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Aspects of burden-sharing of common action to mitigate climate change

by

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PREFACE

This paper discusses some problems in comparing estimates of national costs of reducing emissions in order to mitigate climate change. The paper constitutes a part of a NORCE-project funded by the Norwegian Ministry of Foreign Affairs that aims at analysing the possibilities of achieving agreements on burden sharing of a common action among OECD-countries to reduce emissions of greenhouse gases. The other contributions to the project are “Burden sharing in climate policy: Methods and principles for the estimation of abatement costs” by Per
Political Feasibility of burden sharing between OECD countries in climate negotiations” by Leiv Lunde at FNI. I would like to thank Leiv Lunde, Per Schreiner and Asbjørn Torvanger for valuable comments to the paper.

1 Introduction

UN's Framework Convention on Climate Change (FCCC) recommends industrialized countries to stabilize their emissions of greenhouse gases at the 1990-level. This is to be understood as an advice, and is not binding in any sense. At a later stage of the political climate process, those industrialized countries that have ratified the Convention, may, however, be subject to binding commitments. In this perspective, the cost of such commitments will have to be evaluated against the expected benefits from reduced effects of global warming. From a single country's point of view it is also of vital interest to compare their own contribution within an agreement with that of other countries. This highlights the problem of burden-sharing.

This paper discusses some aspects of burden-sharing in the light of a widely accepted point of departure, namely the "the polluter pays principle". This principle implies that the burden on each country corresponds to their contribution to the problem of global warming. It must be noted that the FCCC does not approve such a principle of burden-sharing. The FCCC states that the industrialized countries have a main responsibility of taking appropriate action to curb climate change. Therefore, the polluter pays principle as a principle for burden-sharing may be a reasonable point of departure only within the group of countries listed in Annex II of the FCCC (OECD except Mexico).

The second strongly simplifying assumption we shall make is that the national targets will be related to the emissions of carbon dioxide, only. We admit that this may oversimplify the problem of burden-sharing, but it may be defended from the fact that most of the economic literature about climate change till now has focused on the control of CO_2. From an economist's point of view, this radically facilitates the analysis, because the emissions then may be charged directly through some economic activity, such as the consumption of gasoline. Within the context of this paper, it may also be defended as a background for the discussion of several studies of the national costs of climate policies (see Schreiner (1995))

Nevertheless, it turns out that a comparison of costs between nations is quite difficult. Direct comparability requires an "ideal" world which we are far from are likely remain

also in the future. On the other hand, it is clear that costs estimates based on observations give indications of the burden for each nation if a common action is agreed upon. A formal examination of cost measures may therefore be helpful in order to say how representative an estimate over “climate costs” of one nation is, compared with estimates for other nations. This paper identifies some aspects to be considered for such an analysis, and discusses their importance. All countries that negotiate a common action to mitigate climate change will be concerned about the importance of these aspects from their own country. It is important to find a commmon apprach to be applied for the parties for dealing with them.

The paper is organized along the following line of thought: On the basis of the assumptions given above, a uniform carbon tax across all the participating countries would provide a cost effective solution to the polluter pays principle if all the countries were parts of a perfect competitive market. In a more realistic setting, it is more likely that the parties will aim at an agreement of emission quotas. Alternatively, therefore, one could allocate quotas according to the reduction of emissions from a uniform carbon tax. Nevertheless, such an allocation would probably not meet the polluter pays principle, and could be regarded as unfair for a number of reasons discussed in Section 2. The expected cost of measures taken to mitigate climate change could therefore provide relevant information for the initial distribution of emission rights. Section 3 discusses the national cost of a climate measure. There are many alternative definitions of this cost, and one cannot claim that one particular definition is the best one. Under some simplifying assumptions, however, the net national product (NNP) may apply. It turns out difficult, if not impossible, to arrive at a measure that is comparable between nations. NNP will nevertheless be used as a reference for the discussion. In Section 4 we relax some of the assumptions about perfect competitive economies in order to study optimal climate measures in “second-best” economies. It is shown that an enforcement of the polluter pays principle in a strict meaning of the concept is not possible. Conflicts between the aim of cost effectiveness and fairness may thereby occur.

2 On the significance of national costs for the evaluation of burden

The traditional economist's answer to the problem of sharing the burden of a common action to mitigate climate change is to levy a tax on the sources of the environmental problem, in this case emissions of CO_2. This is rather simple, namely charging the use of fossile fuels for the emissions of carbon. In this section, we will concentrate on the control of CO_2, but will emphasise that the possibilities for controlling the problem of global warming, and thereby the question of burden-sharing, goes beyond that. Other gases contribute substantially to the concentration of greenhouse gases in the atmosphere, such as CH_4 and N_2O. Moreover, an alternative to emission reductions is to enhance the sinks of CO_2, for instance by afforestation, in order to decrease atmospheric concentrations.

In order to attain a fair sharing of burden across countries, provided that CO_2 is the only subject to control, we will assume that a uniform carbon tax is introduced in all the participating countries. Each government keeps the revenues from the tax and redistribute them according to some optimality criterion. Although this rule does not always lead to the first-best social optimum (see Hoel (1993)), we will refer to it as a "fair" or ideal principle of burden-sharing. This interpretation is in accordance with the polluter pays principle. Within this simple framework, therefore, there is no need to worry about the cost of the measure: Those who pay the most is those who pollute the most, which is fair enough.

Under full certainty, there is a one to one relationship between a given carbon tax and the quantity of reduction in emissions. As an alternative, therefore, the uniform tax may be expressed in terms of reduced emissions in each country - the emission target. Then emission permits could be distributed across countries according to the reductions resulting from a uniform tax. There may be several reasons for expressing the target in terms of permits rather than a uniform tax. One reason is that fossile fuels are heavily taxed in many countries for other reasons than the carbon emissions. These include charges for other pollutants such as NO_x and lead, and charges for road use (see Section 4). It would therefore be difficult to control whether carbon tax imposed by an agreement between many countries substituted previous taxes or actually added to the system of previous taxes.

Another reason, noted by Weitzman (1974), is that quantity control may be more efficient than price control if the costs of mitigation are uncertain. Figure 1 illustrates Weitzman's argument in a simple manner. Costs are measured along the vertical axis and emission reductions along the horizontal axis. The costs of mitigation are uncertain. They will either turn out low, in which case they are represented by the *C*-curve or they will turn out high, according to the *C**-curve.

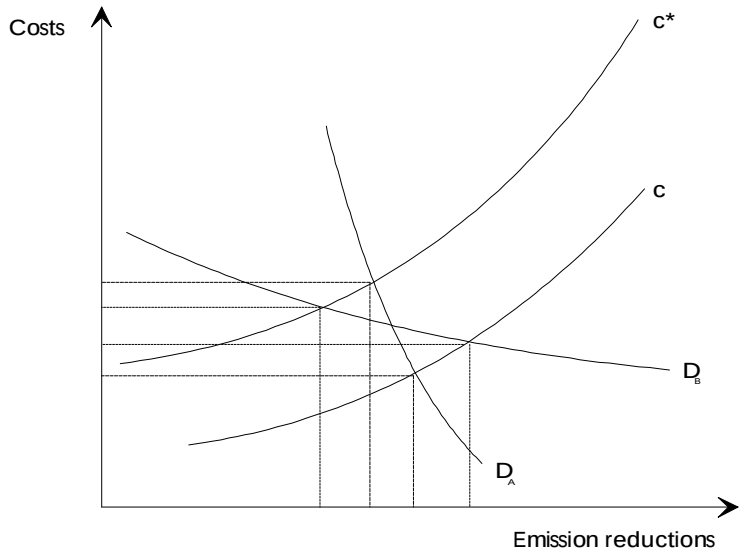

Figure 1. Quantity and price effects of control under uncertain costs.

Whether to impose charges or to use tradeable quotas in order to control the emissions depends on the willingness to pay for emission reductions. A steep (inelastic) demand curve for emission reductions (D_A-curve) means that one is quite determined with respect to the quantity to reduce, and is not so concerned about the cost of reducing the emissions. A gently sloping (elastic) demand curve (D_B-curve) means that the cost of the target is rather decisive for how much to one would like to abate. In the latter case, therefore, it is more important to keep track of the costs of the emission reduction. A tax would therefore apply. In the former case the most important objective is to reduce emissions, and quotas would be the most efficient. In the diagram this is seen from the fact that an inelastic demand curve "transforms" the main

part of the uncertainty to costs, wheras elastic demand mainly results in uncertain emission reductions.

It is not straightforward to say whether the demand curve for reductions in the emissions of CO_2 is "elastic" or "inelastic". The answer will probably differ across countries, too. However, there are many indications that an international agreement on common action to mitigate climate change will aim at assessing quotas rather than common charges. Apart from the problem of controlling charges, it is a fact that the OECD countries actually express their intentions regarding climate policy in quotas, not in charges. Moreover, FCCC urges industrialized countries to keep their future emissions of greenhouse gases on a 1990 level, i.e. it relates to quotas. Although this is not a legally binding commitment for the signatory parties, it may be interpreted as a signal about the formulation of such commitments in the future. In the context of this paper, however, it sufficies to emphasise that there are good reasons to expect that common actions across countries to mitigate climate change will include targets expressed in quotas rather than in tax-levels.

In principle, therefore, a distribution of quotas according to the expected reduction of emissions following a uniform carbon tax would meet reasonable requirements to burden-sharing ("the polluter pays"). This applies, however, only within a perfect competitive static world, which means that unless the negotiators have perfect foresight, the distribution of emission-rights would have to be renegotiated continuously. In a more realistic perspective, therefore, even a “perfect” initial distribution of emission rights, would imply different constraints on different countries. There are many reasons for this.[1] Below, three important objectives are commented:

Future economic growth. The expected future rates of economic growth differ considerably among nations. As emissions increases along with economic growth, the anticipated abatement would have to be higher in countries with a high rate of growth than in countries with a low rate. At the same time, the expected growth rate may be

[1] Clearly, these include the assumptions made in the Introduction, namely that the “polluter pays principle” should serve as the principle of burden-sharing, and that mitigation of climate change is restricited to the emissions of CO_2 .

related to the present level of development. Many less developed countries are expected to attain high economic growth compared with presently developed economies. In that case the principle imposes a higher burden on less developed countries, and thereby runs counter to an explicit requirement in the FCCC, namely that industrialized countries have the main responsibility to take actions against global warming. Also if one focuses Annex II countries of the FCCC (OECD except Mexico) the same problem is likely to arise, because a similar pattern of economic growth and living standard is expected between the rich and the less rich countries within this region.

Economic structure. Different compositions of economic sectors cause differences in emissions growth even if the general economic growth is the same. A fixed target corresponding to the emissions in some base-year will encourage restructuring and substitution towards less emission-intensive activities. Some countries may manage such changes at rather low costs, for instance if one can continue production of the same products by slightly changing technology. The changes will be more painful if a more comprehensive and extensive restructuring of the economy is required. Such changes may imply temporal unemployment and require that the country will have to purchase additional emission rights.

Uncertainty. There is uncertainty as to how future national emissions will develop. As the emissions are decisive for the level of abatement and for the future demand for permits, the abatement costs will also be uncertain. This uncertainty will cleary differ between countries because the economic structure and thereby the energy intensities differ and because secondary benefits of reductions in greenhouse gases, for instance due to reductions in pollutants, vary. Thus, countries even at approximately the same level of development, e.g. the OECD-countries, will have to adapt to different degrees of uncertainty. The uncertainty cleary has a cost.

Even in its simplest form, therefore, emission permits cannot be distributed without a comparison of national costs. The remainder of this paper discusses some of the problems related to the assessment of the national costs of an emission target when the aim is to compare burdens across countries. Unfortunately, it is not very conclusive.

Etimates of national costs are nevertheless likely to be used in negotiations of burden-sharing of a common target for a climate policy. Thus, we find it important to discuss what kind of national characteristics that may be hidden in such estimates, and how these characteristics may influence measurements of national costs differently.

Recall finally, that we have had a perfect competitive economy in mind when discussing burden-sharing so far. This means that climate measures should be undertaken where the costs are the lowest in a global sense in order to satisfy the polluter pays principle. Thus, to minimize the cost of a quantity target, the country subject to the target should not only seach for measures within its own borders, but should also consider to finance measures in other countries. This is the idea of "joint implementation", which is mentioned explicitly in FCCC. As pointed out by Bohm (1994), joint implementation can be regarded as a step towards a global regime of tradeable permits. Tradeable permits implies that an initial emission target is levied on each country. Under the fixed amount of total allowable emissions, each country may, however, add to their own allowable target by buying permits or subtract from their allowable target by selling permits at market prices.

Tradeable permits is a well-known solution to the problem of common properties, first proposed by Gordon (1954) and Scott (1955) for the allocation of fishing rights. The critical problem with tradeable permits is how to assess the initial distribution of quotas. Since there are no legal authority for managing global problems, the parties will have to agree on the distribution of initial emission permits. This is where the problem of burden-sharing comes in. Each party will be concerned about their own anticipated cost of keeping their target relative to the costs imposed on the other parties.

3 The cost of a climate policy.

By costs, one usually refer to the price paid for a commodity or a service. Switching energy use from coal to gas, for instance, requires investments. To a company, therefore, the cost of such a switch includes the investment cost and the added cost of

buying gas instead of coal. The cost at a national level may deviate from the cost at the micro level. The fuel-switch implies less demand for coal and more for gas. This has impacts on the profitability of the extracting activities, which again affects import and export, the investments may replace other activities, and so forth. To assess the national cost of such a switch, therefore, one needs to evaluate all direct and indirect economic effects of the measure.

As illustrated in Box 1, the micro-approach (“bottom-up”) may give significantly different estimates of the cost than the macro-approach (“top-down”). Since the "top-down" assessment aims at a description of the reallocations caused by a policy measure, it should therefore be preferred for the estimation of national costs. In many cases, it may be impossible to describe technical specifications of given measures sufficiently within general macroeconomic models. In such cases, “bottom-up” analyses provides necessary support to the “top-down”-models. The main conclusion is, however, that the cost of the climate policy should be measured in terms of the national cost, e.g. the change in the national product.

When speaking about the burden-sharing of a climate policy it is important, therefore, to state when, if at all, a reduction in the national product can be interpreted as a cost. Second, it should be analysed how comparable such losses in different countries are. The immediate reaction would be that even to the individual who was only concerned about material goods, a loss in the national product might be of less importance if the

Box 1 "Top-down" and "bottom-up" assessment of climate costs

Figure 2 displays the production feasibilities for a country producing two different goods, x_1 and x_2. The concave curve represents the maximum combinations of output, and shows the maximum increase in the output of one good by a given reduction in the output of the other. Perfect market equilibrium occurs at the point where relative price, p^A is tangent to this curve, i.e. point *A*. Assume that due to environmental concerns, x_2 has to be reduced from x_2^A to x_2^B. One approach for assessing the cost of this policy would be to value the physical change at present prices, i.e. $p^A (x_2^A - x_2^B)$. This is often called the "bottom-up"-approach because one focuses the physical change on a micro level and evaluates the cost as if prices were constant. The total national cost is arrived at by adding up the costs of all changes evaluated at the micro level.

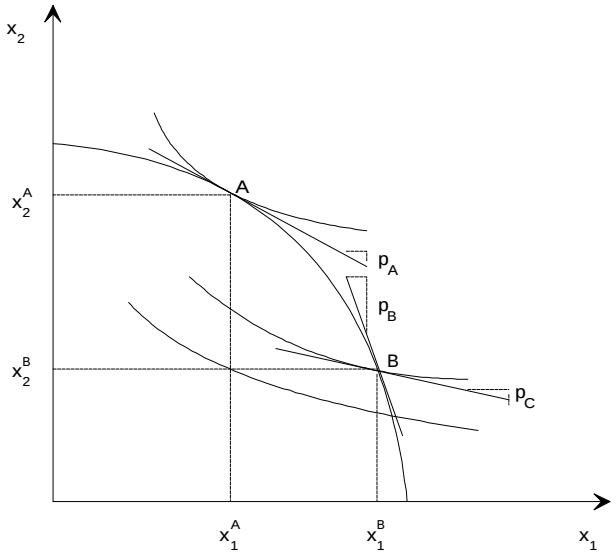

Figure 2 "Top-down" and "Bottom-up" assessments of national costs

However, Figure 2 shows that if the national product is given at the point (x_1^A, x_2^B), it would be possible to increase the production of x_1 to x_1^B, and maintain the environmental policy goal for the production of x_2. In other words, a "bottom-up" assessment would exaggregate the national cost of the environmental policy. This is demonstrated very clearly in Håkonsen and Mathiesen (1993). Many bottom-up studies comes up with lower estimates then usual in top-down studies. This is, however, due to different assumptions, e.g. about technological feasibilities.

However, it is far from evident that the economy approaches the curve again, rather than some point between x_1^A and x_1^B after the tax has been imposed. This concerns the choice of measure, which we will return to in the next section. In the meantime, it suffices to assume that the first-best solution is arrived at in some way. The question is then in what way the value of the reallocation, or loss in the national product, can be interpreted as the national cost. By reference to Figure 2, this loss can be written as $(x_1^A + p_A x_2^A) - (x_1^B + p_B x_2^B)$, where p_A and p_B denote the prices of x_2 relative to x_1 before and after the reallocation.

consumption level were sustained. Moreover, it is questionable whether a loss of consumption is equivalent to the burden. This relates to the dispute about how able economic theory is to explain welfare changes, see e.g. Sen (1979). The discussion is clearly relevant in this context, but will not dealt with any further here. In other words,

we take the point of view that changes in national economic figures give a sufficient representation of welfare changes.

To restrict the scope of the discussion, therefore, we will concentrate on changes in burden measured in terms of aggregate consumption. In a seminal article, Weitzman (1976) showed that the net national product (NNP) had an intuitive interpretation of a welfare measure, namely as the (hypothetical) constant level of consumption for an infinite time horizon that would give the same total utility as the feasible future optimal consumption path. Thereby, NNP represents an intertemporal aspect as well as an arbitrary (conventional) welfare function of consumption. Weitzman emphasises that in order to give NNP this interpretation, the national wealth must include everything of relevance for production. This has lead Hartwick (1990) and Mäler (1991), among others, to extend his result to include corrections of NNP for changes in the stock of natural resources, as the conventional NNP makes no distinctions between rent from the extraction of resources and the return on capital.

These extentions are due to the fact that the interpretation of NNP as a welfare measure applies only if all the factors of relevance for production are included in the concept of the macro production function. If an emission target represents a measure taken to limit the future production feasibilities, it might also represent a (negative) factor of production. However, for the NNP to measure the (constant) consumption level that would be necessary to achieve the same total utility as the optimal feasible consumption path, the factors that affect production have to be allocated over time in order to maximize the present value of consumption. A target for the emissions will usually not be a result of intertemporal optimization. The target will therefore imply a restriction on the use of certain goods and services, which prohibits maximum welfare, defined as the present value of a future consumption stream. Thus, welfare in this sense cannot be defined by NNP, and conversely, a change in NNP cannot be interpreted as the cost. Brekke (1994) makes this point by showing that Weitzman's interpretation does not apply if public policy is time dependent. An emission target implies that policy measures must be initiated dependent on the emission-sources, which become time-dependent under the optimization.

In addition, Asheim (1994) and Brekke (1994) points at several other conditions that has to be fulfilled for NNP to represent a measure of welfare. The most important of relevance for the discussion of burden-sharing are:

(i) The interpretation applies only for closed economies (Asheim (1992)). Open economies are partly subject to exogenous prices. This means that the value of the production in a country is determined also from the supply and demand in countries with which they trade. Accordingly, the value of the production is dependent on "exogenous" prices,[2] and so is also the optimal allocation between consumption, investment and trade. For the consumption-investment ratio to be optimal in Weitzman's model, the relative price between the two has to be determined independent of exogenous prices. This is of particular importance for small, open economies, such as the Norwegian. The effect on NNP from a uniform carbon tax in all the OECD-countries, for instance, cannot be analysed independent of the effects on the world energy market.

(ii) For the welfare interpretation to apply, NNP has to be measured in terms of consumption units (as *numeraire*). Such a measure is usually not observed (see Brekke (1994)). An approximation might be to deflate NNP by the consumer price index. This is, however, highly unusual. NNP in real prices is usually deflated by an overall price index for the gross national product (GNP). Thus, if the investment prices increase compared to the consumption prices, the real NNP deflated by conventional indices will be underestimated compared to the appropriate welfare measure.

(iii) The NNP interpretation refers to the solution of an intertemporal optimization of the consumption-saving decision. Thus, it requires that the tax revenues are redistributed optimally in the economy, i.e. between consumption and investments. This may, however, be a rather awkward task, and the optimal redistribution will differ from country to country. Jorgenson and Wilcoxen (1994) show that the measured loss in NNP as a result of a carbon tax is

critically dependent on how the revenues are redistributed. As an extreme case, they examine the case where all the revenues of the carbon tax are put into investments. This results in an increase in the NNP in the long run as a result of the climate policy.

(iv) In countries where a large part of the economic activity originates from extraction of non-renewable resources, the interpretation of the NNP is once more problematic (Asheim (1992)), especially if the products from the extraction are exported. Again, the welfare significance of the NNP is weakened. An additional problem, of significant importance for Norway, is how NNP actually is measured in the national accounts. Resource revenues can be approximated as the revenues in excess of a normal remuneration on capital. Aaheim (1994) shows that this is not to be interpreted as the income from natural resources. Income should correspond to remuneration on the wealth of natural resources, which is not estimated in the national accounts. For resource-rich economies, therefore, the measured NNP may be far from the welfare measure defined by Weitzman.

In other words, it is hard to find a justification for using NNP as an indicator for the burden of a climate policy, even if the measures under consideration meet important requirements for cost effectiveness. NNP (or rather GNP) is, nevertheless, the most frequently used indicator for measuring the national cost of climate policy. Few will disagree that the value of future consumption is a more appropriate measure of the burden, although not a perfect one. In particular, it is difficult to defend a climate policy at all if welfare depends on the consumption alone. One extention of Weitzman's analysis, therefore, would be to include global warming in the welfare function to see whether, and under what conditions, NNP still might apply as a welfare measure. For practical purposes, such an extention would imply that one had to deal with the aggregation of climate and consumption, which is difficult. It is therefore worthwhile to analyse in what ways NNP differs from the welfare measure applied above as a point of departure for studies of burden-sharing.

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[2] Exogenous prices are prices that are independent of changes in one nation’s economy, such as

The main question of interest is how and to what extent the burden, here defined as the reduction in the value of future consumption resulting from a given policy measure, differs between two countries that face the same loss of NNP as a result of a climate policy. The discussion above indicates factors of importance, such as the openness of the economy, inflation rates, the ability to impose cost efficient policy measures and redistribute additional public revenues efficiently and the extent to which the economy depends on natural resources. A more detailed analysis is required in order to estimate how these factors affect different countries.

To conclude, we may say that NNP in itself has no immediate relevance for the evaluation of the burden of a climate policy. However, a more appropriate measure, the present value of an optimal consumption path into infinity, measured in consumption units, is seldom available. Moreover, such a measure will also be subject to discussion about the choice of a discount rate. Rather than calculating these values, therefore, one may analyse the burden for different countries by studying how a violation of the assumptions required for NNP to apply as a welfare measure affects different countries.

4 The burden of emission charges

According to basic economic theory, the appropriate tax level to achieve a cost-effective climate policy is equal to the marginal social "damage" of the externality. The damage is the sum over the marginal individual disutilities of the externality. This tax is usually called the Pigouvian tax, after Pigou (1920). It reflects the total social effect of the externality. If the tax is not imposed, only the negligible individual effect of the externality would be reflected in the market price, and the individuals would not have any incentives to adjust their market behaviour in accordance with the social effects of this behaviour. For instance, every car driver knows that he causes pollution and enhanced risk for accidents, but he will not reduce these social impacts notably by

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prices which are determined in the world market. Oil prices provide an example for most countries.

limiting his own driving. By embedding the social damage in the price of driving, the Pigouvian tax enforces a socially optimal behaviour by the individual driver.

However, this illustration rests on some strong simplifications. It assumes that we can start from a socially efficient point (the first-best solution) and end up in another efficient point on the production possibility curve in Box 1. Moreover, the policy instrument has only one task, to adjust for market distortions due to the externality in question. For the result to apply as an advice in practical policy making, several modifications of the model are necessary. Monopolies will obstruct the assumption of the first-best solution, and the effect of the externality of an economic activity is quite different from the utility of the commodity or service produced from the same activity. Baumol (1972) showed, however, that "taken on its own grounds, the conclusions of the Pigouvian taxes are, in fact, impeccable". In other words, externalities need not change the character of the goods. It suffices to attach correct prices to them if one can identify the externalities they cause.

Suggestions about higher taxes are usually not popular, even if the reasons for introducing them are acceptable. This may have several reasons. One is that taxation of certain goods has an effect on the income distribution. Another reason is that the government may be accused of hidden motives, namely to enhance the revenues rather than trying to solve environmental problems. In other words, governments have a record, and they have to take their total revenues into account when designing a policy of taxation. Furthermore, they are themselves monopolies and are

Box 2 "First-best" and "second-best"

For the production to increase from x_1^A to x_1^B in Figure 2, Box 1, the environmental authorities must initiate appropriate measures. As pointed out in Box 1, the initial point *A* was established because the relative price line p_A was tangent to the production possibility curve. From the demand side, the combination of x_1 and x_2 is chosen at the point where the welfare indifference curve is tangent to the price line. From the figure it appears that the maximum attainable welfare is achieved also in point *A*. Equilibrium is thereby established. To bring the economy down to point *B* the authorities need to face suppliers and demanders with different prices, namely p_B for the suppliers and p_C for the demanders. They can manage this by imposing a tax on x_2 equal to $(p_C - p_B)$. The market behaviour will then bring both supply and demand down to point *B*, provided that the tax level is correct. In that case, the required reduction in x_2 is obtained together with cost effectiveness, the "first-best" solution. These solutions are usually unsuitable for practical advices. In most cases, the economy is subject to several constraints not taken into account in Figure 2. These constraints include social costs, governmental budget constraints, etc. Optimization of policy instruments under such constraints is often called "second-best" solutions, and implies that a combination of x_1 and x_2 on the production possibility curve is practically infeasible.

able to manipulate market prices and quantities to some extent. A first-best approach to governmental policy is therefore usually inappropriate as a description of the economy. In a realistic analysis of optimal policy it is necessary to include a broader set of restricitions to policy making. This gives rise to theories of the second best (see Box 2).

Charges are paid for the use of fossile fuels in all OECD-countries. A carbon tax to curb climate change will therefore add to existing fuel taxes, for instance charges for road use. The question then arises by how much. Should the cost of the social damage (the Pigouvian tax) simply be added to the previous taxes on fossile fuels, or should all rates of fuel taxation have to be recalculated? Sandmo (1975) shows that an externality tax, e.g. a carbon tax, may correctly be added to the previous taxes. A recalculation, for instance in order to tax complementaries or subsidise alternatives, is not supported.

However, the optimal level of the carbon tax turns out to depend on the previous tax system. The marginal cost of social "damage" constitutes only a part of the additive term. The carbon tax will also depend on the marginal rate of substitution between private and public income: The higher the marginal value of private income compared with public income, the less is to be added because of the concern for carbon emissions. On the other hand, one additional term of taxation occurs. This term includes indirect taxes imposed for other reasons than carbon emissions, for instance to collect revenues. The second-best social price of a commodity or a service with an externality may therefore be written as:

Marginal production costs
+ Revenue taxes
+ Social disutility of carbon emissions adjusted for revenue effects.
= Social price

Newbery (1992) studies the case where gasoline is taxed to obtain revenues needed to build and maintain roads in addition to the concern for carbon emissions. He gives an intuitive explanation of the adjustment of the additive carbon tax term. The aim of the carbon tax is to reduce the demand for fuels. To the extent that this is the effect of the

tax, also the revenues from other taxes previously charged fossile fuels are reduced. This loss will have to be compensated by enhancing the carbon tax compared to the Pigouvian tax.

Another important effect of externality taxes is thay they affect the income distribution. Sandmo (1975) shows that if all individuals have equal preferences but differ in productivity (i.e. their income differs), the total tax on fuels (revenue-motivated as well as the carbon tax) will also depend on the income of those who contribute to fuel consumption. This is rather intuitive when comparing with the above result, since it is easy to accept that the marginal rate of substitution between private and governmental income is dependent on the income. A high carbon tax may be compatible with a moderate total fuel tax if the contribution to fuel consumption from low income groups is high. This is because the elasticity of substitution between private and govermental spending tends to be high for low incomes and low for high incomes. In this case, therefore, a higher share of the total fuel tax should origin from the carbon tax term.

What are the implications of these results for burden-sharing of climate policy? In the previous sections we have interpreted the loss in the NNP as a reference for the evaluation of the burden. We have made no direct link to NNP here, but may take the burden to be the reduction in NNP following a uniform carbon tax across countries. We disregard uncertainty for the moment. Thus, the burden from an emission target assessed from the emission reductions of a uniform carbon tax is equivalent to the corresponding reduction in NNP. In order to interpret the results reported above in the light of burden-sharing, we first need to clarify how to understand a uniform carbon tax. It was noted that the optimal carbon tax consists of two terms, one including the Pigouvian tax (social “damage”), and one referring to the loss of governmental revenues following the carbon tax. In order to be globally optimal, the uniform carbon tax across countries has to refer to the “first-best” Pigouvian tax. Then, the burden of the tax can be analysed in the light of the necessary change in the optimal total fuel tax within different countries. The compensation term will then vary across nations as some nations need to compensate a higher govermental loss than others. This may for instance apply to countries with relatively high expenses on roads and other modes of

transportation. A uniform Pigouvian tax across nations will therefore tend to imply heavier burdens on such countries.

One may negotiate a compensation for the differences in burdens by forcusing the change in total fuel tax rather than the Pigouvian tax term. To equate the burden among all the countries, the point of reference would be that the increase in the total fuel tax was to be equal in all countries. Sandmo (1975) shows in this case that if high income countries contribute to a high share of fuel consumption and low-income countries are most worried (suffer the most) about global warming, the change in the total fuel tax would tend to be high and vice versa. Thus, with high-income "polluters" and low-income "pollutees", the introduction of a uniform increase in total taxes to mitigate climate change would imply a relatively high burden on all countries. It is usually assumed, however, that environmental concerns are given a higher weight the higher the income is. A high share of fuel consumption in high-income countries would therefore tend to exist along with a high concern for global warming. This moderates the required increase in total fuel tax arising from a common target, because the compensation-term in the additive carbon tax would be relatively low.

One important aspect of these results is that there is no sharp distinction between "polluters" and "pollutees". As mentioned previously, one argument in favor of a uniform carbon tax is that it meets some requirements for justice, namely that the polluter pays. This argument is hereby weakened. However, a uniform Pigouvian tax term can not be regarded as "fair", because some countries will have to compensate more of its loss of revenues than others. In the second-best world, therefore, there may be conflicts between the repects to fairness and cost effectiveness when trying to assess emission quotas on the basis of uniform carbon taxes.

4 Conclusions

Before common action to curb climate change can be negotiatied, the participating countries will be concerned about their own burden of an agreement. One reason is to assure themselves that the action is worth the effort. Another is whether or not they

have to pay a fair share of the total costs. Burden-sharing concerns the latter problem. In this paper we have discussed burden-sharing from a highly simplified point of view, namely that emissions of CO_2 is the only subject to control, that the burden can be interpreted as the social economic cost, and that this cost should be distributed according to the polluter pays principle. Ideally, the "fair" cost of a climate measure could then be estimated as the reduction in NNP resulting from a uniform carbon tax. Thus, one did not have to concern about the cost, it would suffice to agree on the level of the uniform carbon tax.

Even from this simplified point of departure several problems related to burden-sharing occur. One problem is that agreements are likely to be negotiated in terms of emission quotas, not in terms of a tax. Except for highly stylized illustrations, it will be impossible to set quotas that corresponds exactly to the reduction of a given tax. Moreover, this "imperfection" is likely to increase over time. Thus, an evaluation of the national cost of an agreement would still be of relevance, also for an examination of burden-sharing. It is diffcult to establish a proper measure of national costs that is comparable between nations. Rather than searching for the perfect measure, however, one may use the conventional measures, e.g. the net national product, and analyse properties of the different economies in the light of a principle for burden-sharing.

If the national emission quotas are distributed according to the anticipated reduction in emissions from a uniform carbon tax, the cost in terms of the resulting reduction in NNP could serve as the "reference-burden". In general, it is important to emphasise that while costs measured in terms of NNP is derived from current observations, its welfare interpretation relates to a problem of intertemporal optimization. Thus, if the conditions for economic development embedded in the current economy changes, the welfare interpretation of NNP no longer applies. For instance, the welfare effect of a change in NNP in a small open economy may be significanly different the same change in a closed economy. Thus, burden-sharing has to be considered in the light of how open the economies of the participating countries are, and in what direction an expected change in world markets will affect each economy.

Observed national product in economies dependent on the extraction of natural resources is often biased as an welfare-indicator, partly because NNP does not account for the depreciation of natural resource stocks. A particular attention should therefore be paid to oil exporting countries, because the effect of a limitation of the use of fossile fuels has an effect on the income distribution between countries. What this implies for burden-sharing is not discussed here, and will partly depend on how the burden should be distributed between consuming countries and producing countries. The income distributional effect turns this into more than a question of the pulluters pay principle. Moreover, it was shown that discrepances between the development of consumer price indices and NNP-price indeces give rise to differences between changes in NNP and welfare. This could, however, be chequed out rather easily.

To compare the burden of a common action to mitigate climate change, one should also consider other costs or benefits incured by the climate measures. These include secondary environmental benefits such as the reduction in pollutants resulting from lower consumption of fossil fuels. Such effects may, however, also be related to the effect on governmental revenues from a carbon tax. The carbon tax will affect the revenues needed to maintain other public tasks related to the use of fossil fuels, such as road maintanance. The need for compensation of this loss may differ considerably between countries.

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