by efficiency analyses. Nevertheless effectiveness is not rooted in a universally accepted theory to justify the adoption of specific policy objectives. Some scientists call for the need to preserve certain natural assets intact, but the choice of specific targets remains controversial.

Ekins [1992] introduced the notion of a critical natural capital[5] which could free the question of effectiveness from arbitrariness. The critical natural capital comprises ecosystems and their services that are indispensable for maintaining life on earth. While it would be difficult to disagree with the fact that depletion of natural capital is an economic loss, the identification of assets that are 'priceless' and hence should be saved at any cost is impossible. Nevertheless some economists advocate for so-called strong sustainability which requires that the natural capital is not depleted.[6] Some environmental policies indeed seem to aim at effectiveness rather than efficiency. For instance, the European acid rain agreement (The Second Sulphur Protocol) is based on the notion of 'critical loads', i.e. maximum allowable depositions of sulphur dioxide that can be absorbed by local ecosystems without their destruction [United Nations 1994].

Admitting that benefits are difficult to be monetized questions the application of efficiency in environmental policies. Cost-effectiveness – i.e. minimizing the cost of achieving an objective – is the natural reference in such situations. The acid rain agreement referred to above follows along these lines by allocating abatement effort among the parties to the Second Sulphur Protocol in a way which minimizes the total cost of not exceeding the critical loads. Some domestic regulations replicate this approach. However, despite the fact that many regulatory authorities acknowledge cost-effectiveness, most often they are ready to sacrifice it for equity which emerges as their key policy concern[7].

Perhaps the best-known example of equity is the concept of 'common but differentiated responsibility for climate change'. As emphasized in reports of the Intergovernmental Panel on Climate Change (IPCC), the predicament has been caused by the past carbon dioxide emissions from industrialized countries. The worst damages are likely to be suffered by the poorest non-industrialized countries, especially in Sub-Saharan Africa. Protecting the climate requires deepest cuts (with respect to the 'business-as-usual' scenario) to be done in newly developing countries, such as China, India, Brazil etc. Hypothetical effective and efficient strategies for climate protection, not necessarily related to history, are contemplated. At the same time, political processes seem to be overwhelmed by equity considerations which are heavily rooted in history. As early, as in 1995, at the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), an agreement was reached that only industrialized countries would take emission reduction commitments[8]. This agreement was next implemented in the Kyoto Protocol to UNFCCC in 1997. As a result, industrialized countries reduced their emissions somewhat, but the total emission kept growing at an even faster pace.

Another important example of environmental policies sensitive to equity considerations is biodiversity protection. It is often declared that participation in costs of biodiversity protection should be determined by shares in benefits. The costs (especially opportunity costs) are typically born by the population living in biodiversity-rich areas, whereas benefits are distributed more widely. Under these circumstances equity calls for creating mechanisms that allow for compensating those who bear the cost. Unlike in the previous example, here equity does not compromise effectiveness.

Even though equity and effectiveness considerations do play a role in framing policies, there are no theoretical models to provide a widely accepted reference for them.[9] Efficiency has played this role, but from time to time analysts observe that actual environmental policies hardly can be justified on these grounds. The aim of this paper is to demonstrate how the efficiency concept has guided economic analyses of environmental and climate policies; in particular, it is discussed whether alternative policy instruments do or do not let achieve declared goals at a reasonable cost.

The rest of the paper is organized as follows. It starts with an exposition of Pigouvian taxes which dominate much of economic analyses. This is followed by their Coasian critique as well as extensions of the main model which take into account asymmetric information and other issues. The next section is devoted to practical applications which are not necessarily consistent with theoretical prescriptions. Two subsequent sections deal with specific questions raised by analysts most frequently. These are: the relationship between market structure and the choice of policy instruments; and the so-called Environmental Tax Reform. An outlook for the future and an agenda for future research conclude the paper.

2. The Pigouvian prescription

It has been known, that economic efficiency is difficult to achieve, if the market fails. The menu of possible market failures has been expanding, but the earliest theoretical detection of this fact involved externalities and public goods in the late 19th century. Walras observed interesting characteristics of market equilibria involving private goods. Lindahl was the first to extend his model to the case when one of the goods is public, i.e. it complies with non-exclusion and non-rivalry principles. His work has become more widely known thanks to Samuelson [1954], and especially Mäler [1985], who explained how the price and quantity of the public good – interpreted as 'environmental quality' – can be determined within the framework of a Walras model.

Independently, a discussion of externalities went on. For many years, it took for granted that the market failure caused by externalities, i.e. 'involuntary transactions' affecting directly consumers' preferences or firms' profits, needs to be corrected by a so-called Pigouvian tax [Pigou 1920]. Even though analysts have often addressed the two issues separately, environmental public goods and externalities are in fact the same phenomena. By providing a public good (or 'bad'), one creates an externality, since the impact of the good does not confine to the provider. And, *vice versa*, by creating an externality, one *de facto* provides a public good.

The non-exclusion principle satisfied by public goods allows for so-called *free riding*, i.e. the behaviour that does not reveal one's true preferences. Economists ponder how to motivate people to truthfully reveal their preferences with respect to public goods. The only instrument that has been recommended so far is the Groves-Clarke tax [Groves and Ledyard 1977]. This hypothetical tax (it has never been applied due to prohibitive administrative costs) levies charges that can be higher than what agents risk by truthfully revealing their preferences. Among many features of the tax, one most remarkable in this context is its interpretation as a Pigouvian tax levied on pivotal agents, i.e. those whose preference with respect to the public good in question change the optimum from including the good to excluding it, or *vice versa*. According to this interpretation, pivotal agents impose an externality by leaving those who liked the good without it, or those who did not like the good with it.

There are many definitions of a Pigouvian tax (PT). The one which is rigorous and consistent with its market-correcting role is the following:

$$PT(q) = MEC(q^0)(q-q_{thr}),$$

where q is the externality-generating activity, q^0 is its socially optimum level, as found from solving the MSB(q)=MSC(q) equation (with MSC=MPC+MEC; MPC stands for the *marginal private cost*, and MEC stands for the *marginal external cost*; if the externality is positive, then MEC<0), and q_{thr} is an arbitrary threshold[10]. There is an alternative formulation of the problem by assuming that MSB=MPB+MEB, where MPB stands for *marginal private benefit*, and MEB – for *marginal external benefit* (the right-hand side of the definition would then read $MEB(q^0)(q_{thr}-q)$). Pezzey [1992] observed that changing the threshold does not affect the short-run motivation to keep the externality at a socially optimum level. In the original formulation of Pigou, there was no threshold ($q_{thr}=0$). If the threshold is set at the socially optimum level ($q_{thr}=q^0$), and the agent keeps its activity at this level, then the tax obligation vanishes (PT(q)=0). If the threshold is sufficiently high ($q_{thr}>q^0$), then the tax is negative, i.e. it turns out to be a subsidy for reducing external costs. The total amount of the tax depends on the length of the interval between q and q_{thr}, i.e. on $q-q_{thr}$.

For obvious reasons, agents prefer higher thresholds rather than low ones. At the same time, tax revenue is higher if the threshold is lower. Agents' long-run motivations do depend on thresholds. Sterner [2003] explains how the surplus from correcting the market failure is allocated between externality-generating agents and society depending on whether the threshold is low or high.[11] If the threshold is low then agents have a stronger motivation to avoid investment in harmful activities. If it is high, then the motivation is weak and as a result, in the long run, the economy has more externality-generating activities than otherwise possible. Because of that, some analysts – especially those who favour Environmental Tax Reform (see Section 5 below) – advocate for the original Pigou concept of the tax, i.e. without any threshold.

Pigouvian taxes with thresholds reflect the rule that efficiency can be decoupled from equity. By manipulating the threshold one can achieve any allocation of burden without compromising efficiency (at least in the short-run). The Swedish nitrogen oxide tax imposed on coal-fired power plants in 1991 serves as an example. Its revenues are recirculated back to the polluters in proportion to electricity production. The formula is thus

$$PT(q_i) = MEC(q^0)(q_i-q_{thr}),$$

where q_i is the emission per unit of electricity produced in plant *i*, $MEC(q^0)$ is a uniform tax rate, $q_{thr}=(\sum_i q_i e_i)/\sum_i e_i$ (average emission per unit of electricity), and e_i is electricity produced in plant *i*. As a result of this definition, each plant has an incentive to abate, but the total revenue for the budget (i.e. the burden for the electricity sector) is zero.[12] Those who emit per unit of electricity produced more than average pay to the budget, while those who emit less than average receive a subsidy from the budget.

For forty years, nobody objected to the Pigouvian solution to externality problems. The tax seemed to be the obvious and the only instrument to correct for the market failure in this case. Coase [1960] was the first to question this view. In what is now called the *Coase Theorem*, he argued that the MSB=MSC criterion would be satisfied if the law allowed parties to negotiate over the allocation of property rights regarding assets that are linked to the externality problem, and the related transaction costs were negligible. The Coase Theorem states that in this case the market failure will correct itself without any government intervention. In other words, no policy is necessary, since economic agents will achieve efficiency spontaneously.

One can easily ridicule the Coase Theorem by pointing out that property rights are rarely well-defined, transaction costs are high and it is nonsensical to expect the pollutees 'bribe' their polluters in order to let them abate. Indeed, there are not many practical applications of the Coase Theorem in environmental policy. Nevertheless its impact has been substantial.

First of all, thanks to the Coase Theorem economists recognized that there are no reasons to let the government *a priori* favour one party in an externality setting. While it is understandable that polluters usually deserve less support than their victims, both parties may have some reasonable remedial activities at their disposal; hence achieving an efficient solution requires that both face some incentives to minimize losses. Moreover, Coase demonstrates that achieving efficiency requires low transaction costs. Government regulations can change these costs; as a rule, the greater the bureaucracy the higher they are. Finally, an open question is always whether economy calls for a regulation at all. Very often it does, but economists need to know how to arrange such a regulation, and – in particular – how to compromise between efficiency (understood as maximization of net social benefits) and equity (understood as choosing winners and losers).[13]

Despite its merits, the Coase Theorem is not universally accepted. Some analysts call it the 'Coase's curse', and blame it for whatever failures environmental policies are responsible for. The critics claim that Coase is responsible for bringing efficiency into environmental policy and thus undermining its effectiveness.[14] This argument does not seem to have any empirical support. Indeed, some policies do not deliver any environmental results. Their failure has been caused by political corruption and lobbying rather than economic undervaluing environmental benefits. If the Coase Theorem were taken seriously then non-environmental arguments of lobbyists should have been assigned economic values and should have been confronted with benefits from environmental protection; but this is not the case. Policy failures are usually caused by departure from efficiency rather than promoting it.

For analytical purposes, the MSB=MSC criterion can be rephrased by assuming that all private items (both costs and benefits) are calculated as net benefits, while all external items (both costs and benefits) – as net costs. In other words, MNPB (*Marginal Net Private Benefit*) is the difference between MPB and MPC, MNPB=MPB-MPC. At the same time, MNEC (*Marginal Net External Cost*) is the difference between MEC and MEB, MNEC=MEC-MEB. By simple substitutions, one obtains that the equation MSB=MSC is equivalent to MNPB=MNEC. Thus the social optimum q^0 is where MNPB=MNEC, and MNEC(q^0) is the Pigouvian tax rate. The tax reads:

$$PT(q)=MNEC(q^0)(q-q_{thr}).$$

There are two ways of meeting the MNPB=MNEC criterion. One is to levy a Pigouvian tax calculated according to the formula above. But if one knows the solution to this equation, one also knows the optimum level of the externality-generating endeavour q^0. The same – socially optimum – result can therefore be achieved by establishing a quantity regulation.

An externality tax implies cost-effectiveness even if it is set at a non-Pigouvian level, i.e. when its rate is set below or above MNEC(q^0). This characteristics of taxes is important when several agents contribute to the same externality, e.g. when they emit the same pollutant affecting the same area. If each of the agents i=1,...,k is subject to the same tax rate τ, then rationality implies that they adjust their behaviour so that $MNPB_i(q_i^0)=\tau$. Consequently, the total cost of meeting the overall externality level $q_1^0+...+q_k^0$ cannot be lowered (if all $MNPB_i$ functions are strictly decreasing, as it is commonly assumed in such analyses). This establishes the cost-effectiveness of the tax.

If the regulating agency knew all the $MNPB_i$ functions, then it could allocate targets q_i^0 for all agents to achieve cost-effectiveness. This, however, is rather unlikely as agents are not willing to disclose information on their private benefits from economic activities. The more likely result is that the agency allocates targets $x_1,...,x_k$ whose total sum is equal to a given number, say, $q_1^0+...+q_k^0$, but individual allocations may differ from the cost-effective ones. The targets $x_1,...,x_k$ may depend on technology or other source-specific considerations, and typically take the form of a standard. Cost-effectiveness can be achieved but by a pure chance.

The question therefore is whether it is possible to achieve cost-effectiveness without the help of a tax. The positive answer – by referring to what we now call marketable permits – was given in the late 1960s and the early 1970s. While many textbooks credit Dales [1968] with the discovery, it was actually suggested somewhat earlier by Crocker [1966]. The idea is very simple. Economic agents are given individual permits $x_1,...,x_k$, and are allowed to trade them, so that their final sum is the same: $x_1^{fin}+...+x_k^{fin} = x_1+...+x_k$. If the market works smoothly, the price of the permit will be equal to τ, i.e. to the tax rate leading to the same aggregate result. A clear exposition of the instrument, together with the proof of its cost-effectiveness, was done by Montgomery [1972]. Moreover, Montgomery was also the first to observe that marketable permits can be used to cost-effectively allocate abatement effort for several pollutants simultaneously. In his model, economic agents buy permits for each of the types of pollution they emit, and it can be proved that the resulting equilibrium leads to an optimum allocation of abatement effort. Pollution markets thus reveal similar characteristics to markets for ordinary goods and services which process information on many commodities at the same time. Later on the result was extended to deal with pollutants that non-linearly contribute to environmental degradation [Zylicz 1994].[15]

There is a symmetry between taxes and marketable permits. The same cost-effective allocation of abatement effort can be accomplished either by a tax or by a marketable permit system. Theoretically they are also equivalent in terms of equity. By allocating tax thresholds or by distributing some permits free of charge, the regulatory agency can achieve any burden-sharing arrangement without compromising cost-effectiveness.[16]

The result above is valid only under the perfect information assumption. In an uncertain world the two instruments are not equivalent. Both achieve cost-effectiveness, but they may imply different costs and different abatement level. In the case of the tax regulation, the marginal cost of meeting policy objective is fixed ($MNPB_1=...=MNPB_k=\tau$), but the environmental outcome is uncertain. In the case of the quantity (marketable permit) regulation it is the other way around: the environmental outcome is fixed ($x_1+...+x_k$), but the cost of meeting policy objective is uncertain. Thus the choice of instrument may reveal the regulator's preference with respect to policy criteria. If priority is given to economy then the tax seems to be a more appropriate choice. If on the other hand priority is given to environment, then quantity regulation is superior. That is why marketable permits can be preferred by environmentalists [Daly 1992].

More rigorous economic analyses demonstrate that in an uncertain world the difference between the two instruments is more complex. Apart from political considerations which point at either taxes (when priority is given to economy), or marketable permits (when priority is given to environment), the two approaches turn out to be by far not equivalent if uncertainty is taken into account. Weitzman [1974] was first to observe that the type of uncertainty may *a priori* indicate which of the two approaches is preferred. His model assumes that MNEC can be approximated by a linear function and known with certainty. In contrast, MNPB – also approximated by a linear function – is not known exactly; only its slope is known, but its exact location is uncertain. In other words, the true $MNPB_{true}$ may differ from the perceived one $MNPB_{perceived}$ by a constant: $MNPB_{true}=MNPB_{perceived}+\eta$, where η is some number, unknown for the regulating agency. Weitzman proved that the choice of the approach depends on the relative slopes of MNEC and MNPB (which are the same for $MNPB_{true}$ and $MNPB_{perceived}$). Namely, if -MNEC'>MNPB' then a potential error (loss of welfare) caused by inadequate tax regulation is lower than a potential error caused by inadequate quantity regulation due to the fact that benefits are not known with certainty. And, *vice versa*, if -MNEC'<MNPB' then a potential error (loss of welfare) caused by inadequate tax regulation is higher than a potential error caused by inadequate quantity regulation. While the proof provided by Weitzman is quite formal, the rule has an easy economic interpretation. The outcome of a tax regulation is affected by MNPB (i.e. private benefits) only; thus it is not surprising that when the MNPB curve is steep, even small errors in its perception may have serious consequences. The constant η does not have any impact on these conclusions.

Of course, there are many ways for imperfect knowledge to be accounted for in such analyses. Weitzman analyzed but one of several uncertainty types of potential interest. For instance, Stavins [1996] looked at the problem of correlated uncertainty, i.e. the case when benefits and costs are random variables that are not fully independent of each other. The conclusion is that under these circumstances the original Weitzman's result may be not valid, with marketable permits indicated as the more preferred instrument in most cases.[17] Yet another extension of this approach are dynamic models with a regulator learning from polluters' reactions to previous regulations [Karp and Zhang 2005]. Sandmo [2002] discusses alternative policy instruments when compliance is not perfect. The general finding of such analyses is that the choice of instruments or of an instrument mix depends on various considerations, but – as a rule – it departs from standards towards market based instruments, once environmental policy goals become more stringent [Toke Skovsgaard Aidt and Dutta 2004].

Tietenberg [2006] summarizes the more recent experience with marketable permits. For many years confined mostly to the United States, this instrument started its new life thanks to the Kyoto Protocol of 1997. The European Commission introduced it to the Union's legislation in the so-called EU ETS (*Emissions Trading Scheme*) Directive[18] in order to facilitate the European compliance with the Kyoto Protocol. Over 10,000 European firms participate in the market, but cost-effectiveness was compromised due to the fact that some sectors (e.g. passenger cars) are excluded from the scheme, and allocation rules were not transparent.[19]

3. Popular principles and 'rules of thumb'

Despite the fact that efficiency has been the guiding theoretical principle in environmental policies, real implementations are usually guided by simplified rules that comply with common wisdom, even though their theoretical justification is vague. In the review below, we concentrate on three such rules: *Polluter Pays*, *Precautionary Principle*, and *Subsidiarity Principle*.

The '***Polluter Pays***' Principle best appeals to the common wisdom, and it has been acknowledged by activists and policy makers for decades. It was first clearly formulated by the OECD Secretariat in 1972.[20] From the very beginning, it was apparent that at least two understandings of the principle can be conceived: a broad and a narrow one. The former assumes that the polluter is financially responsible for whatever harm its pollution may cause now and in the future. The latter confines the polluter's responsibility only to keeping its operations within limits set by a relevant authority. In other words, the latter states that the polluter is not responsible for any harm that may be caused by its pollution as long as it complies with its pollution permit.

Many environmentalists favour the broad understanding of the 'Polluter Pays' principle. Nevertheless, it would be difficult to enforce it, since sometimes the harm occurs when the polluter no longer exists, or it is impossible to unambiguously link the harm to a specific polluter. Thus in 1974 the OECD endorsed the narrow understanding, by emphasizing the role of subsidies that need to be avoided. The application of environmental subsidies is allowed only under three conditions (fulfilled jointly) [OECD 1974]:

> *a) it should be selective and restricted to those parts of the economy, such as industries, areas or plants, where severe difficulties would otherwise occur;*
>
> *b) it should be limited to well-defined transitional periods, laid down in advance and adapted to the specific socioeconomic problems associated with the implementation of a country's environmental programme;*
>
> *c) it should not create significant distortions in international trade and investment.*

While the 'Polluter Pays' Principle seems to have a strong intuitive appeal, it should be stressed that it is not called for by economic theory. As indicated in section 1 above, Pigouvian taxes do not require polluters to bear the cost of pollution. Moreover, an efficient scope of environmental protection can be achieved even under subsidies, at least in the short run, as demonstrated in the previous section. It is true, however that in the long run subsidies do provide a perverse incentive to invest in polluting industries. In addition, they may distort international trade by promoting suppliers from rich countries whose taxpayers can afford higher subsidies. Therefore international cooperation precludes subsidies, and OECD has rightly insisted that environmental protection does not serve as a rear door for a budgetary support for producers.

Doubts were raised regarding the concept of a 'polluter' [Zylicz 2000, p. 143]. For instance, everybody agrees that spraying a pesticide over a field is pollution, but it is not obvious who is a polluter. There are several candidates. The first one in a chain is the producer of the pesticide. But companies that produce toxic chemicals will argue that their products can be used in a number of applications, and it is a long way from the factory to pollution. The next one is the distributor of the pesticide. This intermediary can argue that pollution is caused by inappropriate use of the substance, e.g. by not complying with regulations on the waiting period; thus it does not make sense to impose the financial burden on retailers who are not responsible for emission. The farmer seems to be closest to the notion of a 'polluter', but it is not realistic to place the burden here for a number reasons, including excessively high monitoring costs.

The OECD has advocated for the 'Polluter Pays' mainly as a convenient cost-allocation principle. In the absence of regulations, governments would have a temptation to free 'their' polluters from some obligations thus creating trade distortions. At the same time, it is important to stress what the 'Polluter Pays' Principle is not. First of all, it is not an implementation of Pigouvian taxes. Indeed, a Pigouvian tax with a threshold may include a subsidy load (if the threshold is higher than the actual pollution), and – on the contrary – a polluter regulated by a quantity instrument may be fully responsible for abatement. Second, it is not an 'equity based' principle. Even though polluters are sometimes considered by the society not worthy of subsidies, many environmental subsidy schemes were motivated by equity considerations (whether justified or not). Third, at least in its narrow form, the 'Polluter Pays' is not a liability principle. Pollution permitting authorities are liable for whatever harm the allowable pollution does. This does not preclude litigation against a polluter, but as long as emission complies with regulations, the polluter can claim that all relevant requirements were fulfilled.

The 'Polluter Pays' has been largely recognized as a 'No-Subsidy' Principle. The European Commission has a much more powerful legal potential than the OECD, and European Union countries must comply with its regulations. Most of the 'no-subsidy' agenda refers to non-environmental issues [European Union 2006], but environmental policies are scrutinized too. Even though state aid is banned by the Article 87 of the Rome Treaty [European Union 2008a, renumbered as article 107], there are numerous exemptions. Environmental protection can be subsidized if it goes beyond what is required by the European legislation. In the case of the EU priority areas – renewable energy, energy savings, and cogeneration, among other things – subsidies are allowed to the extent they cover incremental costs of going beyond 'business as usual' [European Union 2008b]. In general, the subsidy is understood in terms of a grant equivalent, i.e. a hypothetical cash payment corresponding to the measure applied, such as e.g. a tax exemption or a bank guarantee. Also in the case of a free allocation of marketable permits (instead of an auction), a grant equivalent is to be calculated. Overall, as in the OECD guidelines, European subsidies need to be screened against international competitiveness criteria.[21]

The 'Polluter Pays' Principle is considered a cornerstone of European environmental policies. All policy documents take it for granted that abatement measures are to be financed by polluters. Careful considerations, however, take place before any such measure is implemented. As a result, abatement costs typically do not exceed what is justified in terms of benefits. This procedure – adopted in many jurisdictions across the world – in the European context brings in specific equity concerns. Unlike in countries with financially strong central governments, establishing an environmental requirement in the European Union may imply a serious regional imbalance of costs and benefits. In nation states, this imbalance is mitigated by a tax redistribution. The European Union budget is too low to absorb compensations expected by the losers. As a result, either measures agreed are not satisfactory for the most ambitious partners, or they are sabotaged by the least ambitious ones. Therefore tensions arise, and from time to time they erupt in slogans about a Europe of 'two speeds'.

The ***Precautionary Principle*** is ranked high too. It says that if there is a possibility of an unwanted outcome, the decision maker should take this into account and act accordingly. For an economist, stated as above, it calls for estimating the probabilities of bad outcomes, and choosing strategies that maximize some notion of an expected net gain. There are, however, two caveats. First, some outcomes can be catastrophic and the decision maker may be unable or unwilling to monetize them. Second, a mere possibility of a bad outcome is disturbing enough, so that there is no need to wait until convincing scientific evidence is gathered and probabilities are estimated. Consequently, the Precautionary Principle serves more as a 'rule of thumb' rather than a scientific reference.

There are efforts to make it scientifically sound, as summarized by Randall [2009]. The main idea behind these is to emphasize that conventional economic analysis incorporating probabilities and net gains is inadequate as a universal base for rational decision making. It works well when risks are small, dispersed and affecting economic agents independently. When a society faces a huge irreversible damage threatening a large population, a totally different approach is appropriate. Randall phrases it as follows: "If there is evidence stronger than **E** that an activity raises a threat more serious than **T**, we should invoke a remedy more potent than **R**." [p. 54] Nevertheless, in most environmental policy applications, it is understood much more simplistically.

Critics of the 'traditional' Precautionary Principle refer to the example of identifying carcinogens among chemical substances. Any such substance can be found carcinogenic, and no experiment – no matter how long and expensive – can fully absolve a substance from such a stigma [Clark 1980].[22] Under these circumstances, the Precautionary Principle calls for a ban. As it would be inconceivable to live in a world without chemical substances produced, policy makers and their constituencies do not apply this principle here. Actual regulations (perhaps partial and imperfect) are based on balancing likely costs and benefits.

In contrast, declared climate policies seem to be motivated by the Precautionary Principle. Their proponents argue that the risk of an unprecedented and irreversible climate catastrophe is too dangerous and too close to wait with protection measures until scientific evidence is absolutely clear and convincing. As a result, sceptics claim that recommended measures are premature and excessive.

It is impossible to find a firm justification for the Precautionary Principle. Its popularity among policy makers and lay people stems from its appeal to the common sense. Most proponents, however, do not appreciate the fact that the rigorous application of the Precautionary Principle implies a total ban for economic activities. Any action may lead to an irreversible damage, so it should be avoided. Of course, people disregard such admonitions and they proceed with economic projects as long as their benefits seem to outweigh their costs. Therefore, despite verbal acknowledgement of the Precautionary Principle, its application is rather casual, limited to instances when potential damages are very high.

In actual applications, the Precautionary Principle serves as a slogan to justify a policy which seems to be efficient, and damages from its abandoning are very high while their probability is difficult to assess. Instead of discussing quantified costs and benefits, politicians prefer to claim that their balance is obvious and it would be unreasonable to postpone decisions until everything is scientifically quantified.

An interesting case is provided by the Nordhaus *versus* Stern debate[23]. So-called Stern [2006] review was published as a report to the British government. The main argument of the report was the efficiency of an early action against the global warming. Stern argued that the net present value of an aggressive climate protection policy is positive. The result depended, however, on the application of an unusually low discount rate: 1.4% instead of higher ones (typically 4%) adopted in many other analyses. Nordhaus [2007] points out that this assumption of Stern's is not consistent with empirical findings on how people take decisions regarding the future. Hence the efficiency of the policy advocated by Stern is dubious.

The Nordhaus-Stern debate touched the very essence of long-term environmental policies. These policies are assessed on efficiency grounds with positive discount rates. The higher the discount rate, the lower relative weight is attached to what happens in the future. As a rule, the poorer the society, the higher the discount rate it applies to economic decisions. In a poor society, where many basic needs are not satisfied, an investment project should yield a very high rate of return to be of interest. Discounting is an empirical fact, and no economist can question its existence. Doubts arise when a discount rate is applied to a very distant future, especially involving next generations. There are convincing arguments that when taking very long-term decisions, people apply non-constant – perhaps hyperbolically declining over time – discount rates [Dasgupta and Maskin 2005]. But this is difficult to verify empirically. Under these circumstances the decisions are not a matter of efficiency, but equity.

Positive discount rates imply that the wealth of grandparents is given more weight than the wealth of grandchildren, as it can be read in numerous blogs published by economists worldwide (see e.g. Cato-at-Liberty [2006]). Howarth [2009] clearly links this issue to the Precautionary Principle. As people who live now know little about future generations' preferences, equity suggests that considerations based on efficiency (including discount rates confirmed in their own decisions) are not a good base for making policies [Portney and Weyant 1999]. In other words – following the Precautionary Principle – it is better to fail in achieving efficiency than to fail in achieving intergenerational equity.

The ***Subsidiarity Principle*** is another rule that European environmental policy makers are eager to refer to.[24] Its strange name has an old history, and some analysts prefer the American concept of federalism which basically contains the same substance. Subsidiarity (or federalism) means that decisions are made at the lowest level that is appropriate given the nature of a problem. Economists add that 'appropriateness' calls for all externalities to be internalized within the area or group entrusted with decision making in the first place [Oates 2002]. Thus subsidiarity implies, for instance, that decisions on the global climate should be taken by a representation of all countries, on the regional acid rain – by the region affected, and on the noise – by the local community. As a rule, it is unreasonable to expect a higher level of the government to take decisions that can be suitably taken by a lower level.

Identifying the right level requires an analysis of possible externalities. Involving a higher level of the government does not violate the subsidiarity principle, if a lower level can create an externality affecting other constituencies. For this reason, it would be wrong to let a small region decide on water abatement if sewage discharged contaminates the environment outside the region. Apart from externality considerations, subsidiarity is motivated by information and incentives. In order to place the decision-making authority correctly, one needs to identify sources of information required to arrive at a reasonable decision, and check incentives for a truthful disclosure of this information. As a rule, the lower the level, the higher the chances for revealing data necessary for decision making. Consequently economic theory identifies two conflicting tendencies to make subsidiarity work. Because of incentives, decisions should be taken at a low level; however, because of possible externalities, the level should not be too low.

Incentives do not confine to economics. Shifting policy making to a higher level – justified by the externality argument – may deprive the lower level of initiative and involvement and reduce gains from solving the externality problem. The political motivation is at least as crucial for the subsidiarity as the economic one linked to information disclosure. An economic argument to shift the decision making authority to a higher level should be confronted with a psychological one to get the local constituency involved.

An important argument against the Subsidiarity Principle in environmental policies is 'race to the bottom'. There is a risk that jurisdictions may compete with each other for capital and in order to attract businesses will relax environmental requirements. While suitable examples can be quoted from around the world (especially when the jurisdictions do not bear external costs of their decisions), attempts to statistically verify the phenomenon have not succeeded (see e.g. Oates and Schwab [1988] for the USA and Mani *et al*. [1999] for India).[25]

Many governments apply the Subsidiarity Principle (or federalism) in environmental policies. The European Commission acknowledges it in important documents. Hence it is difficult to understand why, for instance, the noise of lawn mowers is strictly regulated by five directives (84/538/EC, 85/409/EC, 87/252/EC, 88/180/EC and 88/181/EC). Establishing a common requirement for many countries must violate efficiency, since the 'averaged' standard is too strict for those who derive low benefits from noise abatement, and too lenient for those who derive high benefits from operating silent equipment. Why has the European Commission supported a policy that is apparently inconsistent with the Subsidiarity Principle? The answer goes beyond the logic of environmental policy. Freedom of trade is another important principle that the European Union affirms. In case there is a conflict between an economic principle and environmental one, the latter yields to the former. While it is true that different countries might adopt different noise standards for lawn mowers to achieve efficiency, such a flexibility would hit the freedom of trade, since the same type of equipment considered legal in one country could turn out to be illegal in another one.[26]

4. Market structure and synergies

It has been known for many years that a Pigouvian tax imposed on a monopolist should be somewhat lower than the one imposed on a price-taker [Barnett 1980].[27] This is because a monopolist reduces its output below the social optimum anyway, so the tax should take it into account. This observation opened a wide area of questions what objectives are environmental policies to address. An ideal solution would be have an array of policies each geared towards a simple problem (e.g. a market failure) with environmental polices directed solely towards keeping environmental externalities. This, however, is an unrealistic outcome, and environmental policy analysts are doomed to seeking so-called 'second best' instruments, i.e. tools that solve an environmental policy problem accompanied by some other source of market imperfection.

The menu of accompanying problems is very wide. It includes equity, innovativeness, and international competitiveness[28], to name the few. In this section we will start with market structure, as the literature on this issue seems to be the best developed one.

Early contributions analyzed a monopoly in the product market. Soon, however, the monopoly assumption was substituted with oligopoly [Katsulacos and Xepapadeas 1995], [Ulph 1996]. Under Pigouvian taxation there are two possible market structure distortions of interest to analysts: the lack of price taking in the output market [e.g. Long and Souberyan 1998] and the lack of price taking in the input market [e.g. Hamilton and Requate 2001]. Marketable permits add possible strategic behaviour in the permit market thus making the number of combinations much higher. There were conjectures that firms may use marketable permits as yet another tool of their competitive strategy. Specifically, the fear was that some polluters might hold unused permits in order to hurt their competitors who needed them [Ryan 1981], [Hahn 1984], [Misiolek and Elder 1989]. The empirical evidence so far has not confirmed this fear in all large permit markets[29]. Nevertheless the issue deserves further research, since regulations in some markets are so complex that non-price-taking behaviour hypothesis cannot be easily rejected [Montero 2009, p. 23-25]. Katsulacos and Xepapadeas [1996] provide a useful overview of models used in analyzing polluters' behaviour if the price-taking assumption is relaxed.

Another important area of research is at the interface of environmental policies and innovation policies. Ignoring the 'second-best' philosophy would yield a conclusion that the two areas need to be addressed separately. Nevertheless real-life policies are charged, and are expected to deal, with several issues simultaneously. Hence the question is whether a suitably tailored environmental policy could help achieve competitiveness.

It has been observed that environmental friendly technologies – such as e.g. producing electricity in wind turbines – become cheaper quickly once the technology is promoted by appropriate policies. Offering subsidies for renewable energy sources, in excess to what is justified by environmental externalities, may be considered inefficient. The hypothetical argument in favour of subsidies, however, is based on current selling prices that are not competitive with 'traditional' technologies. These high prices are likely to decrease in response to the adoption of the new technology [Irwin 1998]. Thus a proactive subsidy policy can help to speed up a departure from the old technology while improving the social welfare [Hansen *et al*. 2003], [Jespersen 2004][30].

This conclusion is consistent with conventional cost-benefit analysis, if future production costs are predicted to fall, and when alternative policy scenarios are considered. The practical implementation of this approach is difficult and can be easily abused by lobbyists who may exaggerate the expected pace of cost reduction.

Environmental subsidies are obvious as instruments to promote innovations, but the concept of a *Best Available Technique* (BAT) is by far more popular among policy makers. BAT – a concept sanctioned in the European Union by the so-called IPPC (*Integrated Pollution Prevention and Control*) Directive 96/61/EC[31] – calls for applying best available techniques in key several economic sectors. According to its proponents, BAT forces firms to speed up the diffusion of environmentally friendly technologies with the ultimate goal of protecting the environment and lowering the cost of these technologies. Critics point out that identifying respective BATs for various industries (more than 50,000 installations in Europe) is subject to bureaucratic procedures under the auspices of the European IPPC Bureau in Seville, which issues so-called BREFs, binding guidelines for environmental inspectors who issue pollution permits. The procedures are notorious for heavy lobbying by firms which posses technologies that appear to be more environmental friendly than others and see them as an advantage over competitors [Lévêque and Nadaï 2000]. Its disadvantage over the subsidy alternative is the lack of a clear estimate of environmental benefits expected as a result of a given guideline.[32]

The 'Porter hypothesis' [Porter 1991], [Porter and van der Linde 1995], i.e. a claim that tough environmental regulations promote rather than reduce economic well-being and growth, has been subject to numerous analyses since the 1990s. The theoretical argument behind is that pressing firms to comply with environmental regulations triggers innovativeness that ultimately pays back with economic benefits higher than costs.[33] An important question needs to be raised from the outset. Is the regulation contemplated in the hypothesis an efficient one? If yes, then the assertion becomes trivial by definition, at least with respect to welfare. If no, then it is basically an empirical question, since it would be difficult to *a priori* determine that higher-than-efficient cost is outweighed by non-environmental benefits resulting from technological progress.[34]

Of course, both proponents and opponents of the Porter hypothesis refer to numerous examples to support their views. Economic history abounds in 'win-win' innovations that improve technical efficiency and protect the environment [Desrochers 2008]. Yet there are some important theoretical arguments too. The key motive is the increased efficiency in a firm subject to tough regulations. Opponents, however, point out that opportunities for the increased efficiency exist even in the absence of regulations. In other words, firms can always voluntarily adopt a new technology if it is profitable. A rigorous verification of the hypothesis must rely on statistical analyses where a sufficient numbers of observations with and without regulations can be compared. Such exercises were carried out several times, but the evidence is non-conclusive [Wagner 2003]. The results depend on many factors. First, they are sensitive to whether countries, industries or individual firms are considered. Second, they depend on how 'stringency' of regulations is measured. In many studies this has been simply represented by a dummy variable. Attempts to measure it more precisely may revert the results [Brännlund and Lundgren 2009].

One of the main areas for potential synergies is environmental improvement and economic growth. Apart from innovativeness, environmental protection, i.e. enhanced use of the natural capital, is expected to contribute to growth in the aggregate output. Endogenous growth theory indicates that the relationship is more complicated and synergies may not exist [Rosendahl 1997].

In 2000-2005, the interface between environmental policies and innovativeness was analyzed in the European context specifically. In 2000 the European Commission launched the so-called Lisbon Strategy, *to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion* [European Parliament 2000]. This ambitious goal was in 2001 amended with four specific environmental objectives[35]:

- Protecting the global climate by slowing down fossil fuel consumption,
- Conservation of natural resources (by both protecting nature and recycling wastes),
- Mitigating transport pressure,
- Improving public health.

Soon it became obvious that the goal is unrealistic, since the European Union failed to approach any of the targets set. As a result, a commission was established to update the original documents. The result of its deliberations – the so-called Kok report [European Union 2004] – reduced the environmental agenda to one guideline out of the total twenty-one. The relevant guideline 14 reads:

> *To encourage the sustainable use of resources and strengthen the synergies between environmental protection and growth*

More specifically, it calls for:

- Internalising external costs
- Increasing the energy efficiency
- Support for environmentally-friendly technologies, developed in ETAP (*Environmental Technology Action Plan*)

Environmentalists were upset by reducing the 'environmental dimension' to synergies between the environment and economic growth.

Many believe that such synergies are possible indeed. Nevertheless trimming down the 'environmental dimension' of the Lisbon Strategy to what is consistent with the 'growth-and-jobs' philosophy is a significant departure from policy objectives discussed in Section 1 above. The guideline 14 is obviously sound. The problem environmentalists have with it is that it is surrounded by twenty other guidelines which unambiguously convey the message what is really important. As it is impossible to conceive policies that are fully consistent with all guidelines – just for statistical reasons – emphasis must be diverted from the environment to more immediate concerns.

Besides, hints that supplement the guideline reflect a philosophy which directs the attention to specific policy instruments that are not necessarily preferred for the overall policy objectives. Attaching high priority to energy efficiency reflects the priority assigned by the European Commission to climate change, but can be questioned on the grounds that a number of other important areas are thus omitted. An even more controversial detail is ETAP. By putting emphasis on technical solutions, non-technical (e.g. social, organizational etc.) ones are excluded from the attention of policy makers. Ultimately this may compromise environmental policy objectives. Looking for synergies is understandable, perhaps even commendable, but it should not lose the main purpose of environmental protection.

5. Environmental Tax Reform

Environmental Tax Reform (ETR) has been an important slogan at least since the early 1990s. Economists have taught that 'traditional' taxes, such as VAT (Value Added Tax), PIT (Personal Income Tax), CIT (Corporate Income Tax), and excise are inefficient; they hurt economies by providing disincentives for what is otherwise beneficial. At the same time, taxes need to be collected, since there is no other way to finance public goods that governments are expected to provide. Hence the idea to substitute inefficient 'traditional' taxes with Pigouvian ones which – according to the economic theory – correct market failures, i.e. improve rather than mess up economic efficiency. This is the idea behind ETR.

Despite the rhetoric, little has been done to implement the ETR in the European Union and elsewhere. First of all, it is not clear what payments can be considered proxies for Pigouvian taxes. In some countries there are pollution charges whose rates are set below Pigouvian levels. Technically they cannot be named Pigouvian taxes, but their purpose is close to the idea. Therefore they are covered by the ETR accounting. In addition, there are some VAT and excise taxes imposed on fuels and transport. Even though they are not related to environmental externalities directly, they can be considered 'Pigouvian' on the grounds that fuels are linked to environmental disruption, no matter how advanced is their combustion technology, and also transport hurts the environment in many ways. Consequently they are included in the ETR accounting as well. Following these clarifications, one can refer to the statistical records that indicate a very minor shift in the composition of taxes in Europe. Roughly 7% of all tax revenues in the European Union came from environmental taxes in 2007 (a smaller share than in 1999) [European Union 2009, p. 317]. For most countries this percentage share varies between 5% and 9%. Denmark is an outlier with more than 12%, due to unusually high transport taxes.[36]

The question thus can be raised why ETR does not progress. An explanation that governments behave irrationally is not a very convincing one. A much better insight into the problem is gained by referring to the concept of 'self-erosion' of the tax base. The 'traditional' taxes (VAT, PIT, CIT) do not erode their bases, because people will always purchase goods, consumers will always wish to earn money, and firms will always enjoy revenues. In contrast, Pigouvian taxes are levied in order to reduce an externality. Hence their effectiveness implies erosion of the tax base.[37] An effective pollution charge motivates for abatement and hence reduces charge revenues. Of course there is a possibility to increase charges, but – apart from political problems – this may cause their rates to exceed the Pigouvian level and therefore violate efficiency.

Natural resource taxes (virgin material charges) face the same risk. If a sufficiently high charge is levied on a substance then it will be substituted by something else. Even water which is indispensable for life can be fully conserved. If a water charge becomes sufficiently high then water abstractions can be reduced to zero, so that everything will flow in closed circuits. Every material can be conserved in this way. The only good which cannot be fully conserved is energy. The Second Law of Thermodynamics explains that energy cannot flow in closed circuits. At the same time, energy is a proxy for environmental stress. Thus energy taxes are the only environmentally motivated ones that do not erode their base fully.

It is no surprise that energy and transport are the most important components of environmental taxes in many countries. Except for Denmark and the Netherlands, pollution and natural resource tax revenues are very low. Transport provides several times higher revenues, but it yields to energy which gives three quarters of the total environmental tax revenues in the European Union [2009, pp. 316-323].

Introducing or augmenting environmental taxes is usually presented as budget-neutral, i.e. not leading to higher government revenues. The essence of ETR is to substitute some of the existing inefficient taxes with Pigouvian ones. It is important to appreciate that because of the 'self-erosion' risk, no Minister of Finance is likely to support an overwhelming ETR, a one that implies drastic reductions in VAT, PIT, or CIT rates. According to a realistic expectation of the European Environment Agency[38], just doubling or tripling the current 7% share of environmentally-related taxes would make a 'radical' ETR. As a result, some 'traditional' tax revenues could be lowered thus making the labour or man-made capital cheaper for entrepreneurs.

Whatever is presumed about environmentally related taxes, applies to auctioned marketable pollution permits as well. If the initial allocation of permits is free, then the government does not receive any revenues. Yet if the initial allocation is auctioned then the proceeds can substitute for taxes and the question of budget-neutrality arises. It should be noted that popular ideas to use a portion of such proceeds to earmark in order to finance some government expenditures violate budget-neutrality and have little theoretical justification.

Environmental taxes work against excessive externalities, and this is their first 'dividend'. In addition, thanks to the budget-neutrality principle, they are likely to provide additional jobs, and this is their 'second' dividend. This is how the 'Double Dividend' hypothesis was created [Bovenberg and de Mooij 1994], [Goulder 1995].[39] It has received an enthusiastic support from environmentalists. Economists turned out to be more sceptical. The efficiency-enhancing potential of Pigouvian taxes is demonstrated on the grounds of a partial equilibrium model. The proof does not allow for checking impacts of the revenues collected and other taxes lowered. A general equilibrium model is needed to assess all the consequences, including indirect ones. So-called tax interaction effects – e.g. effects caused by the fact that various taxes may affect each other's outcomes – are responsible for the ambiguity.

Analyses have been carried out for many years, but they are not conclusive, because of strict formal assumptions required in order to trace welfare effects of changing the tax structure.

Nevertheless, from the very beginning it was clear to economists [Goulder 1996], [Goulder *et al*. 1998] that the second 'dividend' crucially depends on the other taxes that environmental ones are to (partially) substitute for.[40] In particular, it cannot be universally assumed that lowering non-environmental taxes brings more jobs.[41] Empirical findings are non-conclusive too, but they tend to confirm that 'green' policies do not harm jobs and economic growth [ILO 2009]. Overall they have resembled very much what emerges from the Porter hypothesis debate.

ETR enthusiasts keep identifying additional dividends. There are triple and quadruple dividend hypotheses. In addition to jobs, environmentally-related taxes are supposed to bring other benefits, such as increased innovativeness, reduced poverty and so on. Unfortunately, there is little theoretical and empirical support for these claims.

An important reason why environmental taxes are difficult to assess competently is that their analysis requires a general equilibrium approach. Building an adequate model is a complex task. To get an overall understanding of how a tax may affect people's welfare, one needs a simple general equilibrium model with, say, two taxable goods (one 'clean' and one 'dirty'). In order to understand distributional implications, one needs to introduce at least two households (one poor, and one rich). However, to obtain results that are politically meaningful, one needs to construct a general equilibrium model with many goods, many consumers and many firms. Then profound statistical and computational problems emerge, so that a distinct category of 'Computable' General Equilibrium (CGE) models was introduced. They were initially applied to international trade problems [Shoven and Whalley 1984], but increasingly they have been used for assessing environmental policies [Bergman 2005]. Building a CGE model is a difficult task, and consequently, there are few such prototypes available. Most of environmental policy assessments in the European Union take advantage of the CGE model GEM-E3 developed at the National Technical University of Athens (e.g. European Union [2008d, p. 40]). Industries who oppose planned EU regulations can challenge this model as inaccurate, but it is hardly possible to substitute it with a reliable alternative.

It is worth noting that ETR helped to elucidate a number of public finance problems. First of all, it has emphasized the issue of budget-neutrality. A typical ETR study declares budget-neutrality and discusses what 'traditional' taxes can be substituted or lowered by environmentally-related ones. Very often labour taxes and social security contributions are lowered as a part of ETR[42] thus alluding to the second 'dividend' obtained through jobs. ETR debates have also emphasized that efficiency and equity can be separated. The former is served by reducing welfare losses caused by distortionary taxation. The latter is affected by a specific choice of taxes to be lowered.

Another important issue is the political economy of ETR. The self-erosion argument – an understandable concern of Finance Ministers – explains why governments in general hesitate to embark on ambitious ETR trajectories. On top of that there are specific arguments why some constituencies are more likely than others to advocate for ETR. The best understood relationship is between density of population and fuel efficiency of cars: the higher the former, the higher the latter too [Evill 1995]. It is then easy to predict that in economies which are more densely populated and therefore better saturated with fuel efficient cars, willingness to tax energy is greater. A comparison of the sparsely populated United States (low fuel taxes) with densely populated Italy (high fuel taxes) illustrates the point, but serious empirical research is necessary in order to clarify whether indeed spatial distribution of economic activities co-evolves with fuel taxes.[43]

Attempts at implementing ETR have also brought to analysts' attention that Pigouvian taxes may have a direct impact on consumers' welfare. For instance, imposing a charge on energy affects households' disposable incomes. Therefore ETR opponents raise objections based not only on CGE modelling, but also on the grounds that such taxes – efficient as they are in reducing externalities – may reduce consumers' surplus [Halvorsen 2009].

ETR debates illustrate tendencies to combine environmental policy with other objectives. Isolated from other considerations, environmental policy could have been addressed perfectly by Pigouvian taxes or equivalent instruments without any deeper analyses. One of the reasons that we have an ongoing debate is that people expect environmental policies to serve a number of other purposes as well.

6. Environmental policy in the 21st century

When the United Nations addressed environmental policy for the first time in the 1960s, the scale of pollution was unprecedented. In many parts of the affluent world people were exposed to toxic substances in unambiguously harmful doses. Constituencies agreed to abate, since immediate benefits clearly exceeded costs of actions taken (in most cases). In the most affluent countries all the drastic pollution cases were solved successfully over the next three decades. Local environmental disruption is still a problem – especially in less affluent regions – but the problem lost much of its academic appeal. Climate protection emerged as the major environmental policy problem.

Climate protection is not a typical environmental problem for several reasons. First it deals with a perfect public good; greenhouse gas emissions mix perfectly in the atmosphere and damage from climate disruption may affect everybody, irrespective of individual abatement actions. Second, it includes significant delays; no generation will enjoy the benefits of its own actions. Third, damages (from not acting) and benefits (from acting) are highly uncertain; some people use the uncertainty to postpone acting while proponents of aggressive climate protection use it otherwise. Fourth, equity considerations play a key role in protection scenarios [Kverndokk and Rose 2008]; the rich and developed are responsible for past accumulated emissions, while the poor and less developed (i.e. those who cannot afford protection activities) are likely to be worst hit by the anticipated climate change.

Climate protection issues challenge not only the world politics, but also established theories. The perfect public good nature of the problem calls for an international concerted action and makes the Subsidiarity Principle irrelevant. Yet it seems to be very difficult to arrive at a global solution, and perhaps progress will depend on unilateral and voluntary commitments of a limited number of actors. Time delays make the issue of discounting of paramount importance.[44] The very different conclusions of Nordhaus and Stern[45] to a large extent depend on the discount rates adopted, and the debate enlivened economists' interest in discounting. The uncertainty made the Precautionary Principle a key reference for decision making, while numerous analysts claim that the principle itself does not have a scientific base. Finally, equity concerns put the Polluter Pays Principle to a serious test. On the one hand, the polluters include the 19th century agents whose emissions contribute to the current carbon dioxide concentration in the atmosphere; can we make them pay? On the other hand, effectiveness requires that relatively worse-off newly industrialized countries, like China, India, and Brazil, accept ceilings for their growing emissions.

Climate concerns do not resemble 'traditional' environmental ones. The latter were much more self-evident and constituencies supported policies whose beneficiaries were themselves. Climate actions will affect generations to come who do not have as yet a political representation. Therefore they can be justified only on the grounds of intergenerational equity which is a rather abstract concept. Here economists have referred to Rawls' [1971] concept of 'justice as fairness' which emphasizes that no party is *a priori* privileged. Specifically to the intergenerational context it was applied by Page [1977].[46] There have been numerous attempts to make the climate policy appealing, but it is certainly much more abstract than a policy aimed at achieving benefits that can be enjoyed directly by the people who implement it.

Nevertheless concepts and measures are introduced which help people to become aware of what is the impact of their activities on future generations. An average high school graduate is aware that cars are classified according to their carbon emissions now, as they used to be according to their mileage per gallon in the past. Corporations and industries are expected to calculate their carbon emissions, and some are expected to take reduction commitments. More educated citizens are familiar with the concept of 'carbon footprint', and sometimes modify their behaviour so as to let it shrink. The so-called rebound effects[47] can make their efforts totally ineffective in the short run, but in the long run 'carbon awareness' may grow, and preferences may change.

Exceptional challenges triggered demand for non-standard policy instruments. Attempts at lowering carbon dioxide emissions without a proportional decline in energy consumption let governments promote renewable energy sources, such as wind, biomass and photovoltaics. They produce less external damages than fossil fuel combustion, but their high private costs do not let them compete commercially. A standard policy prescription would be to introduce Pigouvian taxation in the form of pollution charges on fossil fuels or subsidies for renewables. Alternatively, one can introduce 'green certificates' forcing users to buy a specified portion of energy from renewable sources. In fact, many governments applied such tools in order to reduce their economies' reliance on fossil fuels. The common characteristics of these instruments is the reference – at least theoretically – to the damage cost caused by fossil fuels.

Some governments, however, chose to experiment with an alternative tool called 'feed-in' tariff. The latter means that a public budget is obliged to purchase renewable energy at a price which covers the cost of its production.[48] The difference between this instrument and 'traditional' ones is that the subsidy the former provides for renewables is related to the production cost rather than externality avoided. Only rich governments can afford such a policy, but on top of environmental benefits, a 'feed-in' tariff lets achieve additional objectives. The Danish government helped its wind industry to become the world leader [Söderholm and Klaassen 2007]. Despite that, in 2003, it departed from 'feed-in' tariffs towards less costly instruments – such as 'green certificates' – which also seem to be more consistent with requirements of the European electricity market.[49] Nevertheless governments seem to prefer instruments that provide subsidies to those who do not create negative externalities rather than levy taxes on those who create such externalities, even though the dynamic efficiency of subsidies is questionable.

Climate protection policy brought two 'low-carbon' energy technologies to the spotlight: renewable and nuclear. Both are characterized by high investment and low operations costs. This alone suggests that both technologies fare better under low discount rates. On top of that, nuclear power plants require high decommissioning and waste disposal costs which, however, are postponed well into the future. This, in turn, makes the nuclear technology more attractive economically if the discount rate is high. Discount rate dilemmas are relevant for all long-term decisions, including investment in infrastructure and natural resource conservation, but climate policies made them of interest to the media in the 21st century.

Even though there are convincing empirical arguments for high discount rates, their application to the very long run problems violates equity concerns many people have. This made economists question the time consistency principle – one of the underlining rules of economic analysis. The principle states that preferences with respect to an outcome do not change, whether they are stated now or in the future.[50] Dasgupta and Maskin [2005] explained why it is perfectly 'rational' to apply different rates to time periods of different lengths. Moreover, the longer the time horizon of the analysis, the lower the discount rate is likely to be appropriate. This helps to justify the rationale for a climate protection policy. With respect to the 'renewable *vs.* nuclear' dilemma, it tilts the balance of arguments against the latter (since renewables do not involve high decommissioning costs), but more specific conclusions require more information on the costs of both technologies in the very long time horizon.

While rich developed economies seem to favour low discount rates which explains their concern about climate disruption damages expected in the distant future, developing economies – likely to favour high discount rates – put emphasis on short run considerations. Some analysts looked at co-benefits, 'ancillary' benefits, of climate protection as a motive for developing countries to undertake climate protection. The logic of co-benefits links damages from climate disruption avoided in the long-run (of secondary importance to constituencies in developing countries) to immediate damages avoided as a result of climate protection activities (of primary importance to those constituencies). To the extent climate protection calls for constraints on the consumption of fossil fuels, it also leads to constraints on 'traditional' pollution resulting from combustion. This pollution, including sulphur dioxide, particulate matter, volatile organic compounds etc., affects the population's health, causes corrosion, and reduces harvests. Contrary to carbon dioxide, the 'traditional' pollution is not as global in its scope; its impact largely confines to the neighbourhood of an emission source. The benefits from its abatement are not fully private, but they are not as public as the benefits from carbon dioxide abatement.

Some analysts hope that co-benefits will help developing countries accept climate protection policies. Indeed, if there is a climate protection project with a low cost then demonstrating co-benefits may make it attractive also for a constituency not interested in long-term considerations. While this true, there are few such projects [Zylicz and Czajkowski 2009]. In general, co-benefits are too small in order to motivate developing countries to undertake climate protection at the scale that is justified by the public good nature of the problem.

Climate protection policies have elucidated relationships between efficiency, effectiveness and equity. As most of the anticipated growth in carbon dioxide emissions will come from developing countries, effectiveness calls for ceilings to be adopted by these very countries. On the other hand, equity requires that developing countries – having suffered from the dominance of rich industrialized countries and planning to replicate their economic welfare – do not pay for abatement fully. Luckily there is a way to reconcile these expectations in accordance with economic efficiency. The way can be best explained with the help of marketable permits [Daly 1992]. The total sum should be motivated by effectiveness criteria, while the initial allocation among countries – by equity. A similar outcome can be achieved by a combination of other instruments, but the analysis is particularly instructive if it refers to marketable carbon dioxide permits.

Assuming for simplicity that one looks for a fair allocation of the present global sum of carbon dioxide emissions, let us put $x_1+...+x_k = 32$ billion tonnes. The more difficult task is to suggest an allocation principle. One sometimes referred to is that based on population. Assuming further that the number people in the world is 7 billion, this gives an approximate 'allowance' of 4.5 tonnes per person. Then the allocation principle can be simply $x_i=4.5L_i$, where L_i is the population of the *i*th country. This would leave the European Union, and the United States with allocations much below their current emissions; China – more or less at the level of the current emission; and other developing countries much above. The tradability of permits would then imply a flow of wealth in the direction that is consistent with popular equity convictions.

There are alternative allocation principles conceivable. Some analysts advocate for distributing carbon dioxide emissions in proportion to GDP. This would leave the European Union and the United States with a much higher allocation than under the previous scheme. However, it drastically violates the 'common but differentiated responsibility' philosophy, since those with higher GDP should not assume lower but rather higher abatement commitments.

An often recalled allocation principle is a per capita cumulative allowance. This means that countries which emitted a lot in the past have already used-up (or even exceeded) their allowances. While the equity of this scheme seems reasonable, it may trigger disputes that are difficult to resolve. For instance, countries that were included in the Prussian Empire may not feel responsible for emissions in 1914-1918 which were caused by the production of chemical weapons. Or Americans may object to taking into account their emissions from the early 1940s, as these were partly motivated by helping Europeans to fight against the Nazis. Once again, the 'Polluter Pays' Principle turns out to be less obvious than many analysts claim.

The best service to solving long-term investment and environmental – including climatic – problems can be done when effectiveness, efficiency and equity are studied explicitly and given the high weights they deserve. It is counter-productive to insist on a single criterion, e.g. ethics, to address complicated issues that are multifaceted by their nature.

Several decades of research on environmental policy objectives made many of their characteristics better understood, if not clear completely. Despite that, there are many unresolved problems that need to be addressed not only out of scientific curiosity, but also because of policy relevance.

There is a broad and open-ended area of interest in second-best instruments. It originated from early analyses of Pigouvian taxation in imperfectly competitive markets. One approach could be to let environmental policy instruments aim only at their environmental targets assuming that other considerations will be addressed independently. Reality confirms that these other considerations are often left unattended and environmental economists cannot ignore the fact that their prescriptions must solve problems in the second-best world and compensate for, rather than exacerbate, existing distortions.

Linked to this is the interface of environmental and other policies' domains. The Porter hypothesis is perhaps the best known example of such an interface. A one-page manifesto published in a non-economic journal has mobilized dozens of economists to undertake serious research to check if, indeed, making environmental regulations tougher helps societies to achieve non-environmental goals. Empirical research to validate the hypothesis indicates acute gaps in statistical reporting systems which do not permit easy analyses of what is a 'tough' regulation and what is a competitive success.

The success of the Danish wind turbine technology poses yet another question. High requirements imposed on the power sector, supported by generous budgetary subsidies resulted in unprecedented advances in the Danish renewable energy technology, making their firms world leaders. Of course, it would be difficult to successfully replicate this strategy elsewhere, but the valid question remains whether it makes sense for environmental policies to push beyond what is justified by immediate benefits. And if the answer is 'yes', then what constituencies can be relied on in order to commit significant public resources to projects whose *raison d'être* is not obvious at the time of the commitment?

Serious policy studies rely on general equilibrium models since partial equilibrium approach proves insufficient and even misleading. Some governments have models which are calibrated to mimic actual economies, but the quality of these models is insufficient. They are professionally constructed, but the level of aggregation is too high to guarantee robust conclusions. On the other hand, building a CGE model is time-consuming. Therefore it would be useful to develop a methodology of sensitivity analyses to determine whether a given CGE model is specific enough to support the conclusions necessary for a specific policy.

As apparent from climate disputes, discounting is of paramount importance for choosing adequate policies. There exists a large body of empirical research on how to estimate discount rates for various types economic decisions involving several years. However, in the case of climate protection the time horizon involved is much longer. Economists admitted recently that the longer the perspective, the lower the appropriate discount rate. This opened a new area of research that could not co-exist with the time consistency principle. Empirical estimation of discount rates appropriate for a long period of time, exceeding a single generation, is a challenge that calls for an innovative approach.

In the first decades of the 21st century environmental policies will be shaped by climate protection considerations. In this section we offered some remarks on what are the salient theoretical problems. In broad terms, they indicate how the fundamental concepts of effectiveness, efficiency, and equity relate to each other when the optimal supply of an international public good is to be determined. These problems are important not only for academic reasons, but also because they imply high costs, likely to influence people's well being.

Even though vivid climate policy disputes helped to elucidate a number of theoretical problems, much is to be researched. The subsequent list of topics outlines a research agenda as emerging from the present review.

- Climate policy is a complex long-term issue. Setting specific objectives requires that concerns about economic growth are resolved. To the extent that in an open economy growth is linked to firms' competitiveness, the question boils down to the Porter hypothesis; so far its empirical verification has been ambiguous and more studies are called for. An even greater challenge is to determine macroeconomic consequences of 'decarbonization'. Successful 'de-coupling' stories, i.e. stories of GDP growth coupled with declining energy consumption, are important but correlations need to be robust and supported by convincing causal explanations.

- Once easy choices on abating 'traditional' pollutants have been done, policy dilemmas become much more complex. It is not sufficient to address isolated problems and take care of cost-effectiveness. Contemporary issues call for general equilibrium modelling with emphasis on indirect relationships which link areas that are commonly considered independent.
- Long-term analyses are impossible without discounting. Once economists understood that time consistency can be abandoned, a new demand for empirical studies on discount rates depending on the time horizon has emerged. The question is a complicated one, since – for obvious reasons – revealed preference methods have limited applicability, and stated preference ones require building rather sophisticated scenarios. So far little has been known of how people discount when distant future is concerned.
- Heated policy debates are motivated by diverging views on future production costs. Existing studies confirm that the price of energy derived from renewable sources falls once new technologies are widely adopted and dispersed. Nevertheless the pace of this process is uncertain and depends not only on the amount of installations deployed. It also depends on instruments. Governments experiment with alternative instruments such as 'feed-in tariffs', 'green certificates' and others. All of them have some environmental merits, but policy makers are concerned with non-environmental objectives as well. Consequently, deeper understanding of mechanisms behind price trajectories is urgently needed.
- Climate policies are heavily influenced by intergenerational equity considerations. However, international equity is also of paramount importance. As demonstrated by UNFCCC tribulations, countries may have very different views on who and how is supposed to pay for greenhouse gas abatement. These views have a decisive impact on both effectiveness and efficiency of climate policies. At the same time they seem to be under-researched.
- ETR is both fashionable and appealing academically. While popular arguments refer to partial equilibrium arguments, its political success ultimately depends on how well indirect consequences are traced. In this paper it was argued that energy is the only good not affected by the self-erosion of the tax base. Despite this, it is conceivable that in various countries for limited periods other goods or 'bads' can be included in the ETR.
- Even though climate has been most widely acknowledged as the global public good, biodiversity is also an important example. Its studies bring yet another dimension to economic analyses. Biodiversity protection is always closely linked to the welfare of local populations. Therefore 'Subsidiarity Principle' is perhaps much more relevant in this case and should be researched.

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Notes

[1] A report of the Secretary General, adopted by the General Assembly of the United Nations on May 26, 1969. See United Nations [1969]

[2] Larry Summers had to leave the World Bank, following his famous memo on the efficiency of allocating pollution where its social cost is low was leaked to the press in 1992. See Summers [1991].

[3] It can be often justified that benefits TSB tend to be concave with respect to a certain variable, while costs TSC tend to be convex. Then the difference TSB-TSC=TSB+(-TSC) is concave, since a convex function multiplied by -1 is concave (and *vice versa*), and the sum of two concave functions is concave. Finally, an internal maximum of a concave function is where its derivative vanishes, i.e. where (TSB-TSC)'=0.

[4] Hanley [1992] offers a wide discussion of problems linked to the monetization of environmental costs and benefits, concluding that the alternative of leaving them unmonetized is not attractive at all. Even health benefits resulting from environmental improvements can be monetized [Dickie and List 2006].

[5] See also P Ekins *et al*. [2003].

[6] H. E. Daly [1990] suggested a reasonable non-depletion criterion for the aggregate natural capital by positing that exhaustible resources are extracted at the pace justified by investment in renewable substitutes.

[7] In many regulations there is a provision to waive environmental requirements 'for imperative reasons of overriding public interest, including those of a social or economic nature'; see e.g. the *Natura 2000* legislation, especially European Union [1992], art. 6.4. In transition economies policy makers and their constituencies take it for granted that the welfare of the poor has a priority over nature protection.

[8] The agreement, known as the 'Berlin Mandate' (see United Nations [1995]), frees roughly 160 non-Annex I countries from taking emission reduction commitments. The UNFCCC was signed in 1992.

[9] This applies especially to effectiveness. There are several concepts of equity used by economists (see e.g. Rawls [1971], Sen [1970], and Roemer [1996]). Nevertheless – perhaps except for Rawls – none of them has had a major impact on how environmental policies are analyzed by economists. At the same time, empirical observations – including economic experiments [Bruce and Clark 2010] – confirm that people attach to equity as high a weigh as to efficiency.

[10] There is an alternative definition of a Pigouvian tax with marginal external cost affecting marginal social benefits: MSB=MPB-MEC, where MPB stands for *marginal private benefit*. The two definitions are fully equivalent.

[11] See Sterner [2003], pp. 181-184.

[12] The sum of payments made by all the plants is $\sum_i e_i PT(q_i) = \sum_i (e_i MEC(q^0)(q_i - q_{thr})) = MEC(q^0) \sum_i (e_i (q_i - q_{thr})) = MEC(q^0) (\sum_i (e_i q_i) - \sum_i e_i q_{thr}) = MEC(q^0) (\sum_i (e_i q_i) - q_{thr} \sum_i e_i) = MEC(q^0) (\sum_i e_i q_i - (\sum_i q_i e_i)/\sum_i e_i)(\sum_i e_i)) = 0$.

[13] Coase's critique of the Pigouvian prescription has also helped to clarify definitions of externalities [Vatn and Bromley 1997].

[14] Typing 'Coase curse' in Google returns thousands of entries, some of them including analyses of the Coase theorem impact on environmental policies. Some economists (e.g. Görres [2003]) claim that the Coase theorem is responsible for environmental policy failures. The argument is questionable, but it is characteristic for numerous policy debates.

[15] In the non-linear case, achieving cost-effectiveness requires that permit transactions are accompanied by tax payments, although the taxes are directly derived from permit prices [Zylicz 1994].

[16] It is true, however, that in most applications, thresholds are assumed to be zeroes (as in the original Pigouvian formula).
[17] Shrestha [2001] develops specific conditions under which one instrument is preferred over the other. Caplan [2006] provides yet another example of theoretical research linking the 'prices vs. quantities' debate to inter-jurisdictional competition.
[18] Directive 2003/87/EC which establishes CO_2 emissions trading rules for firms in the European Union. See European Union [2003]
[19] The EU ETS has been researched extensively. See e.g. Ellerman and Buchner [2008], and Convery [2008].
[20] The original OECD [1972] guidelines seemed to favour the narrow understanding, but the broad one was present there too. A later document [OECD 1989] makes it absolutely clear that polluters should take responsibility for whatever harm their accidental pollution may cause.
[21] The Danish government has followed a somewhat different pattern applying environmental subsidies widely. Its policies in this respect were justified by promoting innovativeness [Georg *et al*. 1992].
[22] Identifying carcinogens resembles witch-hunting; if a doubt arises, there is no empirical method of acquittal. The only conclusion justified is to confirm the initial conjecture.
[23] The debate culminated in a seminar at the Yale University in 2007 [http://www.ycsg.yale.edu/activities/events_video.html]. Many scientific journals produced special issues to address the debate (e.g. Special Topic [2008]).
[24] It was included in the Treaty of Rome, and then reaffirmed – as Article 5 – in the Treaty of Lisbon [European Union 2008b].
[25] See, however, also a critical assessment of this literature [Blair 2008].
[26] Huhtala and Samakovlis [2002] explain how environmental policy harmonization violates efficiency when local economic conditions are different, and Pearce [1998] observes in general that environmental policy of the European Union failed to take advantage of systematic cost-benefit analyses.
[27] In fact, the rule is more complicated and the tax depends on how the externality is related to the demand [Ebert and von dem Hagen 1998]. The practice of critically assessing the Pigouvian prescription from the point of view of market structure dates back to Buchanan [1969].
[28] It should be noted that constraints imposed on protectionist trade policies triggered interest in Pigouvian taxes that serve both environmental and trade purposes [Batabyal 1994]. Withagen [2007] reviews literature on how environmental policy instruments affect international trade under imperfect competition.
[29] Such as e.g. the US sulphur dioxide [Tietenberg 2006] and EU carbon dioxide permit markets [Ellerman and Joskow 2008]. Nevertheless the European market was very far from price-taking. Vigorous forward trading (buying at a zero discount rate) firms' own future permits was clearly motivated by a perspective of a large supply of unused permits from firms who could not trade in the first 18 months of the scheme due to some administrative obstacles.
[30] Fees and Muehlheusser [2002] develop a theoretical model of using a 'clean technology' to achieve non-environmental objectives. Klaassen *et al*. [2005] provide detailed statistical results of analyses how the production cost in windmill electricity production decreased in several European countries. The results depend on econometric specification of learning curves, but the overall conclusion is robust: industry costs revealed a strong downward trend over the last two decades. Gerlagh *et al*. [2009] derive theoretical rules for optimum subsidy schemes to trigger innovation related to renewable electricity. David and Sinclair-Desgagné [2010] argue that – under plausible assumptions – subsidies should be paid directly to producers of the 'clean technology' rather than polluters who adopt it.
[31] Later codified as the 2008/1/EC Directive [European Union 2008c].
[32] Also on theoretical grounds, BAT regulation implies less innovativeness than alternative instruments [Bansal and Gangopadhyay 2005]. Nevertheless there are empirical results suggesting that BAT does improve technical efficiency of firms [Larsson and Telle 2008].
[33] The hypothesis was objected to by economists who did not want to acknowledge that economic agents might fail to achieve efficiency without government intervention (see e.g. Bromley [2003]). Nevertheless it triggered substantial theoretical research focused on alternative strategies for technology adoption and diffusion. See e.g. Xepapadeas and de Zeeuw [1999] and Kriechel and Ziesemer [2009] to appreciate the seriousness of analytical endeavour aimed at analyses of the Porter hypothesis.
[34] Van der Vlist *et al* [2007] offer such an empirical test for the Dutch horticulture. By demonstrating that more strictly regulated firms improve their technical efficiency, the test confirms the Porter hypothesis in this case.
[35] By the end of the 2009, however, the original 'environmental dimension' of the Lisbon Strategy virtually disappeared; the WWW site [http://europa.eu/eur-lex/en/com/cnc/2001/com2001_0264en01.pdf] referred to from the Gothenburg Summit document is not available any more.
[36] Nevertheless many countries list 'environmental' taxes that were introduced with an explicit purpose of lowering labour and income taxes. See e.g. Brännlund [1998].

[37] The self-erosion of the base calls for tax rates to be increased thus leading to an even stronger future erosion or the lack of fiscal stability that governments would like to avoid. See Romstad and Folmer [2000] for more detailed analyses.

[38] In seminars and presentations prepared by the European Environment Agency [Gee 2009], a target of 15%-30% of tax revenues coming from environmentally-related items by 2030 is considered 'radical'. There are no serious plans of eliminating VAT, PIT and CIT in the course of ETR.

[39] It should be noted, however, that the need for a more careful inference was noted by Sandmo [1975] much earlier.

[40] Some studies indicate that even the 'first dividend', i.e. environmental improvement, is not guaranteed by the ETR [Bayindir-Upman 2004].

[41] The conclusions are even more ambiguous when overlapping-generations models are analyzed [Chiroleu-Assouline and Fodha [2005].

[42] This was the idea of the German ETR, some of which was actually implemented [Greenpeace and DIW 1997]. Full budget-neutrality was to be achieved by adequate reductions in social security compensations.

[43] Sterner [2007] explains how fuel taxes co-evolve with spatial development patterns.

[44] Discount rates are explicitly present in economists' debates. Nevertheless they are also implicit in any political discussions on long-term choices.

[45] See section 3 above.

[46] Pearce [1987] extended it to justify fairness with respect also to non-human species.

[47] A rebound effect takes place when an improvement of a product's feature (e.g. its energy efficiency) promotes an increase in demand, which in turn causes the final effect to differ from earlier estimates. The first economist to notice this was Jevons [1865], who rightly predicted that improved energy efficiency of the steam engine will initiate a wave of new applications, leading to increased coal extraction. Rebound effects are studied, and the outcomes are varied [De Haan *et al*. 2006], [Sorrell 2007].

[48] Of course there are some provisions that protect tax payers from purchasing energy at arbitrarily high prices. Nevertheless the tariff is supposed to finance 'legitimate' costs of production for a specified period of time, in specific locations, and/or for specific technologies.

[49] There are also theoretical arguments (based on general equilibrium modelling) that subsidies for new 'environmentally friendly' technologies do not necessarily improve economic welfare [Kverndokk *et al*. 2004].

[50] Constant discount rate illustrates the time consistency rule, since $(X/(1+r)^{K})/(1+r)^{N}=X/(1+r)^{K+N}$. In other words, the present value of X K+N years from now can be calculated as the present value of X K years from now and then as the present value of this intermediate result (K+N)-K remaining years (i.e. N years) from the intermediate moment. Of course, the formula does not work if there are different discount rates applied to the periods N+K and K.