REPORT

A Flexible Pollution Tax

Preliminary Research Investigation

For NUTEK

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Executive Summary

This report outlines preliminary research and analysis into a flexible pollution tax proposed by Anders Höglund that could be used to help put a price on some forms of pollution. The tax provides a mechanism by which pollution can be reduced in an economically efficient manner. The basic principle for the mechanism is that the pollution abatement should be cost efficient, not only concerning the distribution between the measures of abatement but also concerning the speed by which the total amount of pollutant emissions is reduced over time. The concept combines those efficiency advantages of a pollution tax with an innovative way of setting the level of the tax using the decisions of individual firms acting on an open market. Höglund's tax does not consider damages to the environment when setting the level of the tax. Rather, the level of the tax is dependent on the development and adoption of cleaner technology. Höglund's tax also subjects polluting firms to short-term volatility. This is in fact driving firms to buy and sell pollution contracts on market in order to hedge their abatement decisions.

The research undertaken here involved contributions from several important agencies and institutes including; **Nutek** (project's financier), Miljödepartementet, Naturvårdsverket, Näringslivsdepartementet, Gothenburg University, Elforsk, Energimyndigheten. IVL hosted two reference group meetings where the concept and research results were presented and dicussed. The valuable input obtained from these organisations served to strengthen and improve the analysis.

Further research and analysis of Höglund's flexible pollution tax policy is required if its advantages and disadvantages with respect to other pollution policies are to be understood and its viability as an environmental policy is to be established.

Contents

1 Introduction

Finding an effective way to price externalities is a continuing challenge faced by policy makers. This paper outlines some preliminary research and analysis into a flexible pollution tax that has been proposed as a mechanism to price some forms of pollution. Putting a price on pollution helps society shift the way it allocates resources and a successful policy should help reduce the unsustainable use of "common"[1] goods or services. The concept builds on the idea of a Pigouvian tax[2] that is set, not by a centralised authority, but by actors in a marketplace.

Höglund's tax could provide a mechanism by which pollution can be reduced in an economically efficient manner. The principle of the Höglund tax is that the pollution abatement should be cost efficient, not only concerning the distribution of the measures of abatement between the different sources of pollution but also concerning the speed by which the total amount of pollutant emissions is reduced over time. The concept combines those efficiency advantages of a pollution tax with an innovative way of setting the level of the tax using the decisions of individual firms acting on an open market. The proposed concept does not explicitly consider the cost of environmental damage, rather the the level of the tax is mainly dependent on the alternative cost of pollution abatement and the cost of development and adoption of new technology. A natural consequence of the proposed market pricing of the pollution tax is that firms will be subjected to a genuine uncertainty concerning the tax level in the future. This, however, is one of the conditions for a functioning futures market. Environmental taxes have often been subject to criticism due to their redistributing effects in the economy but the nature of an effective environmental tax is, by definition, that it has to impose a redistribution of resources on the economy. It is possible to design the pollution tax so that the accompanying redistribution of resources will have long term beneficial effects on the whole economy. Pollution taxes which do not have long term positive effects on, firstly the human capital and, secondly, the natural capital and the real capital should be avoided.

[1] Hardin (1968)

[2] Arthur C. Pigou (1920). A Pigouvian tax is levied to correct the negative social side-effects of an activity. For instance, a Pigouvian tax may be levied on producers who pollute the environment to encourage them to reduce pollution and to provide revenue that may be used to counteract the negative effects of the pollution.

1.1 The Scope of the research project

This preliminary study has been financed by **Nutek**, the Swedish national agency that handles issues concerning industrial policies and is under the charge of the Ministry of Industry, Employment and Communication. **Nutek's** mission is to strengthen the international competitiveness of Swedish enterprise through action on three core issues: entreprenurship, business development and regional development. These issues are approached through various actions, including: the simplification of rules, the supply of capital, among others and is why **Nutek** is financing the research into this new and innovative concept. The Scope of the research project The purpose of the research project is to provide a preliminary investigation on the viability of a flexible pollution tax proposed by Anders Höglund[3]. The research draws on a preliminary theoretical policy analysis that contributes as much as possible to a better understanding of the concept as well as the benefits and costs of the concept with respect to other similar policies and to point the way forward on new research.

1.2 The research team

1.2.1 The Swedish Environmental Research Institute (IVL).

IVL is an independent research organisation, operated in the form of a limited not-for-profit company, supported by the government (Ministry of the Environment) and the Swedish industry. IVLs in-house competence is wide, covering ecological, biological, chemical, physical, technical and socio-economical aspects of sustainability. IVL has a broad experience of working with decision support, industrial pollution problems, emission and effluent monitoring, policy instruments and sustainability management. In addition, IVL is a leading institute in Sweden for air and water quality measurements and environment assessments. IVLs international experience is extensive, including contracts performed in Europe, Asia, Africa and South America. IVL has 145 employees, where of 80 have academic diploma and 20 PhD degrees. IVL has certified laboratories, dealing both with research-based and consulting environmental analyses. IVL has worked with research and consulting in the finance industry for 10 years.

1.2.2 Cargine AB

Cargine Engineering AB is a Swedish company devoted to development and marketing of combustion engine technology reducing emissions and fuel consumption while improving performance and customer value. The company offers consultant services and simulation software in various fields, including; combustion engine technology, physics, chemistry, mechanics and environmental economics.

1.3 Methodology

Several key activities form part of the research project, these are namely:

Literature review; set the scene in terms of state of the art thinking around environmental policy instruments and use this foundation to build on the analysis of Höglunds Tax. The review also

[3] Anders Höglunds description of the system is provided in Appendix A.

served to solidify the assumptions upon which the analysis is based and clarify the mechanics of the policy proposal.

Simulation; undertake a simplified modelling exercise in order to demonstrate the mechanics of the policy in a dynamic context and to illustrate the effects of the policy on pollution emissions.

Discussion and Analysis; building on the results of the literature review and the simulation, analyse and discuss the advantages and disadvantages of Höglund's Tax over other environmental policies. The research undertaken here involved contributions from several important agencies and institutes including; Miljödepartementet, Naturvårdsverket, Näringslivsdepartementet, Gothenburg University, Elforsk, Energimyndigheten. Two reference group meetings were hosted by IVL where the concept and research results were presented and discussed. The valuable input obtained from these organisations served to strengthen and improve the analysis.

Reporting and results dissemination; in addition to engaging researchers and policymakers through the reference group, a report and a draft scientific article have been prepared. The article will be submitted to select scientific journals and will also serve as a key document for applications to research funders.

2 Literature review

This section provides a review of Höglund's own ideas with respect to his policy proposal[4]. It also provides an overview of the state of the art with respect to environmental policy and natural resources economics.

2.1 Why consider a flexible pollution tax concept?

The aim of pollution regulation is assumed to be one of finding ways of reaching a socially optimal level of pollution. The flexible pollution tax concept could be applied to a number of different types of pollution such as greenhouse gases (carbon dioxide) or other stock pollutants. The tax is used to "price" a specific pollution providing economic incentives to invest in and/or strengthen incentives to develop abatement technology. Pigouvian taxes[5] and quantity constraints[6] are two types of government intervention that can be compared with Höglund's flexible pollution tax. Though Höglund's tax is analogous to the Pigouvian tax, the advantages and disadvantages of Höglund's tax with respect to other policies provide a useful reference for comparison. To begin with, there are some important differences between quantity limits and a Pigouvian tax.

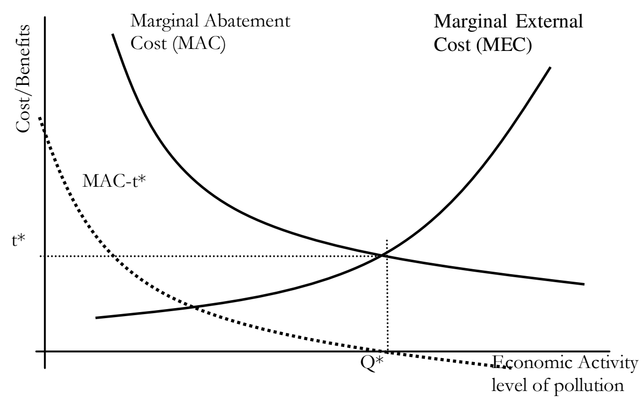

Figure 2-1 – Optimal pollution level Q*

Traditionally, the optimal tax on pollution is determined by the intersection of a Marginal Abatement Cost (MAC) curve and a Marginal External Cost (MEC) curve.[7] Practically, the difficulty comes down to establishing the shape of both the MEC and MAC curves and

[4] Höglund's proposal is provided in Appendix A.

[5] An optimal Pigouvian tax is defined by Pearce and Turner (1990) as a tax that is equal to the marginalexternal cost (i.e. marginal pollution damage) at the optimal level of pollution. Simply put, by collecting a tax on pollution, the government sets a price to pollution that provides an incentive to firms to reduce their emissions to an optimal level.

[6] A quantity constraint, as adopted by the Montreal Protocol or the Kyoto Protocol, sets a physical limit to pollution emissions. Tradable permits are a feature that has recently been introduced in order to help reduce the economic cost of reaching these limits.

[7] See Pearce and Turner (1990)

understanding how they change over time. An optimal level of pollution is achieved where the MAC and MEC curves intersect, see Figure 2-1.

If the relationship of abatement costs (MACs) and environmental damages (MECs) are known with certainty, then the differences between quantity limits and a Pigouvian tax in terms of efficiency disappears. Either one lead to the same level of pollution and the possibility of an error is assumed away. However, when these relationships are known only approximately, the key to the choice is whether costs or benefits change more rapidly as the level of emission control is varied. In other words, it depends on whether MACs or MECs change more with the level of pollution.

A quantity constraint (stipulated by the Montreal or Kyoto protocols) is preferred if MECs are sensitive to the level of pollution emission. A tax is preferred where MACs are more sensitive to changes in the level of pollution emission change more rapidly than marginal benefits, e.g. where cleaner technology is very expensive. Consider a case where the damages, MECs, rise steeply as the level of control is relaxed (perhaps because of some threshold effect) but the marginal control costs do not differ greatly among levels of control. In this circumstance, it is more important to get the quantity right i.e. a cap.[8]

Fixing the price with a tax when costs are uncertain leaves the quantity undetermined, and the response of emitters to the emissions price may turn out to produce emissions that are higher than expected.[9] In this case, it is important that the environmental damages, the MECs, are less sensitive to changes in the level of pollution.

Figure 2-1 illustrates the effect of a static pollution tax on levels of pollution, assuming perfect competition. By imposing an optimal tax of t*, the level of pollution is reduced from some level Q (which would be where the MAC curve crosses the horizontal axis) to an optimal level Q*. Similarly, a quantity constraint would fix the cost of pollution such that Q* is reached. Approaching the pollution issue from this perspective, the challenge for policy makers becomes formulating policy which arrives at a tax level that approaches t*, or a quantity constraint that approaches Q*.

It is, in many cases, difficult to identify a reliable MEC curve, particularly with longer-term environmental issues such as climate change. In the case of the climate debate for example, substantial resources have been devoted towards developing a better understanding of the MEC. The International Panel on Climate Change and their assessment reports are an example of the steps that are being taken.

MAC curves on the other hand have been derived either using a "top down" or a "bottom up" methodology. Top-down curves are derived from economic models. These are generally produced from Computable General Equilibrium (CGE or GEM) models. Such curves cannot distinguish accurately which sectors or technologies produce abatement and are dependent on the extrapolation of past trends when deriving their curves. On the other hand, bottom up curves are derived from engineering studies and technology assessments. Such curves exhibit good detail but often have gaps in one or more sectors due to a lack of data and do not include feedback effects on other economic variables of investing in certain options.[10] Deriving the MAC curve is difficult for a variety of reasons, commercial confidentiality being another important example. Indeed, many economist consider that the government is in a poor position to extract this information and some

[8] Morgenstern, R. (2002)
[9] Morgenstern, R. (2002)
[10] Ellermann et al. (1998)

even go so far as to argue that the existence of this information asymmetry is enough to preclude government intervention.[11]

In this regard, environmental policy faces a considerable challenge. On the one hand, the MEC curve must be known to some degree. The less that is known about the result of pollution damages, obviously, the more difficult it is to formulate an effective policy. On the other hand, the MAC curve must also be known to some degree. The less that is known about the MAC curve, the harder it is to formulate an effective policy. Without the certainty of reliable MAC and MEC curves, there is the risk that the policy will overshoot or undershoot what is economically or environmentally optimal.

The flexible pollution tax would allow firms to act on an open market based on the information they have about their own abatement costs. By hedging their abatement investments (or even hedging their decision not to invest), a level of the pollution tax is established. The tax level would, in the long run, be a function of an aggregate MAC of those firms that participate on the market and the life of their abatement investments. How this is brought about is discussed in the next sections.

2.2 Understanding the mechanics of the system

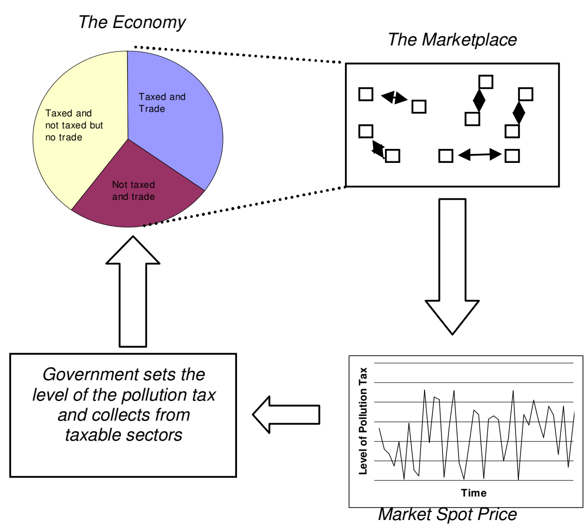

Figure 2-2 An overview of Höglund's proposal

Figure 2.2 provides an illustration of how Höglund's flexible tax[12] would work. The government would decide which sectors of the economy would be subject to the tax - that is to say the government would collect a fee per ton of pollution emitted from certain sectors of the economy. The government would commit to collecting this tax at regular intervals, monthly for example. Firms and other organisations would then be free to trade pollution tax futures contracts on an

[11] Pearce and Turner (1990)
[12] As described in Höglund's proposal in Appendix A.

open market.[13] The futures market would be open to anyone – not only those firms that are covered by the tax. There would be no limit to the amount of short or long contracts any market participants could enter beyond the usual limits imposed on derivatives such as margin requirements or price limits.

The spot price on the market would determine the level of the tax for a given period. For example, if the spot price on the market were 10 SEK/kg of pollution, the government would commit to collecting the tax at this level for the next time interval, over the next month for example. In other words the government would adjust the level of the pollution tax, at regular intervals, to the spot "price" of the market. The regular adjustments made by the government, matching the tax level to the spot price of the pollution tax market, makes the tax in effect, flexible.[14]

This cycle, as illustrated in Figure 2.2, would be repeated; the tax level is set by the market, the government collects the tax, firms trade pollution contracts on the market, which sets the level of the tax, and so forth.

The pollution futures concept builds on some of the instruments already existing in the financial services sector, namely the buying and selling of interest rate futures. The analogies with trading interest rate derivatives makes trading in pollution tax futures seem less radical. A comparison between the pollution tax and these derivatives is taken up in Section 3.2.1 – Other analogous derivatives.

As with a standard flat tax, the flexible tax would provide a number of economic effects. [15]

- A *revenue recycling effect*, where Pigovian tax revenues are used to compensate for usage/damage of common goods or services.
- A *tax interaction effect*, which is related to the loss in welfare that is due to the distortionary effects of taxes on the economy.
- The *input-substitution effect*, which refers to the submission of "cleaner" inputs for "dirtier" ones in production, in other words an upstream effect.
- The *output-substitution effect* or adjusting outputs so that the production process can be cleaner, in other words a downstream effect.
- The *abatement affect* – the incentive to invest in cleaner technology.

The last three are strategies that firms adopt in order to maximise profits in the face of the tax. This last effect (the abatement effect), is the focus of the discussion here since it plays a critical role in determining the level of Höglund's pollution tax. Suppose a firm can reduce its annual carbon emissions from 100 tons/year to 80 tons/year for a cost of 250 000 SEK, that the investment has a life of 10 years, and that the level of the carbon tax is constant at 1000 SEK/ton. Before the investment, the carbon tax due is 100,000 SEK/year whereas after investment it is 80,000 SEK/year. Thus investing in new technology at the given tax level would provide 20,000 SEK/year in savings. In other words, if the Net Present Value (NPV) of tax savings is greater than the NPV of the Marginal Abatement Costs, the firm will chose to abate. Thus, the level of the tax triggers a firm's investment decision, providing an incentive to invest. A higher tax level will, naturally, provide more of an incentive to invest. If the tax savings from abatement are not greater than the

[13] The futures contract would specify; an amount and type of pollution, the delivery date, expiry date, price limits, margin requirements and other issues that are included in standard futures contracts. See www.cbot.com for more information and some examples of standard futures contracts for commodities.
[14] More background information is provided in Appendix A.
[15] Gerlagh (2003) and Goulder (1998)

cost of abatement, the firm will not invest. One could rephrase a firm's investment decision formally:

$$NPV\left[\tau_i - \tau_f\right] \geq NPV\left[I\right] \qquad \textbf{Equation 2-1}$$

Where $NPV[\tau_i - \tau_f]$ is the net present value of expected future pollution tax savings from abatement and $NPV[I]$ is the net present value of the capital investment required in order to realise the reduction in pollution.[16] Such pollution taxes not only create an incentive to invest in cleaner technology, but they also provide an incentive for the development of cleaner technology.[17]

In principle, the incentive to abate that is provided by Höglund's tax is no different than that provided by a standard static tax on pollution/emissions, such as Sweden's existing tax on carbon emissions.[18] The difference with Höglund's proposed tax is that the future level of the tax is uncertain, i.e. $[\tau_i - \tau_f]$ creates a level of uncertainty for firms faced with an abatement investment decision.

The risk that the firm assumes is that the expected tax saving is not realised. In other words, they miscalculate the future levels of the pollution tax. For example, if the firm invests assuming that the future tax will be at 1000 SEK/ton and it turns out to be significantly lower, then the actual NPV of future tax savings will not be sufficient to pay for the investment. If the tax level turns out to be higher, then the savings from the investment would be also higher.
This uncertainty would drive some firms to hedge their abatement investments by buying or selling pollution futures. The buying and selling of pollution futures would determine the level of the pollution tax and the level at which these futures would trade would be a function of firm MACs. It is by subjecting firms to this uncertainty that firms reveal their MAC, and a level of the tax is discovered. In the next section, we look closer at the mechanics of the system and how the level of the tax would develop.

2.3 Hedging and speculating with pollution tax futures

The demand and supply for futures contracts would be driven by both hedging and speculating against future changes in the level of the pollution tax. A hedge is successful when most of the price variation in the spot market is offset by the opposite futures transaction. A hedge is "perfect" when gains or losses in the cash market are neutralised by losses or gains in the futures transaction. A hedger deals in the spot market and futures market simultaneously.[19]

Hedgers include those firms that have invested, will invest or have chosen not to invest in abatement technology. They decide to hedge their abatement investment decision with the use of the futures contracts. For hedgers, taking long or short positions on the futures market is a means of reducing the risk of a capital investment. If a firm is considering an investment in a new machine that will reduce the firm's pollution by a certain amount then the expected benefits of this investment should outweigh the expected cost if the project is to go forward. However, there is a

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[16] I is simply the area under the Marginal Abatement Cost (MAC) curve for the level of pollution abatement achieved.
[17] Gerlagh (2003)
[18] Swedish Environmental Protection Agency (1997)
[19] Winnipeg Commodities Exchange Inc. www.wce.ca

risk that the benefits and the costs associated with the investment could turn out to be different from what was originally expected. The firm that is considering the investment can hedge its risk exposure by taking a short position on the pollution tax market. By selling futures contracts, the firm intends to offset losses and gains that result from an unexpected change in the level of the pollution tax.

Similarly, a firm that decides not to abate would prefer to buy futures contracts in order to offset losses and gains from unexpected changes in the level of the pollution tax. Said differently, the firm would want to lock in its future tax level and take a long hedge.

Speculators on the other hand look to profit from expected tax level changes, and are willing to accept higher risk for the potentially higher gains. To speculate is to buy, sell or hold onto cash commodities, or to buy or sell futures contracts in order to profit from potential favourable price changes. The speculator assumes price risk expecting to profit from price changes.[20] Table 2-1 and 4-2 map the potential outcomes for hedgers and speculators respectively on a pollution tax futures market.

Table 2-1 Outcomes for Hedgers

Abate and take a short position		**Not Abate and take a long hedge**	
Tax level increases	Tax level decreases	Tax level increases	Tax level decreases
Lose on futures	Gain on futures	Gain on futures	Lose on futures
Gain more than expected from abatement.	Gain less than expected from abatement.	Gain less than expected from abatement.	Gain more than expected from abatement.

Table 2-2 Outcomes for Speculators

(Abate and) take a long position		**(Not Abate and) take a short position**	
Tax level increases	Tax level decreases	Tax level increases	Tax level decreases
Gain on futures	Lose on futures	Lose on futures	Gain on futures
Gain more than expected from abatement.	Gain less than expected from abatement.	Gain less than expected from abatement.	Gain more than expected from abatement.

2.3.1 Arguments for and against hedging

Most companies are in the business of manufacturing or providing a service and have no particular skills or expertise in predicting variables such as interest rates, exchange rates and commodity prices. It therefore makes sense for them to hedge the risks associated with these as they arise. Simply said, by hedging, they avoid unpleasant surprises such as sharp increases or decreases in price.[21]

Despite the advantages of hedging, there are good reasons why companies do not adopt hedging strategies. Shareholders, it is argued[22], can do the hedging themselves by having an appropriately managed portfolio. Or, if hedging is not the norm in a certain industry, it may not make sense for a particular company to choose to be different from all the others. Despite the advantages of hedging, there are issues that prohibit its more widespread adoption; understanding how to edge

[20] Winnipeg Commodities Exchange Inc. www.wce.ca
[21] Hull (2003)
[22] Hull (2003), p. 73

effectively being one serious obstacle. With hindsight, hedging can seem like a bad idea. But if participants are well informed of the mechanics of hedging, then the benefits of hedging become clearer and the more widespread adoption of the practice becomes possible.[23] In the context of the flexible pollution tax, hedging plays a critical role in setting the fundamentals that determine the level of the tax.

2.3.2 Arguments for and against speculating

Speculation, as an investment strategy, is often criticised on the grounds that it does not create value for society but simply involves buying or selling a financial asset with the aim of making a quick profit. Speculators are also accused of moving prices away from economic fundamentals (speculative bubbles).[24] Speculation has brought about some serious crises on financial markets; witness the devaluation of the Swedish Krona in 1992 at the hand of speculators or the crash of several Asian economies in 1997.[25]

Despite the costs, speculators actually play a valuable role in financial markets as their appetite for frequent buying and selling provides liquidity to the markets. This benefits longer-term investors as it enables them to get a good price when they do eventually sell. Another important role for speculators is to assume risk from those who buy and sell goods for production, investment, and consumption.

Another fundamental aspect of speculation is that, in general, speculation which reduces harmful price fluctuations is rewarded with profit and speculation which increases harmful price fluctuations is punished with losses. The net result of this fact is that harmful speculators, causing damage to the market, will sooner or later lose their money and power to influence the market.

In the context of the flexible pollution tax, speculators, though often criticised, provide important services to markets. For example, speculators, it is argued, improve the ease of transaction execution by increasing market "liquidity". They increase the number of buyers and sellers and help to facilitate trading. Speculators provide a valuable service to hedgers by taking on some of the risk that hedgers wish to avoid.

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[23] Hull (2005)
[24] www.economist.com A-Z economics.
[25] Krugman (1996)

3 Analysis and Discussion

3.1 Reference Group Discussions

Two reference group meetings were held during the course of the project. These were held on 17 March 2005 and 12 May 2005. The meetings were brought together a group of researchers and policymakers that provided feedback to the research team as well as disseminate the results. The first meeting on 17 March served primarily to present the project and research subject as well as obtain feedback on the proposed research methodology. The second meeting on 12 May served as a forum to discuss the draft results of the analysis and gain feedback on where the research should be taken should further research on the subject be undertaken.

The reference group participants included:

- Anders Höglund, Cargine AB
- Anders Lundin, Näringslivet
- Elin Kronqvist, Miljödepartementet
- Erik Filipsson, Energimyndigheten
- Gunnar Hovsenius, Elforsk
- Lasse Zetterberg, IVL
- Lennart Hjalmarsson, Göteborgs Universitet
- Mark Sanctuary, IVL
- Mark Storey, Naturvådsverket
- Markus Åhman, IVL
- Stefan Nordin, Nutek

Comments from the first reference group meeting are listed below:

1. **General Comments:**
   - 1.1. This policy instrument could be applied to a number of different pollutants and is not limited only to carbon dioxide.
   - 1.2. The analysis of the viability of this system requires comparison with other policy instrument currently in practice such as Cap and Trade.
   - 1.3. Considering the behaviour of the system over longer time periods produced significantly different results in the GETS 2 and 3 simulation exercises – particularly in terms of investment decisions. Could be the same with this type of system.
   - 1.4. Some firms cannot get around the emission of a certain amount of pollution and might suffer from high tax levels if they do not have an investment option.
   - 1.5. Political references and language in the "teoribeskrivning" document should be removed – the document should be focussed on the problems and the tasks under analysis.
   - 1.6. "Optimum" versus "cost effective" are different issues and are not clearly distinguished in the theoretical description – this must be clarified.
2. **More specific issues**
   - 2.1. How is the price set? What drives price formation and reduction in pollution? Is it simply a matter of policy speculation or is it a reflection of an average marginal abatement cost?
   - 2.2. How can short term market interests be translated into action on long term intangible issues?
   - 2.3. How would one simulate trading with such a complex set of conditions?
   - 2.4. Why is there a demand/supply for futures contracts? Is it driven by uncertainty of the tax level, or are there other important determinants?

Comments from the second reference group meeting are listed below:

1. **General Comments:**
   1.1. The level of the tax would be technology driven and is not connected to the cost of damage to the environment – marginal external costs in other words are not considered when setting the level of the tax.
   1.2. First analyses will set forth assumptions of perfect markets, risk neutral agents and so forth. Though the assumptions are unrealistic, it is the basis for more elaborate analysis.
   1.3. Do not focus on issues of market liquidity, it is too difficult to model at this stage it is better to focus on more fundamental issues.
   1.4. Uncertainty is disliked by industry – the system would need to have some very strong selling points in order to convince industry to support the concept. Might prefer a higher stable tax than a lower flexible tax.
   1.5. It is not clear if it is worth subjecting firms to uncertainty in order to extract marginal abatement cost information from firms.
   1.6. The analysis should steer away from political discussions before the economic theory has been shown to be sound.
   1.7. The rational expectations of participants could undermine the market.[26]
   1.8. Need to consider the incentives such a system would pose to different actors: Government, producers and consumers.
   1.9. The concept is interesting and at the very least will provide ideas and insight on other pollution policies, both those that are being developed and those that have been implemented.
   1.10. It might be difficult to get a journal to review the article if there is not a sound model that could be used to support the function of the market.

2. **Recommendations on next steps:**
   2.1. Develop a model of the market that includes consumers, policy makers and producers, and identify the most salient variables.
   2.2. Tighten the analysis as much as possible, building on the comments from the reference group, and prepare an article that could be submitted to a reputable journal. This might allow us to obtain feedback from the journal's review panel if not get to get it published.
   2.3. Miljödepartementet[27], has a commission that is looking at different pollution policies – and there is an interest in reviewing new/alternative pollution policy options. This concept could be an issue that they would look into.
   2.4. The final report will be made available to all reference group participants and the possibility of convening a follow up meeting during the fall of this year will be considered.

3.2 Price discovery

The level of the tax would be determined on a market where anyone, not just those who are directly subject to the tax, buy and sell contracts in order to insure against or profit from future changes in the tax level. Hedgers and speculators would both play an important role in shaping the market and creating a price for the tax.[28] Understanding the formation of the tax level is necessary in order to

[26] Mark Sanctuary will speak with Lennart Hjalmarsson to get a more precise clarification of the comment.
[27] under Proposition 2004/5:150 Section 21.1.5
28 For the moment, we will not consider arbitrageurs since we will limit the analysis to only one simple market. Arbitrageurs are those market actors that lock in a risk free profit by simultaneously entering into transactions in two or more markets.

understand the potential benefits or costs that such a system brings and whether or not it is a viable pollution policy alternative. Will the price approach t*, the optimal Pigovian tax, or is it possible that the price will overshoot or undershoot t*? How long will it take to reach such a level? The government would collect revenues from the pollution tax that would equal the product of the price of the pollution tax and the volume of pollution emitted.

The flexible pollution tax would derive a price level for pollution that would be a function of not only a firm's MAC curves but also the level of their risk aversion. Under these conditions there would be three different types of actors on the market.

1. *Hedging firms that abate and take a short position* (i.e. sell futures contracts). These firms would sell as high as possible. This would reduce their exposure to a decrease in the tax level. They would not be willing to sell futures at a price that was too low so that their abatement project would no longer provide a positive net present value.
2. *Hedging firms that do not abate and take a long position* (i.e. buy futures contracts). Hedging firms that take a long position would buy as low as possible. This would reduce their exposure to an increase in the tax level as much as possible. They would not be willing to buy futures at a price that was too high so that it would make more sense to invest in an abatement project.
3. *Speculators, that will take short and long positions depending on their expectations on the future tax level.* Those who believe that the tax level will increase would take a long position and those who believe that the tax level will decrease would take a short position.

It is the hedgers that will buy and sell pollution futures around the aggregated marginal abatement cost of participating firms. The cost of abatement and the lifetime of the projects/technology investments would also determine how the price changes over time in the long run. One can suppose that a sequence of events would look like the following:

- A firm invests in machinery that has a life of 2 years and sells pollution futures (take a short position) to hedge against volatility over those years.
- The pollution tax provides an incentive to those with relatively cheap abatement costs to invest in abatement technology. In other words, "low hanging fruit" would be the first to react to the pollution tax.
- 2 years on, when the machinery needs to be replaced, it would go through the process again, using a new set of futures prices to judge whether or not to abate.
- The new set of pollution futures would again reflect the bid-ask spread around participating firm's MACs.
- Those firms that had chosen to abate earlier would now face higher abatement costs. This would in turn lead to higher futures prices.

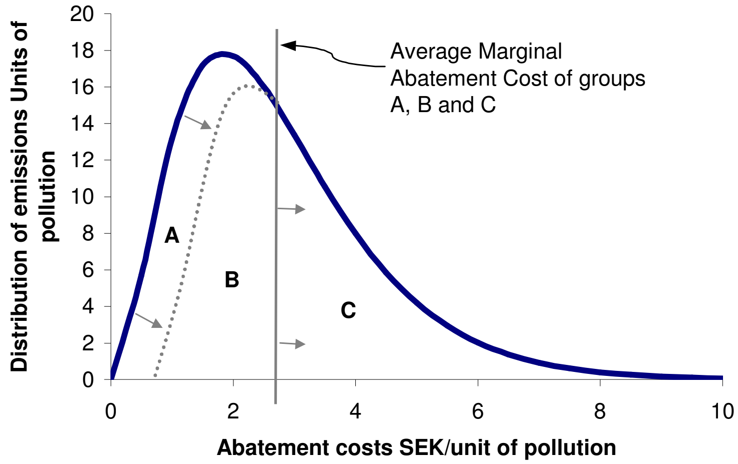

Figure 3-1 – Emissions across the economy

With most "low-hanging fruit" gone, there would be fewer and fewer abaters with low MAC and more abaters with higher MACs. This would help drive an increase in the level of the tax. This cycle of abatement and increasing marginal abatement cost would gradually increase the price of the futures contracts over time as cleaner and cleaner technology is adopted. At the same time, improvements in technology would serve to flatten MAC curves, resulting in lower abatement costs and lower pollution tax levels. Figure 3-1 provides a graphical illustration. Suppose the distribution of emissions across the taxed economy at a certain point in time is such that most emitters face abatement costs as described in the figure. Those firms with the cheapest abatement costs would have the strongest incentive to invest to reduce their pollution levels. With time, the trailing edge of the curve would therefore move to the right (as illustrated by the dashed line). The speed at which the curve would shift in this manner would be a function of the strength of the financial incentive and the lifetime of firm's abatement investments.

According to Höglund, the long-run tax level would follow the average marginal abatement cost of those firms that are covered by the pollution tax – shown in Figure 3-1 as the centre of gravity of the area under the function. As the curve shifts to the right, the long-run level of the pollution tax would also increase.

To see why, one must consider the incentives that firms face. Divide taxed firms up into three different groups as shown in Figure 3-1. *Group A* includes those who have abated, *Group B* are those that are considering abatement or will abate in the near future, and *Group C* are those that are not currently considering any abatement investment. Accordingly, all of *Group A* and some of *Group B* [29] firms hedge their abatement investment by selling futures contracts and would be seeking the highest possible price for the contracts (to protect against a fall in the tax level). The rest of *Group B* (those who do not have any immediate plans to abate) and all of *Group C* hedge by buying futures contracts. They would seek to buy futures at the lowest possible price in order to hedge against an increase in the tax level.

[29] Depending on the timing of their expected investment

Thus there is a zone of possible agreement (ZOPA)[30] that exists between the buyers and the sellers of the futures contracts. The extent of the ZOPA is determined by the MACs of the respective buyers and sellers and indeed the ZOPA should cover the average aggregate MACs of the participating firms, see Figure 3.2.

Firms that will abate (i.e. those with a MAC below the level of the tax) would seek to hedge by taking a long position in futures contracts. They would seek to buy contracts at the lowest possible price in order to maximise the potential benefits. Likewise, firms that would not abate would seek to hedge by taking a short position. As firms abate and sell contracts, the lower limit of the "seller's settlement area" would move steadily to the right (in other words, price would increase) and squeeze the ZOPA. The higher price being asked by sellers would provide an incentive to non-abaters to abate and would also increase the upper limit of the buyer's settlement range. On the other hand, if there are many buyers with low abatement costs, sellers could be in a poor position since they are unlikely to "un-abate" and move back to the buyer side. With time, as firms abatement investments age, firms would find themselves back in group A or B, i.e. buyers of futures contracts.

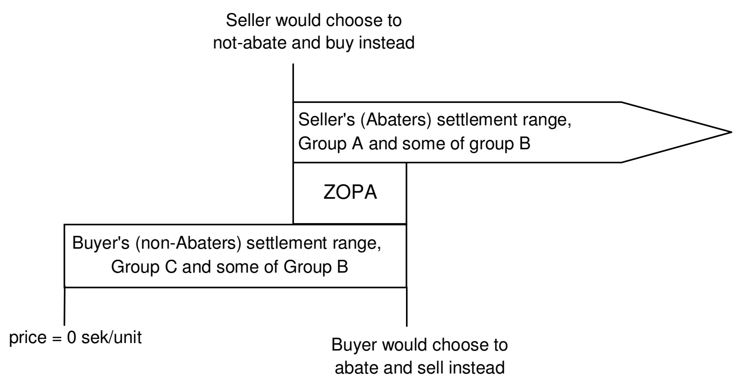

Figure 3-2 – The Zone of Possible Agreement (ZOPA)

As mentioned, traditional policy instruments set the optimal level of pollution by balancing marginal abatement costs with some marginal environmental damage. The system proposed here, on the other hand, is not at all connected to the environmental damage of pollution. It is rather connected to the lifetime of abatement investments; it is technology driven. The level of the tax on the contract is a function of the distribution of MACs of buyers and sellers.

Höglund's tax is an efficient way of reducing emissions and that the main point of such policy, it could be argued, is not so much to arrive at an "optimal" level of pollution but to reduce pollution at reasonable economic costs. The lack of clear information on environmental damages, MACs of firms, and even market structure[31] make it difficult in reality to formulate an optimal Pigovian tax[32]. Höglund's tax does not consider environmental damages, and so the question then becomes how

[30] For more background on the ZOPA see Watkins and Rosegrant (2001).
[31] Setting an optimal Pigovian tax is more complicated under oligopoly conditions. See Pearce and Turner (1990) for some more background.
[32] Pearce and Turner (1990)

long would it take to reduce emissions by a certain level? Perhaps a flexible tax could be considered a *second best*[33] policy alternative? See further discussion on page 29.

3.2.1 Other analogous derivatives

Forward rate agreements are over-the-counter agreements that a certain interest rate will apply to a certain principal during a specified future period of time.[34] This is a close analogy to the pollution tax, which could be termed in similar language as an over-the-counter agreement that a certain tax rate will apply to a certain volume of pollution during a specified future period of time. Calculating exact theoretical futures prices for these types of forwards contracts is difficult to determine because the short party's (seller of the contract) options with respect to the timing and delivery and choice of the bond that is delivered cannot be easily valued.[35] In other words, it is difficult for the seller of these forward contracts to know what type of bond they will need to deliver. Valuing pollution futures might also be similarly challenging in that it would be difficult for the seller of the pollution future contract to know exactly what the characteristics the "cheapest-to-deliver" pollution contract will have. Trading with these types of contracts is more complex than trading with standard commodities contracts on coal or rice simply because forward rate contracts have special features.[36]

3.3 The economic impacts of pollution policies

Identifying the benefits and the costs of environmental regulation provides a reference for informed judgement on policy options. There is already a significant body of literature covering the debate on quantity constraints (cap and trade) versus pollution taxes.[37] Most of this literature focuses on climate policy. The following section reviews the literature and then moves on to consider the implications of a flexible tax versus the cap and trade in terms of who loses and gains and by how much.

Distribution and efficiency are two of several dimensions[38] that are used to gauge the effectiveness of policy. Pollution control policies have been compared and evaluated against each other and a number of important differences in terms of both efficiency and income/cost distribution have emerged. It is important to note that the advantages and disadvantages of these respective

[33] Lipsey and Kelvin (1956). "Second best" refers to the optimal policy when the true optimum (the first best) is unavailable due to constraints on policy choice.
[34] Hull (2003)
[35] Hull (2003)
[36] Traditionally, derivative markets are based on underlying assets – in other words a derivative such as a futures contract is a financial instrument whose value is derived from the values of other, more basic underlying variables.[36] A futures price on an asset, in its simplest form can be calculated using $F_o = S_o e^{rT}$, where F_o is the futures price, S_o is the price of the asset underlying the futures contract today, r is a risk free interest rate and T is the time until delivery. The value of a futures contract is derived from changes in the futures price relative to the price agreed to when the contract is written. Futures contracts are equal to zero when they are written. Thereafter, and up until maturity, this value may prove to be positive or negative, depending on how the S_o, the price of the underlying asset, changes before delivery. In this context, futures contracts are a way of betting on future scarcity or abundance of certain inputs to the economy. The pollution tax is not "derived" from a scarce commodity and therefore the analogy here is weak.
[37] See for example Zhang and Baranzini (2003)
[38] Costs of administration and transaction, enforceability, political economy of decision making and the power of polluters are other important issues.

instruments are sensitive to the assumptions upon which the analysis/comparison rest. The traditional view among many academics is that pollution taxes are superior, in terms of efficiency, to command and control policy particularly when the costs of externalities/pollution are incomplete. In terms of distribution, pollution taxes are less favoured. For example, as we have already mentioned, in an idealised economy (first best) where information is perfect and markets are efficient, the difference between a Pigouvian Tax policy and a Quantity limit policy vanishes[39]. With more sophisticated assumptions, the respective costs and benefits of these two policies emerge.

Resources for the Future compare the cost-effectiveness of pollution taxes and quantity constraints and other policy options.[40] Using a general equilibrium framework, they compare five different policies under two scenarios; a first-best setting[41] and a second-best setting [42].
Figure 3-3 illustrates the findings from their study. *Graph A* illustrates the relative costs to the economy across levels of emission reductions for different pollution policies under first-best assumptions. The costs of the different policies are normalised against an idealised Pigovian Tax under first best assumptions. Under, these conditions, there is no difference in the cost to the economy of a Pigouvian Tax on pollution or a quantity constraint. Both are, theoretically, equivalent here. [43] The other policies, namely performance standards, a tax on fuel and technology mandates perform less well in terms of cost.

Graph A

Graph B

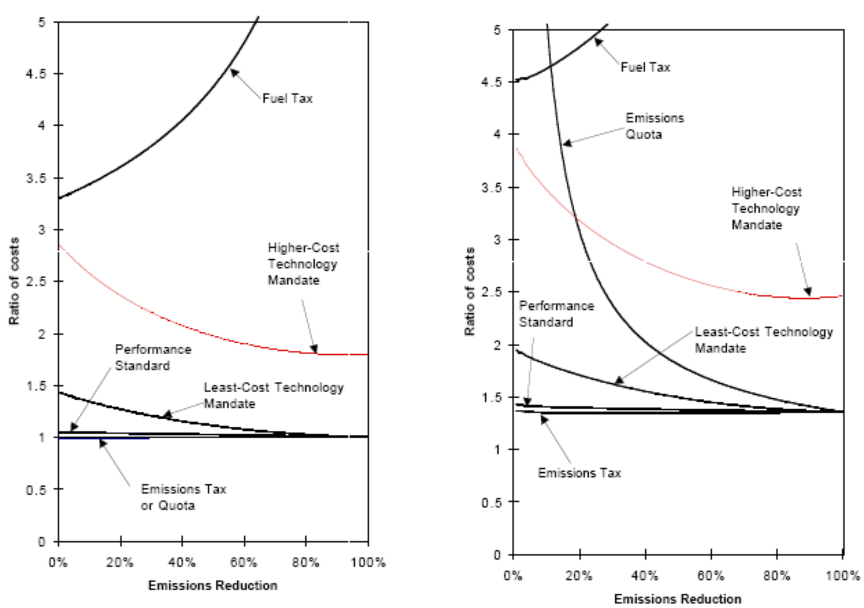

Figure 3-3 Ratio of cost for a policy alternative with respect to cost under first-best emissions tax. (Graph A is for a first-best world and graph B is for a second-best world).[44]

[39] See Section 2.1.
[40] Goulder L. et al. (1998)
[41] First best refers to a situation where the economy is not subject to distortionary taxes.
[42] As mentioned earlier, a second-best setting includes that assumption that the economy is subject to distortionary taxes.
[43] which is why the curve for an pollution emission tax is flat at 1.0
[44] These figures are taken directly from Goulder et al. (1998)

These findings help explain why the debate around pollution policies have lately focussed on tradable permits or taxes. *Graph B* on the other hand illustrates the relative costs under second-best assumptions, where the economy was already subject to distortionary taxes. The significant change is that the cost for the quantity limit policy (called emissions quotas in the figure) is significantly higher here, particularly under lower levels of pollution reduction.

For Graph B, two welfare effects are the most important in explaining the difference between Pigouvian Taxes and Quantity Limits in a second-best setting. The first is that by adding an environmental tax to an already taxed economy produces a welfare reducing *tax-interaction effect*.[45] The second is positive *revenue-recycling effect*[46] which can offset the tax-interaction effect. Both the tax and the quantity limit produce both these effects, but the issue here is the degree to which the different policies offset each of the effects. Simply put, under a pollution tax, the revenue-recycling effect offsets the tax-interaction effect. While a Quantity Limit is not as effective at leveraging the revenue-recycling effect, and thus results in larger efficiency losses to the economy.

The analysis by Goulder et al. (1998) concludes that under the more realistic assumption of a tax distorted economy, the effectiveness of a pollution tax is less costly to the economy than a quantity limit and most other forms of pollution policy. The cost to the economy of these different policies is also proportional to the level of pre-existing taxation. These results are based upon a simplified model of the economy where different sectors are not distinguished from one another. The paper does not consider the distributional effects of the different policies.

Though arguably more economically efficient, environmental taxes are generally considered regressive – in that low-income groups spend a higher proportion of their income on basic necessities, which tend to be more resource intensive than luxury goods. Redistributing the tax revenue appropriately, or even a well-designed policy can help offset the regressive nature of the tax.[47] There are also distributional issues between industries. For example, under a carbon-tax scenario in the USA, carbon intensive industries such coal mining, petroleum refining and electric utilities experienced the largest percentage reductions in profits.[48] The generally poorer distributional performance of environmental taxes has served as an important impediment to the use of these policies. Quantity limits are seen as less regressive than taxes. The debate around the performance of quantity limits and environmental taxes is far from decided and the conclusions depend upon the assumptions made.[49]

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[45] The tax interaction effect is related to the loss of consumer surplus and real wages that are due to distortion of the preferred consumption basket and reduces labour supply and tax incomes, leading to further losses. See Sterner (2003) for more information.

[46] The revenue recycling effect is a positive effect whereby the revenue collected from an environmental tax can be used to cut other distorting taxes, such as social security taxes and corporate income taxes. Reducing these taxes increases the level of employment and investment, and thereby produces an economic gain. The gain from the revenue-recycling effect can offset most, but typically not all, of the added cost from the tax-interaction effect. See Sterner (2003) for more information. That the tax interaction effect will cause losses in the economy that the revenue-recycling effect can not completely offset may be correct in a narrow and short term perspective but simple logic says that the only reason to introduce an environmental tax is if it can produce a long term net economic gain and, in the broadest sense, only if the tax will improve the conditions for the long term survival of man.

[47] Carraro and Metcalf (2000)

[48] Goulder (2001)

[49] A good overview of distributional issues of environmental taxes is available from Hamond et al. (1999) and Metcalf (1998) and Carraro and Metcalf (2000)

3.3.1 Economic impacts of Höglund's tax

Höglund's proposed tax is analogous to a standard Pigouvian tax however there are some important differences between the two policies. Given the volume of literature covering environmental taxation, there is room for a well-structured economic impact analysis that could make a meaningful contribution to establishing the viability of Höglund's proposal. A detailed economic model is beyond the scope of this study but such an exercise would be useful for quantifying some of the issues raised during this analysis.

Though Höglund's policy is, in many respects similar to a standard Pigouvian tax, some issues require a closer look. One of the most important distinctions is that Höglund's tax subjects polluting firms to more short-term volatility than a static tax. It is in fact this uncertainty that drives firms to take long or short positions on the pollution futures market in order to hedge their abatement decisions. Presumably, the uncertainty will impose a cost to firms and that the magnitude of this cost will be proportional to the level of uncertainty – higher volatility will impose higher costs to polluting firms. The importance of speculation will determine, to a degree, the level of volatility of the tax level. One way of looking at this short-term uncertainty is that it is necessary in order to bring the tax level down to an efficient level. Whether the benefits of a more efficient tax level outweigh the costs of short-term uncertainty is a matter that requires a quantitative analysis.

In the longer-term, the price should converge to an average MAC of firms participating on the market. Since Höglund's tax relies on technology (adoption and development thereof) to drive long-term changes in the tax level, an important issue is to establish a measure of the development of the tax level over time. Will it spur reductions in pollution more quickly than a static tax policy for example? This question can be answered with a yes or a no depending on the level of the corresponding static tax. A very low static environmental tax will have a very small influence on the emission of pollutants. A very high static environmental tax, on the other hand, can cause an almost arbitrarely rapid reduction of pollutant emissions but then to the cost of an extremely high degree of tax interaction effect. The idea behind the Höglund tax is its flexibility and (in theory) its ability to catalyze a market driven and cost effective structural change of firms and society in an environmentally adapted direction. Understanding the role the different variables play in driving the evolution of the tax would be necessary in order establish whether or not the policy would set an appropriate price to pollution. For the moment, the long-term price is a function of; the level of risk aversion among firms; the lifetime of their abatements; and the marginal costs of abatement investments. The promise, by the government, to collect the pollution tax at regular intervals at a rate that is decided on the market, is also an important factor. Furthermore, the level of the tax may provide more of an incentive to certain industries over others to participate in the market. This in turn might affect the long-term level of the tax. The sensitivity of the tax level to these, and other variables, is an important issue that needs to be considered if its effectiveness in reducing pollution and its effects on the economy are to be understood.

Long-term and short-term considerations would also lead into a discussion on the advantage and disadvantages of Höglund's tax over a static tax in terms of efficiency and distribution. Under a static tax, there is less short-term volatility than under Höglund's tax. However, in the long-term, it is not so clear cut which tax policy would create more uncertainty. A static tax policy needs to be adjusted in order to reflect changing technology, however one runs into the situation again where the centralised authority is in a poor situation to determine how and when technology has an affect on MACs. Höglund's tax, though it would hardly generate a predictable tax level in the long-term, would follow market rules. A static tax, would be determined more or less by political rules.

Enforcement might be another issue that requires consideration. Firms may seek to hedge their abatement investments using other channels or other services besides taking long or short positions on a pollution tax market. There may be a need for supportive legislation in order to make sure that the market performs as intended.

Many previous studies on ecological taxes have come to quite different conclusions depending on the assumptions of the analysis.[50] Under first best, perfectly competitive markets, with perfect foresight, the difference between Höglund's tax, a static flat tax, and quantity limits would disappear. If one adds in distorted economy from pre-existing taxes – some differences would surely emerge between the three policies. Presumably, a better understanding of Höglund's tax will probably require even more sophisticated assumptions and tools to not only capture the subtle aspects that make Höglund's tax different from a standard tax but also to capture the respective costs and benefits of the policy.

3.4 An illustrative simulation

A simple simulation has been developed in order to illustrate the dynamics of the system. The simulation is based on the assumptions of an idealised, frictionless market.[51] The simulation shows how, over time, the tax level would evolve as well as how pollution abatement would proceed.

3.4.1 A simulation over three time periods:

A first time period of 9 years is simulated with discrete political adjustments of the pollution tax from an initial level of 0.19 SEK/kg to a final level of 0.91 SEK/kg. This simulation is mainly based on data from the Swedish CO2-tax history. During this time period the market is strongly coupled to the politically determined pollution tax level which is adjusted at regular intervals. Observe! There was no functioning futures market in Sweden during this time but still all the people and all the firms in the economy were affected by the tax, directly or indirectly, and the amount of CO2-emissions in Sweden during this time period was reduced more than would otherwise have been the result as a response to the non-zero price of CO2-emissions. In a market economy all taxes will penetrate the whole economy (mostly indirectly). This time period is now history.

A second time period of 1 year, following the first time period, is simulated with a free market adaption of the pollution tax mainly due to fundamental hedging from an initial price level of 0.91 SEK/kg to the average aggregated margin abatement cost of 2.44 SEK/kg. During this time period of the market is learning to set the price with less and less influence from a politically determined pollution tax. This is a transition period in the near future after the creation of the Carbon Tax Market.

A third time period of 10 years, following the second time period, is simulated with a gradually rising, more or less fundamentally driven and balanced, market price due to investments abating the pollution with the lowest marginal abatement cost, below the left portion of the green pollutant mass distribution curve. In this process the left portion of the green pollutant mass distribution curve is gradually shifted downwards and to the right. This shift will automatically increase the average marginal abatement cost of the remaining amount of pollution.

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[50] See Section 3.3 – Economic Impacts of Pollution Policies

[51] The specific simulation assmptions are provided in Appendix B.

Not included in the simulation so far; a fourth period with a gradually decreasing market price due to the development of new pollution abatement technologies 'shifting the green pollutant mass distribution curve to the left', as a function of decreasing marginal abatement costs.

3.4.2 Calculated and/or plotted curves

1. Aggregated pollution mass distribution (green curves). The green curve shows the distribution of pollutant emissions across the economy as a function of abatement cost (the vertical axis is "units of pollution" and the horizontal axis is "abatement cost per unit of pollution") – it is similar to the curve shown in Figure 3-1.
2. Accumulated aggregated pollution mass (red curves) – simply the integral of the green curve and shows the accumulated mass of pollutant emissions below a given abatement cost.
3. Fundamental (relative) supply function (red curves) based on aggregated accumulated pollution mass.
4. Fundamental (relative) demand function (blue curves) based on the complement of the aggregated accumulated pollution mass.
5. Fundamental market price shown by vertical green lines through the intersection points between the the aggregated red and blue curves.
6. Actual pollution tax level and/or market price (vertical green lines).
7. Aggregated pollution abatement cost distribution (not shown).
8. Accumulated aggregated pollution abatement cost (not shown).

3.5 Examples of simulation results

Figure 3-4 shows a graphic representation after 3 simulation periods and a total elapsed time of 240 months. The evolution of the different curves, leading up to the results presented in Figure 3-4, are presented below.

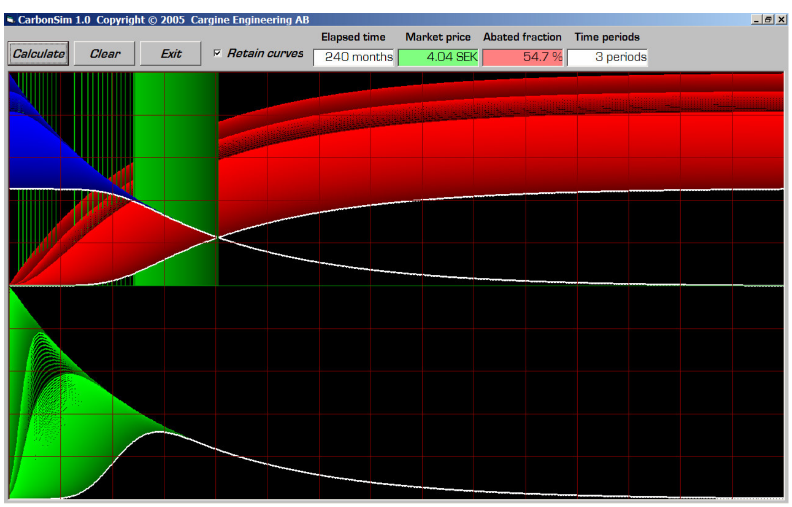

Figure 3-4 Illustration of simulation result after three periods

Figure 3-5 shows a graphical representation of the first time period spanning over 9 years. It is simulated with discrete political adjustments of the pollution tax from an initial level of 0.19 SEK/kg to a final level of 0.91 SEK/kg.

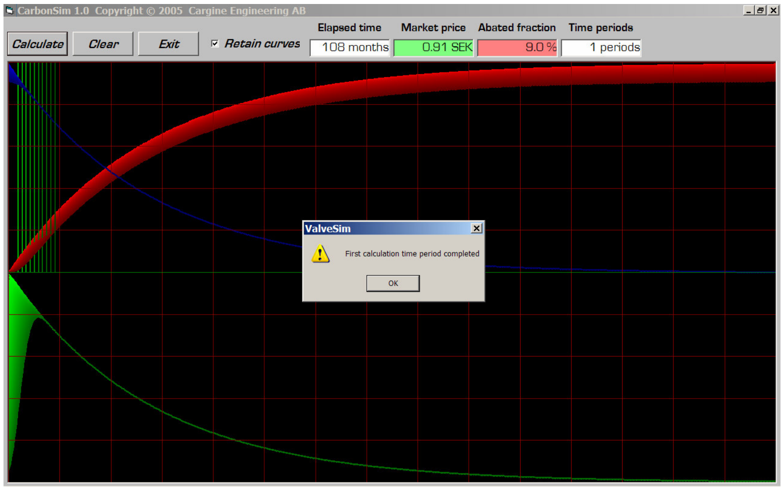

Figure 3-5 Simulation results for the first time period (years between 0-9)

The simulation is mainly based on data from the Swedish CO2-tax history. During this time period the pollution tax level was politically determined and adjusted at discrete time intervals.

There was no functioning pollutant emissions futures market in Sweden during this time but the whole economy was affected by the tax and the amount of CO2-emissions in Sweden during this time period was reduced more than would otherwise have been the result without the tax. It is a well known fact that in a market economy such a tax will penetrate the whole economy. Note that the CO2 tax (green vertical lines) during the whole time period was lower than the fundamental market price given by the intersection between the supply curves (red) and the demand curves (blue). This time period is now history.

Figure 3-6 shows a graphical representation of the simulation result after the first and second time period.

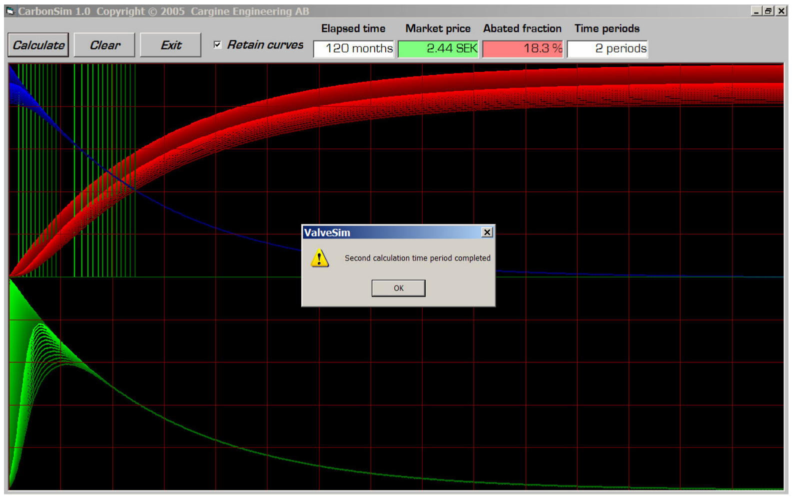

Figure 3-6 Simulation results for the second time period (years 9 to 10)

The simulation is assuming a free market adaption of the pollution tax mainly due to fundamental hedging from an initial price level of 0.91 SEK/kg to the final average aggregated margin abatement cost of 2.44 SEK/kg. Note that the final polltion tax (green vertical line to the far right) now coincides with the intersection point between the final supply curve (red) and the final demand curve (blue).

During this time period of the market is learning to set the price with less and less influence from a politically determined pollution tax. This is a transition period in the near future after the creation of the Carbon Tax Market.

Figure 3-7 shows a graphical representation of the result after a third time period of 10 years, further into the future. The simulation is showing a gradually rising, more or less fundamentally driven and balanced, market price due to investments abating the pollution with the lowest marginal abatement cost,. In this process the left portion of green curve is gradually shifted downwards and to the right. The shift during this time period causes an increase of the average marginal abatement cost of the remaining amount of pollution from the initial price level of 2.44 SEK/kg to the final average aggregated margin abatement cost of 4.04 SEK/kg

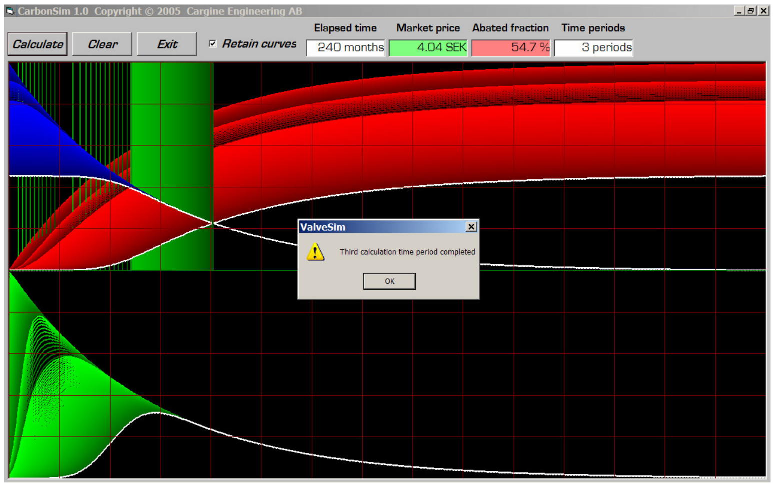

Figure 3-7 Simulation results for the third time period (years between 10 - 20)

The white curves in Figure 3-7 show the final stage of the simulation curves. The final market price is shown by the green vertical line farthest to the right in the cluster of lines, coincident with the crossing between the final (white) demand and supply curves. The cluster of green pollutant mass distribution curves (bottom left of the figure) show how the amount of pollutant has been abated gradually in response to the increasing tax level. Note that the simulation is based on theoretical assumptions about the conditions for the market and do not claim to reflect accurately the real timelines and actual evolution of the tax level.

4 Conclusions

The flexible tax, as specified by Höglund[52], is a new way of putting a price on pollution. The policy would remove the responsibility of setting the level of the tax from a central authority and would instead rely on exchanges on an open market to determine the level of the pollution tax. The tax level would reflect an aggregate average marginal cost of abatement of the polluters trading on the market. This is accomplished by subjecting firms to uncertainty over the future level of the tax, providing them with an incentive to hedge their abatement decision, which in turn leads to the formation of a tax level.

In principle, the incentive to abate pollution emissions provided by Höglund's tax is no different than that provided by a standard static tax on pollution. The difference with Höglund's tax is that the future level of the tax is uncertain. The risk the firm assumes is that the expected tax saving from an abatement investment is not realised. In other words, they miscalculate the future levels of the pollution tax. This uncertainty would drive some firms to hedge their abatement investments by buying or selling pollution futures.

The demand and supply for futures contracts would be driven by both hedging and speculating against future changes in the level of the pollution tax. Hedgers include those polluters that have invested, will invest or have chosen not to invest in abatement technology. For hedgers, taking long or short positions on the futures market is a means of reducing the risk of a capital investment. Hedgers buy and sell pollution futures around their aggregated marginal abatement costs and it is these exchanges that drive the formation of the tax level. The cost of abatement and the lifetime of the projects/technology investments would also determine how the price changes over time in the long-term. Speculators on the other hand look to profit from expected tax level changes, and are willing to accept higher risk for the potentially higher gains. In the short-term, speculation would serve as an important driver of the tax level's volatility.

Traditionally, the optimal tax on pollution is determined by the intersection of a Marginal Abatement Cost (MAC) curve and a Marginal External Cost (MEC) curve.[53] Practically, the difficulty comes down to establishing the shape of both the MEC and MAC curves and understanding how they change over time. In this regard, environmental policy faces a considerable challenge. On the one hand, the MEC curve must be known to some degree. The less that is known about the result of pollution damages, obviously, the more difficult it is to formulate effective policy. On the other hand, the MAC curve must also be known to some degree. The less that is known about the MAC curve, the harder it is to formulate effective policy. Without the certainty of reliable MAC and MEC curves, there is the risk that policy will overshoot or undershoot what is economically or environmentally optimal.

Höglund's tax has potential in that it could provide a mechanism by which pollution can be reduced in an economically efficient manner. The idea behind Höglund's tax concept combines those efficiency advantages of a pollution tax with an innovative way of setting the level of the tax using the decisions of individual firms acting on an open market. This avoids the situation where a centralised authority is required to "guess" an appropriate fixed tax level in the face of poor or unclear information on environmental damages and/or abatement costs. The advantage of

[52] See Appendix A
[53] See Pearce and Turner (1990)

Höglund's tax becomes even more interesting when one considers the issue over a longer time period. Improving technology and the adoption of technology would influence the level of Höglund's tax. In a static Pigouvian tax regime, the government needs to reassess the situation continually and is a source of risk to the economy in itself. Considering the limited amount of information available to governments, the advantage of Höglund's tax becomes clear.

At first sight Höglund's flexible pollution tax would seem to have some disadvantages with respect to other (theoretically effective) pollution policies. For one, the concept does not directly consider damages to the environment when setting the level of the tax, rather the level of the Höglund tax is dependent on the alternative cost of pollution abatement and the development and adoption of new technology. However, when comparing the Höglund tax to other pollution policies the calculation of environmental costs, especially in a long term perspective, is a very uncertain undertaking with the result that the other, theoretically effective, policies are far from effective i practice. The issue becomes one of how the level of the tax will evolve over time. How long, for example, would it take for the economy to reach a reduction in pollution of 50% under a Höglund tax regime?

If the pollution reduction is obtained in a cost efficient way this need not be an issue! And if the pollution reduction is a political problem there could be a considerable advantage with the Höglund tax market driven solution.

Consider the following alternatives:

<u>Both the MAC and MEC are fully known.</u>
No need for the Höglund tax, at first sight. Just apply the correct time dependent tax (or time dependent quantity restriction) to reach the optimal pollution level with the least societal cost. This alternative is rarely, if ever, encountered. And if encountered, there could be a serious political problem implementing the policy. If the political issue is difficult enough, applying the Höglund tax could be a way to circumvent the difficulty.

<u>The MAC is known but the MEC is unknown.</u>
No advantage with the Höglund tax <u>if the political cost of applying the necessary time varying tax or time varying quantity policy is negligible</u>. In that case just apply the correct time dependent tax (or time dependent quantity restriction) to reach a certain pollution level with the least societal cost. However the well documented difficulty of solving environmental problems by political means could make the Höglund tax quite useful in this alternative.

<u>The MAC is unknown but the MEC is known.</u>
Here the Höglund tax could be a useful tool to reach a certain level of pollution, determined by the MEC, in a cost efficient way.

<u>Neither the MAC nor the MEC is known from the start.</u>
Here the Höglund tax could also be a useful tool to reach a certain level of pollution in a cost efficient way. Of course the level of pollution could be adjusted as more and more information about the MEC is gathered over time.

Another potential issue is that the policy subjects firms to uncertainty. Under a standard static pollution tax, firms are relatively certain of the tax level in the short-term. In the longer-term, the tax level is more likely to change, in order to match changing technologies, new information, etc. Arguably, in the long-term, a static tax is not very static. Höglund's tax on the other hand subjects firms to both short-term and long-term uncertainty. In the short-term, the tax fluctuates according to the actions of traders on an open market. In the long-term, changes in technology and the spread of technology through the economy will also change the level of the tax. The issue that needs the be addressed here is how much these different types of uncertainty cost the economy. These costs can then be weighed against the benefits of the a static tax versus Höglund's flexible tax. A final issue regarding Pigouvian taxes in general (Höglunds or otherwise), is that though they are arguably more economically efficient, they are also generally considered more regressive. Practically however, implementing new taxes is done in an economy that is already subject to varying degrees of taxation. The real question whether or not the new policy regime performs better than the older policy regime,[54] i.e. which taxes are removed and which taxes are applied and what is the result on the economy?

The concept combines those efficiency advantages of a pollution tax with an innovative way of setting the level of the tax using the decisions of individual firms acting on an open market. Future research will hopefully shed light on the viability of the concept, but may also help improve other existing environmental policies.

5 Recommendations and Next Steps

5.6 Future research

Höglund's tax policy deserves a more detailed analysis in order to properly establish its advantages and disadvantages with respect to other pollution policies. The role of any further analysis will be to better quantify the costs and the benefits of Höglund's Tax with respect to other more established environmental policies. Two principle areas of study are identified.

Firstly, a better understanding of the market structure of the pollution tax is required. Issues such as the valuation of pollution futures contracts, structuring the contracts, governance and regulation need to be more carefully considered and studied. This will provide a better foundation for understanding the economic implications of a pollution tax market as envisaged by Höglund.

Another, equally important area that needs to be explored are the costs and benefits of Höglund's tax with respect to other environmental policies. The viability of Höglund's tax not only depends on whether or not it could function but also on how if performs in terms of efficiency, distribution, enforceability, and so forth. Under what type of scenarios would Höglund's tax be most effective in terms of efficiency and distribution? This area of work alone represents a substantially complex exercise in itself.

There are other issues that require further analysis. How would government start the market? At what level is the signal from the tax strong enough to bring about abatement investments and also induce firms to hedge their abatement investments on the market? So far, the analysis here as assumed that the level of the carbon tax actually sends a strong enough signal. Barriers to entry or high transaction costs the preclude firms from participating in the market.

The analysis of Höglund's tax presented here seeks to not only provide a better understanding of the tax concept, but to also lay the groundwork for future analysis. It is our hope that this paper

[54] As argued by Sterner (2003)

will play a part in spurring futher work and that it will extend our understanding of environmental policy design.

There are a number of research funds that could support further development Höglund's tax. Some examples are listed below:

SSS Strategiska Forskningsstiftelsen: http://www.stratresearch.se

KAW Knut och Alice Wallenbergs Stiftelse: http://wallenberg.org

MISTRA Stiftelsen för miljöstrategisk forskning: http://www.mistra-research.se/

RJ Stiftelsen Riksbankens Jubileumsfond: http://www.rj.se/

STINT Stiftelsen för internationalisering av högre utbildning och forskning:

http://www.stint.se/

Vårdal Stiftelsen för vård- och allergiforskning: http://www.vardal.se/

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Appendix A – Höglund's description of the policy proposal

En terminsmarknad för miljöavgifter
En effektiv metod att minska utsläppen av växthusgaser
av Anders L Höglund, MScEngPhys

SAMMANFATTNING
Marknadspriser kan fungera som effektiva informationsbärare av resurskostnader i komplexa ekonomiska system. En nödvändig förutsättning för att marknadspriser ska kunna styra samhällets resursanvändning på ett acceptabelt sätt är att kostnader för miljöpåverkan är internaliserade i marknadsekonomin.
Med priser som inkluderar tillräckligt höga avgifter för utsläpp av växthusgaser, är det möjligt att uppnå en styrverkan i ekonomin som minskar utsläppen av sådana gaser till en långsiktigt uthållig nivå.
Här beskrivs en metod att synliggöra kostnaderna för minskning av miljöstörande utsläpp och att fördela utsläppsminskningen så att samhällsekonomisk kostnadseffektivitet uppnås i både tid och rum.
Metoden kan göras konkurrensmässigt neutral, såväl nationellt som internationellt. Den kan alltså tilllämpas av ett enskilt land eller, med fördel, av flera länder i samverkan. Av naturliga skäl blir metoden mest effektiv om den tillämpas globalt.
Metoden har fördelen att de väl fungerande och effektiva svenska reglerna och rutinerna för indrivning av miljöavgifter kan behållas.

1 INLEDNING

1. Det är, i de flesta fall, svårt att värdera de långsiktiga samhällsekonomiska kostnaderna som har orsakats och som kommer att orsakas av miljöstörande utsläpp. Att kostnaderna för de miljöstörande utsläppen dessutom varierar i både tid och rum gör värderingen ännu osäkrare. Osäkerhet om verkliga kostnader och avsaknad av konkreta priser leder i sin tur till osäkerhet i ekonomiska beslut. Följden blir att livsviktiga, långsiktigt hållbara, investeringar uteblir eller blir kraftigt fördröjda på grund av bristande incitament.
2. Det existerar dock en enkel och allmängiltig princip för indirekt värdering av en ren miljö. Principen är att låta den genomsnittliga kostnaden för att undvika miljöstörande utsläpp bestämma en avgift som läggs på utsläppen.
3. En avgift på utsläpp, vilken avspeglar den genomsnittliga kostnaden för utsläppsminskning, ger företag med högre kostnader än genomsnittet en tidsfrist, det vill säga en möjlighet till ordnad anpassning eller avveckling med minsta möjliga kapitalförstöring, och företag med lägre kostnader än genomsnittet ett tillräckligt starkt incitament att minska sina utsläpp.
4. Det betyder att den praktiskt omöjliga uppgiften att värdera den totala samhällsekonomiska kostnaden för miljontals delutsläpp, kan reduceras till den hanterbara uppgiften att finna den genomsnittliga kostnaden för utsläppsminskning.
5. Den förenklade uppgiften att finna genomsnittskostnaden kan lösas genom användning av ett effektivt och beprövat verktyg – terminskontraktet.

2 EN MARKNADSEKONOMISK METOD

1. Om miljöavgiften för utsläpp av ett visst miljöstörande ämne är mycket högre än kostnaden för utsläppsminskning leder det visserligen till en snabb minskning av utsläppen av detta ämne, vilket kan vara synnerligen gynnsamt för miljön, men risken finns att miljöförbättringen åtföljs av en samhällsekonomisk förlust som är större än värdet av miljöförbättringen. Detta på grund av kapitalförstöring genom en alltför snabb avveckling och utskrotning av funktionsdugliga anläggningar, med mera. Observera dock att en sådan temporär kapitalförstöring inte nödvändigtvis behöver innebära någon minskad sysselsättning, någon minskad tillväxttakt i BNP eller några långsiktiga skador på samhällsekonomi och människor.
2. Om avgiften, å andra sidan, är mycket lägre än kostnaden för utsläppsminskning fortsätter utsläppen vilket med tiden kan leda till synnerligen höga kostnader. I detta fall är risken överhängande för långsiktiga, irreversibla skador på miljö, samhällsekonomi och människor.
3. Någonstans mellan dessa ytterligheter finns det en avgiftsnivå, som är lagom hög, för uppnåendet av samhällsekonomisk kostnadseffektivitet i en långsiktigt uthållig samhällsutveckling.
4. Av resonemanget ovan följer att den erforderliga miljöavgiften för samhällsekonomisk kostnadseffektivitet kan förväntas hamna i närheten av den genomsnittliga kostnaden för utsläppsminskning. Vid en sådan nivå på miljöavgiften är det möjligt att fortsätta att effektivt utnyttja befintligt realkapital som då kan samexistera med nytt miljöanpassat realkapital. Under dessa förutsättningar kommer gammal teknologi kontinuerligt att bytas ut mot ny. Omvandlingstakten kommer att vara beroende av det aktuella realkapitalets genomsnittliga åldringstakt (avskrivningstakt).
5. En terminsmarknad är i första hand en pris- och kostnadsförsäkringsmarknad och som en sådan lockar den fram ett pris- och kostnadsavslöjande beteende hos aktörerna. Det är därför möjligt att använda en terminsmarknad för att finna den sökta genomsnittliga nivån på utsläppskostnaderna.
6. Handeln i terminskontrakt på en 'Miljöbörs' kan fungera enligt samma principer som handeln i terminskontrakt på en råvarubörs. Denna form av handel har visat sig kunna ge god likviditet och låga transaktionskostnader – nödvändiga förutsättningar för en effektiv resursallokering. De regler och säkerhetskrav som sedan många år är etablerade på terminsmarknaderna kan också tillämpas på en Miljöbörs.
7. Följande villkor gäller för miljöterminer:
8. Terminskontraktet är ett bindande avtal mellan köpare och säljare om framtida leverans av miljöavgiften, för en given utsläppsmängd, av ett givet ämne, under en given avgiftsperiod, till ett bestämt pris – kontraktspriset vid avtalets ingående.
9. Leverans innebär en enkel avräkning mot terminskontraktets marknadspris på slutdagen.
10. Rent handelstekniskt är miljöterminerna identiska med vanliga terminskontrakt (futures) av samma typ som handlas på råvarubörsen COMEX i New York.

11. När en terminsmarknad för miljöavgifter har öppnats kan företag och privatpersoner införa kända framtida miljökostnader i sina budgetar, och genom att agera på marknaden, undvika onödigt risktagande.

12. De aktörer som finner det billigare att minska sina utsläpp än att betala miljöavgiften, kommer att vilja sälja kontrakt, om de önskar minska sin riskexponering. De som finner det billigare att betala miljöavgiften, än att minska sina utsläpp kommer att vilja köpa kontrakt, av samma anledning. Naturligtvis finns även utrymme för spekulanter vars aktivitet bidrar till att minska fundamentala fel i prissättningen och att öka likviditeten på marknaden. Eftersom miljöavgifterna måste betalas till RSV varje månad är de nödvändiga grundförutsättningarna för en fungerande marknad uppfyllda.

13. Under varje fastställd utsläppsperiod, till exempel, månad, betalar alla miljöavgiftsregistrerade företag, i förhållande till sina inköp av avgiftsbelagda ämnen, den av marknaden bestämda miljöavgiften för den givna perioden. Denna princip är allmängiltig och gäller oberoende av företagens agerande på marknaden och oberoende av eventuella kontraktsinnehav. Detta har fördelen att det enkelt, utan några förändringar eller komplikationer, går att tillämpa nuvarande regler och lagstiftning för indrivning av miljöavgifter på till exempel kolinnehållet i fossila bränslen. Observera att de flesta företag och alla privatpersoner endast kommer att betala indirekt för sina utsläpp. Så snart ett bränsle som innehåller fossilt kol har importerats kommer miljöavgiften för detta bränsle att ingå i marknadspriset på samma sätt som momsen.

14. En av Miljöbörsens funktioner är att tillhandahålla kontrakt som täcker en efterfrågad mängd utsläpp under en given tidsperiod och därmed göra det möjligt för en aktör, som så önskar, att försäkra sig om att kunna släppa ut en viss mängd till ett känt pris som är lika med det betalade priset på de ingångna kontrakten. Visserligen betalas den verkliga miljöavgiften under perioden, enligt ovan, men företaget har samtidigt gjort en vinst eller förlust som precis täcker mellanskillnaden.

15. En närmare analys av figur 1, som visar en hypotetisk fördelning av befolkningen som funktion av utsläppsmängd per individ, kan avslöja att cirka två tredjedelar av befolkningen i Sverige skulle gynnas av en miljöavgift på koldioxid, som återbetalades i lika andel till alla. Ett annat sätt att uttrycka samma sak är att konstatera att det i alla utsläppsfördelningar finns 'en svans åt höger' i diagrammet, som förskjuter genomsnittsmängden uppåt. Någon balanserande 'svans åt vänster' i diagrammet finns inte eftersom den nedre gränsen går vid nollutsläpp.

16. I många utvecklingsländer är resurs- och utsläppsfördelningen så skev att mer än fyra femtedelar av befolkningen skulle gynnas av miljöavgifter på utsläpp som återbetalades i lika andel till alla. En sådan omfördelning gynnar de resurssvaga, som genom omfördelningen får ökade resurser och köpkraft, vilket kan göras samhällsekonomiskt fördelaktigt. Visserligen missgynnas de resursstarka men de har full frihet att förändra sitt konsumtionsmönster, och flytta sig åt vänster i diagrammet, så att även de gynnas av omfördelningen av miljöavgifter. Naturligtvis är det precis sådana förändringar i konsumtionsmönstret som är själva poängen med införandet av miljöavgifter.

17. Att en omfördelning av miljöavgifter på detta sätt alltid gynnar en majoritet underlättar naturligtvis ett införande av tillräckligt höga avgifter på demokratisk väg.

18. Observera att nyintroducerade miljöavgifter som återbetalas fullt ut, till exempel via en allmän miljöfond, är budget- och skattemässigt neutrala.

3 STANDARDISERADE TERMINSKONTRAKT

1. Exempel på information i en standardiserad miljötermin:
2. UNDERLIGGANDE TILLGÅNG: Miljöavgiften för angivet ämne, i angiven mängd, under angiven avgiftsperiod.
3. ÄMNE: Koldioxid, från förbränning av fossilt bränsle, CO_2
4. MÄNGD: 1000 kg
5. AVGIFTSPERIOD: Juli månad 2010
6. SLUTDAG: Sista börsdagen i juni månad 2010
7. VILLKOR: Terminskontraktet är ett bindande avtal mellan köpare och säljare om framtida leverans av den underliggande tillgången till ett, på förhand, överenskommet pris. Leverans innebär en avräkning mot terminskontraktets marknadspris på slutdagen.

4 NIVÅN PÅ MILJÖAVGIFTERNA

1. En viktig faktor av betydelse för balansen på Miljöbörsen är att det är privatekonomiskt och företagsekonomiskt möjligt att minska sin riskexponering genom att sälja terminskontrakt när den egna kostnaden att minska utsläppen är lägre än börspriset och att köpa terminskontrakt när den egna kostnaden att minska utsläppen är högre än börspriset.
2. Utan möjligheten att säkra lönsamheten och konkurrenskraften, för miljöinvesteringar, riskerar företag, som satsar på reningsteknik eller alternativ teknik, att drabbas av lönsamhetsproblem i händelse av fallande utsläppsavgifter. Möjligheterna för företag och privatpersoner att kunna försäkra sig mot prisförändringar, räkna hem investeringar och säkra konkurrenskraften befrämjar en samhällsekonomiskt kostnadseffektiv resursfördelning.
3. De potentiella säljarna av terminskontrakt står för utsläpp vars elimineringskostnad är lägre än miljöavgiften och de potentiella köparna står för utsläpp vars elimineringskostnad är högre än miljöavgiften.
4. Dessa två komplementära strategier hos börsaktörerna medverkar till att priset på miljöterminerna styrs, naturligtvis med fluktuationer, i riktning mot den genomsnittliga kostnaden för utsläppsminskning.
5. Figur 2 visar en hypotetisk fördelning av koldioxidutsläppen i Sverige som funktion av kostnad för utsläppsminskning. Eftersom de breda staplarnas yta är proportionell mot utsläppsmängden finns en balans, med avseende på utbudsmängd och efterfrågemängd, enligt ovan, mellan aktörerna vars kostnader för utsläppsminskning ligger till vänster respektive till höger om den smala stapeln, som visar ackumulerad mängd, med längden 50 procent.
6. Det är utjämningen av kostnader och risk mellan aktörer med olika förutsättningar, genom handel i terminskontrakt, som styr miljöavgifterna i riktning mot de samhällsekonomiskt optimala. Det är denna samhällsekonomiskt önskvärda, kostnadsavslöjande, funktion som kanske är det tyngsta argumentet för en Miljöbörs.
7. En Miljöbörs kan, precis som en råvarubörs, fungera även utan spekulation, enbart med aktörer som agerar med avsikt att försäkra sig mot prisförändringar. En lagom volym av spekulativ handel är dock fördelaktig eftersom den ökar likviditeten på marknaden.

5 NYTTIGA EFFEKTER AV MILJÖBÖRSAKTIVITET

1. Förutom att utsläppen av miljöstörande ämnen successivt kommer att minska, när utsläppsminskande åtgärder, med en kostnad som är lägre än miljöavgiften, blir lönsamma, medför Miljöbörsen flera andra nyttoeffekter.
2. Miljöbörsen kommer att avspegla företagens kostnader för utsläppsminskning och alternativ teknik men börsen kommer också att locka fram, och påverkas av, analyser av miljöavgifternas företagsekonomiska och samhällsekonomiska effekter.
3. Miljöavgifterna måste variera, om de ska kunna uppfylla det primära kravet att styras av, och avspegla, aktörernas varierande kostnader och den information som finns tillgänglig och som ständigt omprövas och fördjupas.
4. Miljöbörsen kommer precis som en råvarubörs vara utsatt för falsk information. Detta är nödvändigt för upprätthållandet av aktörernas förmåga till kritisk analys och värdering av den information som är av betydelse för prissättningen. Ett 'steriliserat' informationsflöde, befriat från all vilseledande information kan ha en förödande inverkan på börsens 'immunförsvar' mot skadlig spekulation.
5. Med en fungerande Miljöbörs blir det lönsamt att satsa på forskning, både på bredden och på djupet, som leder fram till ny kunskap, ny teknologi och ny infrastruktur, som naturligtvis kommer att återverka på börsen. Denna ekonomiska återkoppling är önskvärd, eftersom information om och kunskap om verkligheten är en grundförutsättning för effektiva beslut.
6. Miljöbörsen kompletterar marknadsekonomin, genom att internalisera, med andra ord; värdera och inkludera, samhällsekonomiskt skadliga effekter som annars skulle hamna utanför marknadsekonomin. Miljöbörsen har alltså egenskapen att kunna harmonisera privatintresse och samhällsintresse, mikroekonomi och makroekonomi.
7. Den samhällsekonomiska potentialen i en kompletterad, samhällsanpassad, marknadsekonomi är synnerligen hög. Den kan dessutom avlasta politikerna den demokratiskt svårhanterliga uppgiften att fatta impopulära beslut, med avseende på de miljö- och resursfördelningsproblem som hotar miljarder människors existens.

8. Om tanken på en helt marknadsstyrd prissättning av miljöavgifter inte är politiskt acceptabel är det dock inget som hindrar att en Miljöbörs introduceras samtidigt som någon övervakande statlig myndighet, så länge som det anses nödvändigt, regelbundet justerar nivån på de miljöavgifter som ska betalas in till RSV. I ett sådant läge kommer Miljöbörsen att fylla två viktiga funktioner, dels som ett prognosinstrument dels som en försäkringsmarknad med avseende på framtida justeringar av miljöavgifterna.
9. De flesta positiva samhällsekonomiska effekter som är förknippade med en Miljöbörs kommer att göra sig gällande även vid valet av en kompromisslösning med avseende på prissättningen av miljöavgifterna.

6 FRÅGOR OCH SVAR

1. Miljöbörsen bygger på enkla marknadsekonomiska principer, men eftersom den även baseras på ett visst mått av nytänkande finns det åtskilliga invändningar och frågor:
2. **Fråga 1:** En fungerande marknad kräver att alla som berörs av marknaden kan påverka priset genom att visa sina önskemål och preferenser. Hur kan det ske på Miljöbörsen?
3. **Svar 1:** Påståendet och frågan bygger på en missuppfattning av marknadens sätt att fungera. I det inledande påståendet ligger ett underförstått krav om att aktörerna ska kunna påverka eller styra priset efter sina önskemål och preferenser. Till exempel genom att välja att agera som köpare, i avsikt att höja miljöavgiften på något ämne, för att minska utsläppen av detsamma.
4. Priset på utsläpp bör inte, och ska inte, styras på det sättet eftersom det skulle innebära en helt och hållet spekulationsstyrd marknad. Det strider mot de grundläggande principerna för fungerande marknader. Vi kan dessutom konstatera att en fri marknad har naturliga skyddsmekanismer mot ett sådant missbruk. Historien är full av misslyckade försök att tvångsstyra marknader.
5. Det är inte stora eller små aktörers önskningar eller vilja att styra eller påverka som ska vara den grundläggande prisbestämmande principen på en fungerande marknad, utan en sammanvägning av många enskilda mikroekonomiska beslut om köp eller försäljning baserade på konkreta, privatekonomiska och/eller företagsekonomiska överväganden vid aktuellt börspris. Ett visst mått av spekulation kan vara gynnsamt för likviditeten på marknaden och behöver inte nödvändigtvis skada prisbestämningsprincipen.
6. För en försäkrare (hedger) på Miljöbörsen räcker det att göra en enkel analys av egen nytta, av köp respektive försäljning, beroende på hur stor mängd som ska prissäkras.
7. För en risktagare, det vill säga spekulant (trader), är förutsättningarna för beslutsfattande annorlunda och utan en djupare kunskap och kompetens, för analys av fundamentala faktorer, blir risktagaren, i längden, en förlorare på marknaden.
8. Råvarubörserna fungerar, trots att endast en liten minoritet av befolkningen agerar på dessa marknader. De flesta människor lever i okunnighet om prisbildningen på råvarubörserna. Dessutom är som regel terminskontrakten så stora att de, kostnadsmässigt, ligger utom räckhåll för de flesta privatpersoner. Resurser fördelas, trots detta, genom att kostnader för råvaror, förr eller senare, kommer att avspegla sig i priset på olika varor. Slutkonsumenterna styr sedan resursfördelningen, indirekt, genom alla led, ända upp till råvarunivå, genom att agera mikroekonomiskt och köpa varor och tjänster, efter eget huvud, för sina pengar. Den efterfrågefördelning som då uppstår sänder signaler, till mellanhänder och producenter, om hur resurser bör fördelas för att ge bästa avkastning. På samma sätt som en råvarubörs sänder även Miljöbörsen ekonomiska signaler genom hela ekonomin.
9. Naturligtvis är det också möjligt att bestämma storleken på terminskontrakten på Miljöbörsen, så att de i praktiken hamnar utom räckhåll för majoriteten av medborgarna. Men eftersom miljöavgifterna, indirekt, kommer att ha en betydande inverkan på medborgarnas privatekonomi, kan det vara pedagogiskt motiverat att storleken på kontrakten avpassas så att möjlighet finns även för privatpersoner, utan förmögenhet, att agera på börsen.

10. Ingen är tvungen att göra några makroekonomiska analyser i en marknadsekonomi, för att kunna agera rationellt, utan det räcker att optimera resursfördelningen mikroekonomiskt – det vill säga företagsekonomiskt och/eller privatekonomiskt.
11. **Fråga 2:** Vem ska bestämma priset på terminskontrakten och vem ska bestämma den totala mängden utsläpp och takten i utsläppsminskningen?

12. **Svar 2:** Denna fråga bygger på en missuppfattning om Miljöbörsens funktion. Vem bestämmer den totala mängden av en vara och/eller priset på denna vara? Det är bäst att låta utbud och efterfrågan avgöra detta. Tidigare erfarenheter visar att försök till planstyrning av utbud och/eller prissättning i de flesta fall medför samhällsekonomiskt negativa konsekvenser.

13. På Miljöbörsen kommer utbud och efterfrågan på terminskontrakt att bestämma priset. Detta pris kommer att påverka den totala mängden utsläpp, fördelningen av utsläpp, takten i utsläppsminskningen samt fördelningen av utsläppsminskningen, på ett samhällsekonomiskt effektivt sätt.

14. Eftersom framtiden är oviss, kommer en terminsmarknad, där priset tillåts variera fritt och där priset på terminskontrakten bestämmer en avgift för miljöstörande utsläpp, vilken måste betalas enligt lag, att locka fram ett beteende hos aktörerna, vilket indirekt visar deras individuella kostnader för minskning av utsläppen, genom deras beslut om köp och försäljning av terminskontrakt.

15. Den samhällsekonomiskt effektiva avgiften för minskning av utsläpp kommer att variera att vara starkt kopplad till den genomsnittliga kostnaden för utsläppsminskning.

16. Marknadens prissättning av utsläppen kan ses som en sammanvägning av alla aktörers tillgängliga information, verklighetsuppfattning, kunskaper och bedömningar – ofta motstridiga och varierande. Det kan, spontant, vara svårt att acceptera den typen av oprecist beslutsfattande, i ett så, till synes, ofullkomligt ekonomiskt system, inom ett område som är så viktigt för samhället. Ingen har dock kunnat bevisa att det existerar något effektivare system. Betänk att även samhällets främsta experter kan ha diametralt olika åsikter i miljö- och värderingsfrågor.

17. **Fråga 3:** Måste alla som gör utsläpp köpa terminskontrakt som täcker utsläppen?

18. **Svar 3:** Nej, börsen är öppen för alla aktörer men det behövs inget krav att alla som gör utsläpp måste köpa terminskontrakt som täcker dessa utsläpp. Det vore samhällsekonomiskt oförsvarbart, på grund av alltför höga transaktions- och kontrollkostnader. Däremot måste det med nödvändighet vara ett lagkrav att miljöavgifter ska betalas regelbundet av de företag som ålagts redovisningsskyldighet för utsläpp, tillverkning, utvinning och/eller import av direkt eller potentiellt miljöstörande ämnen, i aktuell tillämpning; fossilt kol. Marknadsekonomin ser sedan till att kostnaderna genomsyrar ekonomin och påverkar alla ekonomiska beslut direkt och/eller indirekt. Men även dessa redovisningsskyldiga företag har full frihet att välja mellan att agera på börsen eller att avstå.

19. **Fråga 4:** Vad hindrar att företag eller privatpersoner dumpar priset, genom att utfärda obegränsat med terminskontrakt när kravet på fysisk leverans är borttaget?

20. **Svar 4:** Motkrafterna som förhindrar ohämmad spekulation och skadlig samverkan mellan aktörer, är bland andra:

1. de verkliga kostnaderna för minskning av utsläpp
2. den kontantinsats som alltid avkrävs aktörerna och som är proportionell mot antalet sålda (utfärdade) kontrakt och starkt kopplad till de verkliga kostnaderna för minskning av utsläpp – en effektiv broms mot spekulativt massutfärdande av kontrakt i avsikt att dumpa priset
3. den hävstångsverkan som ökar utan gräns för köparen, när kontraktspriset går mot noll, eftersom köparen av ett kontrakt alltid bara behöver betala aktuellt pris för kontraktet (den maximalt möjliga förlusten har en övre gräns som är lika med det betalade priset och som nås om kontraktets marknadspris faller till noll) medan däremot säljaren, som utfärdar kontraktet, måste ställa en extra säkerhet (på grund av att den maximalt möjliga förlusten saknar en övre gräns när kontraktets marknadspris stiger) som blir allt större, relativt kontraktspriset, när priset sjunker
4. miljömedvetna företag, föreningar, grupper och individer som medvetet vill utnyttja en eventuell hävstångseffekt genom att köpa kontrakt för egen vinning och/eller för att höja marknadspriset av miljöskäl
5. den kontinuerliga utslagningen av misslyckade spekulanter vars resurser (pengar) tar slut
6. den spekulation som med tiden eliminerar alla observerbara systematiska prisförändringar och trender som inte beror på verkliga underliggande kostnadsförändringar med andra ord; marknaden serverar inga 'fria luncher'
7. den med tiden ökande kunskapen och erfarenheten hos aktörerna och börsmäklarna
8. massmedia och det fria informationsflödet som naturligtvis kan innehålla information om de motkrafter som nämnts här ovan

21. I inget av dessa avseenden är det något som skiljer terminshandeln på Miljöbörsen från terminshandeln på en råvarubörs. Observera att säkerhetskravet, det vill säga kravet på en kontantinsats, vid utfärdandet av terminskontrakt sätter en definitiv övre gräns för det antal kontrakt som kan utfärdas eftersom mängden finansiellt kapital är begränsad.

22. Praktiskt taget alla funktioner som finns på Miljöbörsen, finns även på en råvarubörs och praktiskt taget alla invändningar och frågor som uppstår i samband med Miljöbörsen kan besvaras genom en hänvisning till reglerna för terminshandel på en råvarubörs.

23. Det finns redan marknader där kravet på fysisk leverans är ersatt med avräkning på stängningsdagen. En sådan är penningmarknaden, där handel sker i standardiserade terminskontrakt på räntebärande värdepapper. Den frivilliga möjligheten till leverans är till och med belagd med en straffavgift som tas ut av bankerna och fondkommissionärerna för att ge kunderna incitament att inte göra avslut med leverans.

24. **Fråga 5:** Vad hindrar att marknaden påverkas av rykten, falsk information, bedrägerier och liknande störningar?

25. **Svar 5:** Ingenting annat än aktörerna själva. Det är olämpligt, och på lång sikt skadligt, att skydda en marknad mot sådant. Bättre är, att informera om värdet och nödvändigheten av kritisk granskning och kompetent analys av kurspåverkande information samt om riskerna förknippade med spekulation. Inte heller här skiljer sig Miljöbörsen från en vanlig råvarubörs.

26. **Fråga 6:** Är det lämpligt att återbetala miljöavgifterna till företagen?

27. **Svar 6:** Det är mindre lämpligt med en återbetalning av miljöavgifterna till företagen på grund av den fundamentala svårigheten att finna en snedvridningsfri princip för en sådan återbetalning. För att undvika att prissignalerna förvanskas måste en sådan återbetalning vara kopplad till samhällsnyttan hos företagens produkter, vilken är vansklig att beräkna.

28. Det finns en, långsiktigt hållbar, princip för bedömning av produktnytta. Den utgörs av konsumenternas beslut om köp, eller icke köp, av produkterna på en fri marknad. Observera att denna princip, indirekt, leder till en återbetalning av miljöavgifterna till företagen. Därför bör återbetalningen av miljöavgifterna i första hand ske till konsumenterna och helst i lika andel till varje individ. Detta är ett naturligt framtida steg som kan tolkas som att alla och ingen äger planeten därför bör vi betala till varandra när vi tar dess resurser i anspråk. Att så snart som möjligt uppnå ett globalt samarbete inom detta område vore det bästa för planetens framtid.

29. Naturligtvis kan inkomsterna från miljöavgifter, helt eller delvis, även användas för sänkt skatt på arbete, med andra ord till en skatteväxling.

30. **Fråga 7:** Kommer inte omsättningen på Miljöbörsen att upphöra när berörda företag väl en gång har gjort sina transaktioner med avseende på framtida utsläpp?

31. **Svar 7:** Risken att omsättningen på Miljöbörsen skulle upphöra efter en viss tid är inte större än att omsättningen i en aktie på Aktiebörsen skulle upphöra efter fullbordad aktieemission, eller att handeln i terminskontrakt skulle upphöra på en råvarumarknad. Det kommer alltid att finnas ett behov av löpande kostnadssäkring av investeringar och utsläpp.

32. **Fråga 8:** Blir inte marknadsprissättningen av miljöstörande utsläpp felaktig när priset på Miljöbörsen inte har någon direkt koppling till kostnaderna för skadeverkningarna av utsläppen?

33. **Svar 8:** Miljöbörsen är inte till för att prissätta de skador som orsakas av miljöstörande utsläpp utan endast för att prissätta själva utsläppen, så att de bakomliggande orsakerna till skadorna elimineras på ett samhällsekonomiskt kostnadseffektivt sätt.

34. Miljöproblemen beror inte på att våra kunskaper om skadeeffekterna och skadekostnaderna är för dåliga eller att det saknas tekniska möjligheter att minska utsläppen. Vi vet redan tillräckligt för att inse att det krävs omedelbara åtgärder. En kvalificerad majoritet av experter, forskare, politiker och medborgare har sedan länge varit överens om att utsläppen av miljöstörande ämnen måste minskas. Vad som hittills har saknats är demokratiskt genomförbara metoder med tillräckligt starka ekonomiska styrsignaler som gör utsläppsminskande åtgärder tillräckligt lönsamma.

35. **Fråga 9:** Blir inte miljöavgifterna alldeles för höga om miljömålen ska kunna uppnås med en avgiftsmetod? Är det inte bättre och billigare att staten emitterar utsläppsrätter för en utsläppsmängd som uppfyller miljömålen?

36. **Svar 9:** Frågan bygger på en missuppfattning. Om man bortser från skillnader i transaktionskostnader kostar det lika mycket att uppnå ett givet miljömål med utsläppsrätter som med avgifter. Den totala kostnaden för alla utsläppstillstånd vid en given total utsläppsnivå är lika stor som den totala

miljöavgiften vid samma utsläppsnivå. För ett företag spelar det ingen roll om det betalar en miljöavgift för en viss utsläppsmängd eller om det betalar ett utsläppstillstånd för samma utsläppsmängd.

37. Skillnaderna i systemkomplexitet, transaktionskostnader och likviditet mellan de båda metoderna talar dock entydigt till avgiftsmetodens fördel.

38. Observera att en av de grundläggande principerna med Miljöbörsen är; att avgiften, som sätts av börspriset, ska kunna variera i tiden för att kunna bestämma inte bara storleken på utsläppsminskningen utan även takten i utsläppsminskningen.

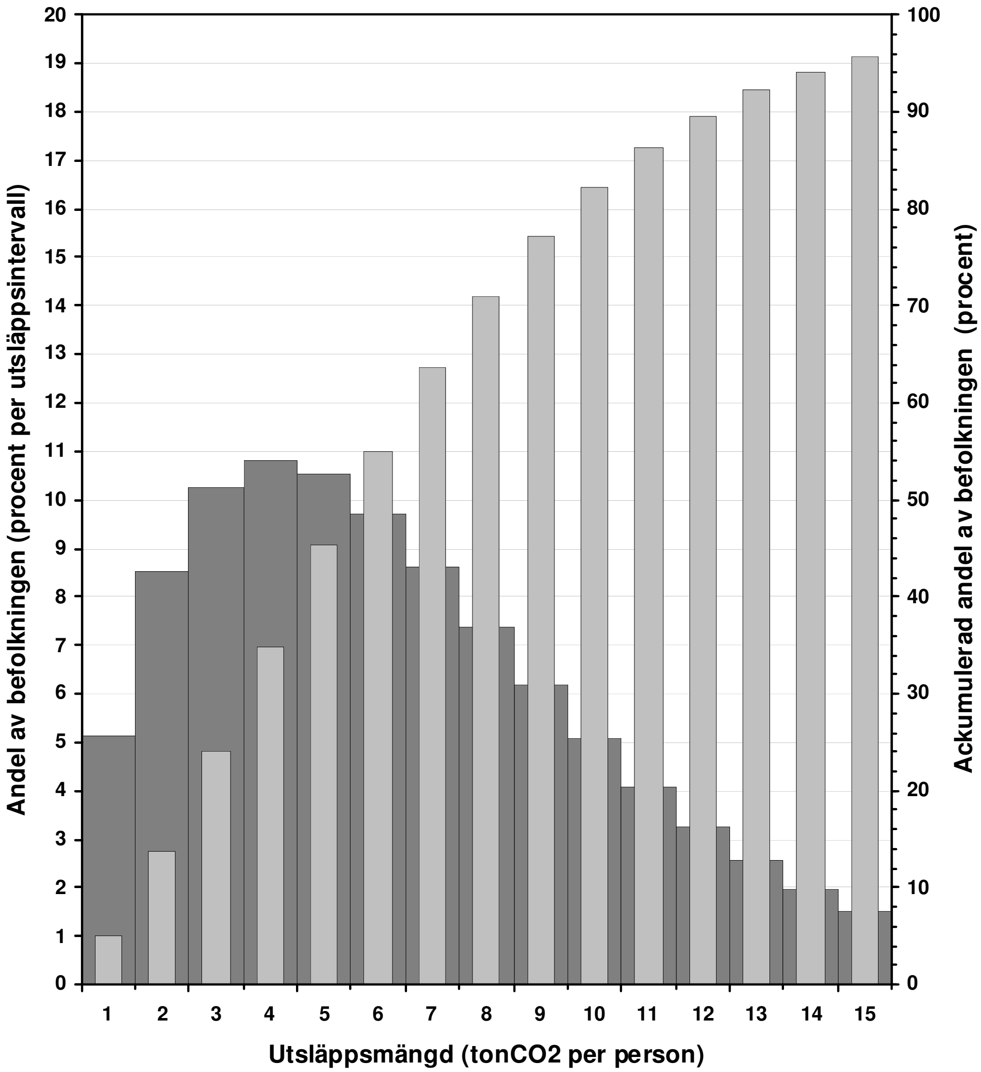
39. För Sveriges del finns också möjligheten att behålla nuvarande effektiva system för indriving av miljöavgifter och att komplettera det med en Miljöbörs.

40. **Fråga 10:** Blir det inte väldigt dyrt för samhället att minska utsläppen av växthusgaser till en långsiktigt uthållig nivå och sjunker inte tillväxttakten i BNP oacceptabelt mycket?

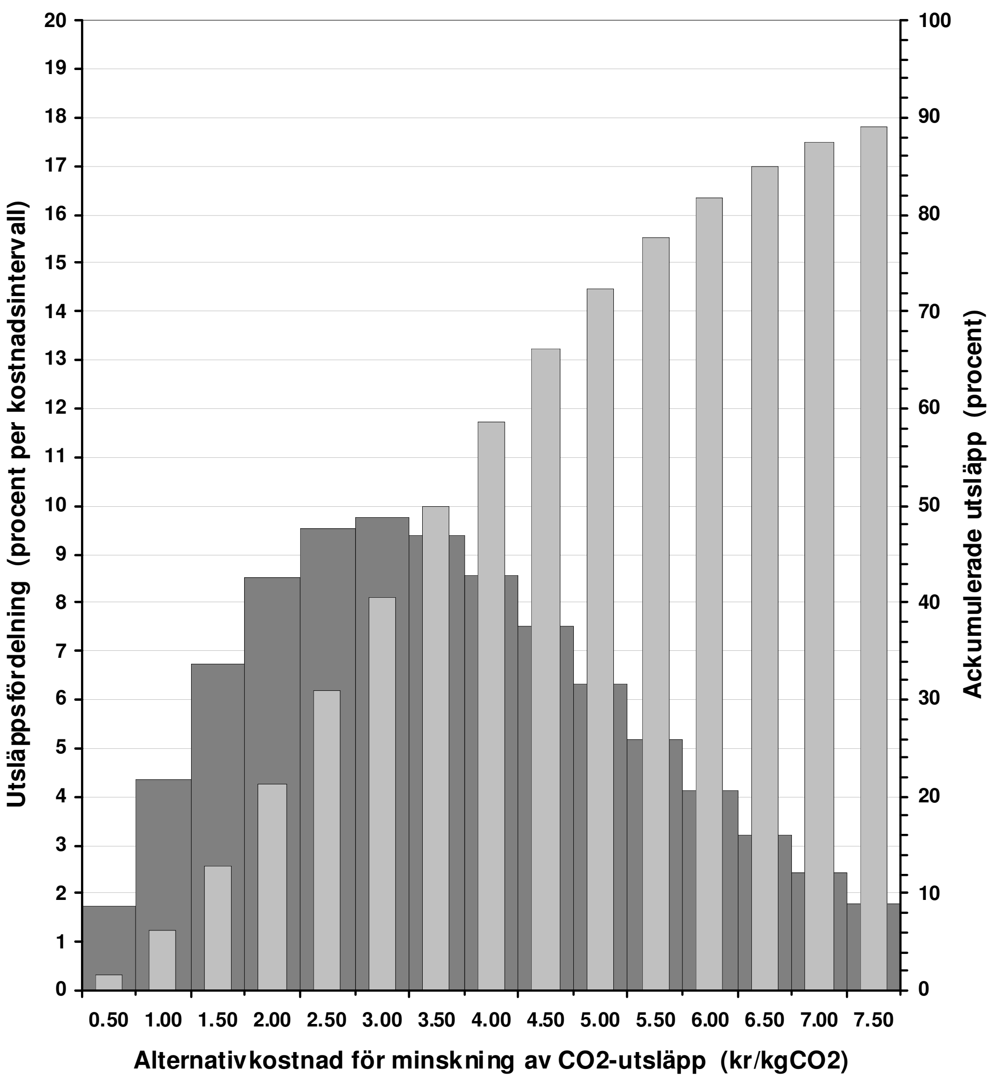
41. **Svar 10:** Frågan baseras på en överförenklad och vilseledande syn på verkligheten. Miljöavgifterna, även om de för Sveriges del skulle uppgå till åtskilliga procent av BNP i framtiden, är inga verkliga kostnader för samhället utan endast en omfördelning av finansiella resurser. Dessutom motsvaras varje utgift för en utsläppsminskande investering av en exakt lika stor inkomst i samhällsekonomin. Ett exempel: När ett företag investerar och betalar för en ny miljöanpassad produktionsanläggning så är det naturligtvis en kostnad för just det företaget men för det företag eller de företag som levererar anläggningen blir denna kostnad en exakt lika stor inkomst som räcker till insatsvaror, löner, skatter, räntor, avgifter, med mera. Om efterfrågan i samhällsekonomin optimeras, med hjälp av en samhällsekonomiskt sund finans- och penningpolitik, så behöver ingen oönskad arbetslöshet uppstå vid en fri marknadsprissättning av miljöavgifterna. Det finns heller ingen anledning att låta ökningstakten i BNP påverkas negativt vid en långsiktigt uthållig samhällsutveckling. Tvärtom, i den nuvarande eran, med en, i de flesta länder, oacceptabel och problemskapande arbetslöshet kan en miljöanpassad resursomfördelning, enligt de villkor som beskrivits ovan, med åtföljande ökad köpkraft hos de grupper som använder en relativt större andel av sina inkomster till konsumtion än genomsnittet, innebära en synnerligen välgörande tillväxtinjektion i ekonomin.

7 FIGURER

Figur 1. Hypotetisk fördelning av befolkningen i Sverige som funktion av CO2-utsläpp



Figur 2. Hypotetisk fördelning av CO2-utsläpp i Sverige som funktion av alternativkostnad



Appendix B – Simulation's basic assumptions and source code listing

- All curves are hypothetical macroeconomic curves based on the aggregate of 'assumed microeconomic distribution curves' for the type of pollutant emission modeled.
- The 'green curve(s)' show(s) the distribution of pollutant emissions as a function of marginal abatement cost.
- The total surface area below the green curve is, by definition, equal to the total amount of emissions.
- The 'red curve' is the integral of the green curve and shows the accumulated amount of pollutant emissions as a function of marginal abatement cost.
- The 'blue curve' is the complement of the red curve and shows the difference between the total amount of emissions and the accumulated amount shown by the red curve.
- The pollutant emissions abatement process is shown by the successive shifts in the green curve, downward and to the right, the area between two successive curves is proportional to the amount of abated pollutant emissions during each timestep interval.
- In the simulation, the actors behavior is modeled from the assumption that; The greater the difference between a certain actor's pollutant emissions marginal abatement cost and the market price of pollutant emissions futures contracts (or the carbon tax), and the greater the amount of that actor's emissions at that abatement cost, the greater the willingness for that actor to buy a certain number of contracts to the market price. This gives rise to the modeled aggregate demand curve. And as a complement; The greater the difference between the market price of pollutant emissions futures contracts (or the carbon tax) and a certain actor's pollutant emissions marginal abatement cost and the greater the amount of emissions, for that actor, at that abatement cost, the greater the willingness to sell a certain number of contracts to the market price. This gives rise to the modeled aggregate supply curve.
- For the whole of the economy this can be mathematically expressed as; The change in the pollutant mass distribution curve at a certain point on the x-axis, as a function of time, is proportional to the level of the mass distribution curve, at that x-value, and the price difference between the abatement cost, shown by that same x-value, and the current pollution tax level, or market price. In compact mathematical form; $dY/dT = Constant * Y * (Xtax-X)$ where dY/dT is the time derivative of Y. This type of differential equation has an exponential decay function as a solution.
- The 'red curve', the same as the red curve above, is also the fundamental supply curve. It is assumed to be proportional to the amount of pollutant emissions with a marginal abatement cost below the cost shown on the x-axis.
- The 'blue curve', the same as the blue curve above, is also the fundamental demand curve. It is assumed to be proportional to the amount of pollutant emissions with a marginal abatement cost above the cost shown on the x-axis.
- The 'vertical green lines' show the pollution tax or the market price during the calculated time periods.
- The market price is assumed to approach the intersection of the supply curve and the demand curve when the market has been set free.
- The actors seek to hedge (insure) 100 percent of their abatement tax savings/expenses on the futures market.

- There is a negligible contribution of distorting speculation and irrationality.
- The market is efficient and mature. In other words, there are no problems concerning liquidity, inexperience, power concentration, etc.
- The transaction costs are sufficiently low to not disturbe the basic function and equilibrium if the market.
- All other relevant variables, such as; interest rates, inflation, growth, etc, are constant and/or stable enough to have a negligible disturbing influence on the market behavior.

CarbonSim Source Code Listing:

```
DefDbl A-Z

Sub CarbonSim()

'Program name:          CarbonSim 1.0
'Author name:           Anders L Hoglund
'Creation date:         05-01-12
'Latest revision date:  05-09-12


'Define dimensions of vectors

Dim f1(5001)
Dim f2(5001)
Dim sumf1(5001)
Dim sumf2(5001)

'Set constants

pi = 3.141593

xs = Form1.Picture1.ScaleWidth
ys = Form1.Picture1.ScaleHeight

DrawWidthParameter = 2
Form1.Picture1.DrawWidth = DrawWidthParameter


'Initialize first time period

nc = 500                    'Number of calculation points           'points
ns = 9                      'Number of pollution fee change steps   'steps

Prange = 15                 'Calculation price range                'SEK
P0 = 2                      'Abatement cost distribution parameter  'SEK
Pbegin = 0.19               'Initial market price                   'SEK
Pend = 0.91                 'Final market price                     'SEK

tcalc1 = 108                'Calculation time span                  'months
tcalc = tcalc1
vabt1 = 5                   'Abatement speed parameter              '(%/month)
vabt = vabt1

counter1 = 0
counter2 = 0

CalculationParameter = 1


'Calculate initial mass distribution curve

For x = 0 To nc

    f1(x) = Exp(-Prange / P0 / Log(4) * x / nc)

Next


'Calculate  first time period

For i = 0 To tcalc
    counter1 = counter1 + 1

    If counter1 >= tcalc / ns Then

        counter2 = counter2 + 1

        counter1 = 0

    End If

    xmarket = Pbegin / Prange * nc + (Pend - Pbegin) / Prange * nc * counter2 / ns
```

```
    GoSub Calculate

    If i = 0 Then InitialAverageMarginCost = mean1 / nc * Prange

    If i < tcalc And CurveMemoryParameter = 0 Then Form1.Picture1.Cls

    Form1.Label1(0) = Format(i, "######0 months")
    Form1.Label1(1) = Format(xmarket / nc * Prange, "###0.#0 SEK")
    Form1.Label1(2) = Format(2 * Y6 / ys, "###0.0 %")
    Form1.Label1(3) = Format(CalculationParameter, "######0 periods")
    Form1.Label1(4) = Format(Y5 / ys, "######0 SEK")

Next i


MsgBox "First calculation time period completed"


'Initialize second time period

ns = 12              'Number of pollution fee change steps   'steps

tcalc2 = 12          'Calculation time span                  'months

tcalc = tcalc2

vabt2 = 5            'Abatement speed parameter              '(%/month)

vabt = vabt2

counter1 = 0
counter2 = 0

CalculationParameter = 2


InitialAverageMarginCost = mean1 / nc * Prange


'Calculate second time period

For i = 0 To tcalc
    counter1 = counter1 + 1

    If counter1 >= tcalc / ns Then

        counter2 = counter2 + 1

        counter1 = 0

    End If

    xmarket = Pend / Prange * nc + (mean1 - Pend / Prange * nc) * (counter2 / ns) ^ 0.5


    GoSub Calculate


    If i = 0 Then InitialAverageMarginCost = mean1 / nc * Prange

    If i < tcalc And CurveMemoryParameter = 0 Then Form1.Picture1.Cls

    Form1.Label1(0) = Format(i + tcalc1, "######0 months")
    Form1.Label1(1) = Format(xmarket / nc * Prange, "###0.#0 SEK")
    Form1.Label1(2) = Format(2 * Y6 / ys, "###0.0 %")
    Form1.Label1(3) = Format(CalculationParameter, "######0 periods")

Next i


MsgBox "Second calculation time period completed"


'Initialize third time period

ns = 120             'Number of pollution fee change steps   'steps

tcalc3 = 120         'Calculation time span                  'months
```

```
tcalc = tcalc3

vabt3 = 3              'Abatement speed parameter              '(%/month)

vabt = vabt3

counter1 = 0
counter2 = 0

CalculationParameter = 3

InitialAverageMarginCost = mean1 / nc * Prange


'Calculate third time period

For i = 0 To tcalc

    counter1 = counter1 + 1

    If counter1 >= tcalc / ns Then

        counter2 = counter2 + 1

        counter1 = 0

    End If

    xmarket = mean1

    GoSub Calculate

    If i < tcalc And CurveMemoryParameter = 0 Then Form1.Picture1.Cls

    Form1.Label1(0) = Format(i + tcalc1 + tcalc2, "######0 months")
    Form1.Label1(1) = Format(xmarket / nc * Prange, "###0.#0 SEK")
    Form1.Label1(2) = Format(2 * Y6 / ys, "###0.0 %")
    Form1.Label1(3) = Format(CalculationParameter, "######0 periods")

Next i

MsgBox "Third calculation time period completed"

GoTo Finish



Calculate:

For j = 1 To CInt(tcalc / tcalc)


'Initialize values

X10 = 0
X20 = 0
X30 = 0
X40 = 0
X50 = 0
X60 = 0

Y10 = 0
Y20 = 0
Y30 = 0
Y40 = 0
Y50 = 0
Y60 = 0


For x = 0 To nc


'Model the abatement speed as a function of emissions level and 'price distance' from
market price.  Trigonometric Sine function used for curve smoothing.

    If x < xmarket Then
```

```
'        If CalculationParameter = 2 Then vabt = vabt1 - (vabt1 - vabt2) * i / tcalc
'
'        f1(x) = f1(x) * (1 - vabt / 100 * Prange / nc * (xmarket - x))
'        f1(x) = f1(x) * (1 - vabt / 100 * Prange / nc * (xmarket - x) ^ 2 / xmarket)

        f1(x) = f1(x) * (1 - vabt / 100 * Prange / nc * (1 - Sin(pi / 2 * x / xmarket))
* (xmarket - x))

    End If

    f2(x) = x * f1(x)


'Integrate distribution curves

sumf1(0) = 0
sumf2(0) = 0

For k = 1 To nc

  sumf1(k) = sumf1(k - 1) + f1(k)
  sumf2(k) = sumf2(k - 1) + f2(k)

Next k


'Find price at 50 percent accumulated mass

For k = 1 To nc

  If sumf1(k) >= sumf1(nc) / 2 Then

    mean1 = k + (sumf1(nc) / 2 - sumf1(k - 1)) / (sumf1(k) - sumf1(k - 1)) - 1.1

    If CalculationParameter = 2 Then mean1 = k + (sumf1(nc) / 2 - sumf1(k - 1)) /
(sumf1(k) - sumf1(k - 1)) - 1.7

    Exit For

  End If

Next k

Next x


For x = 0 To nc


'Set curves


'Mass distribution curve

X1 = x / nc * xs
Y1 = (1 - 0.5 * f1(x)) * ys


'Fundamental market price line (position on x-axis)

X2 = mean1 / nc * xs
Y2 = (1 - 0.5) * ys


'Cost distribution curve

'X3 = x / nc * xs
'Y3 = (1 - f2(x) / (nc * P0 * Log(4) / Prange)) * ys


'Actual pollution tax (position on x-axis)

X4 = xmarket / nc * xs
Y4 = (1 - 0.5) * ys


'Accumulated mass curve
```

```
X5 = x / nc * xs
Y5 = (1 - sumf2(x) / (nc * P0 * Log(4) / Prange) ^ 2) * ys


'Fundamental relative supply curve

X6 = x / nc * xs
Y6 = 0.5 * (1 - sumf1(x) / (nc * P0 * Log(4) / Prange)) * ys


'Fundamental relative demand curve

X7 = x / nc * xs
Y7 = 0.5 * (1 - (sumf1(nc) - sumf1(x)) / (nc * P0 * Log(4) / Prange)) * ys


'Fundamental trade volume distribution

'X8 = x / nc * xs
'
'If x < mean1 Then Y8 = 0.5 * (1 - 0.5 * sumf1(x) / (nc * P0 * Log(4) / Prange)) * ys
'If x > mean1 Then Y8 = 0.5 * (1 - 0.5 * (sumf1(nc) - sumf1(x)) / (nc * P0 * Log(4) /
Prange)) * ys



'Plot curves

CurveMemoryParameter = Form1.Check1(0)


'Mass distribution curve

Form1.Picture1.PSet (X1, Y1), RGB(0, 255 - CurveMemoryParameter * i * 150 / tcalc, 0)

If x > 0 Then Form1.Picture1.Line -(X10, Y10), RGB(0, 255 - CurveMemoryParameter * i *
150 / tcalc, 0)

If CalculationParameter = 3 And CurveMemoryParameter = 1 And i = tcalc Then
    Form1.Picture1.DrawWidth = DrawWidthParameter
    Form1.Picture1.PSet (X1, Y1), RGB(255, 255, 255)
    If x > 0 Then Form1.Picture1.Line -(X10, Y10), RGB(255, 255, 255)
End If


'Fundamental market price line (position on x-axis)

Form1.Picture1.DrawWidth = DrawWidthParameter
If CalculationParameter = 3 Then Form1.Picture1.Line (X2, Y0)-(X2, Y2), RGB(0, 255 -
CurveMemoryParameter * i * 150 / tcalc, 0)


'Cost distribution curve

'Form1.Picture1.PSet (X3, Y3), RGB(255, 0, 255)
'
'If x > 0 Then Form1.Picture1.Line -(X30, Y30), RGB(255, 0, 255)


'Actual pollution tax line (position on x-axis)

Form1.Picture1.DrawWidth = DrawWidthParameter
Form1.Picture1.Line (X4, Y0)-(X4, Y4), RGB(0, 0.75 * (255 - CurveMemoryParameter * i *
150 / tcalc), 0)


'Accumulated mass curve

'Form1.Picture1.PSet (X5, Y5), RGB(255, 255, 255)

'If x > 0 Then Form1.Picture1.Line -(X50, Y50), RGB(255, 255, 255)


'Fundamental relative supply curve

Form1.Picture1.PSet (X6, Y6), RGB(255 - CurveMemoryParameter * i * 150 / tcalc, 0, 0)
```

```
If x > 0 Then Form1.Picture1.Line -(X60, Y60), RGB(255 - CurveMemoryParameter * i * 150
/ tcalc, 0, 0)

If CalculationParameter = 3 And CurveMemoryParameter = 1 And i = tcalc Then
    Form1.Picture1.DrawWidth = DrawWidthParameter
    Form1.Picture1.PSet (X6, Y6), RGB(255, 255, 255)
    If x > 0 Then Form1.Picture1.Line -(X60, Y60), RGB(255, 255, 255)
End If


'Fundamental relative demand curve

Form1.Picture1.PSet (X7, Y7), RGB(0, 0, 255 - CurveMemoryParameter * i * 150 / tcalc)

If x > 0 Then Form1.Picture1.Line -(X70, Y70), RGB(0, 0, 255 - CurveMemoryParameter * i
* 150 / tcalc)

If CalculationParameter = 3 And CurveMemoryParameter = 1 And i = tcalc Then
    Form1.Picture1.DrawWidth = DrawWidthParameter
    Form1.Picture1.PSet (X7, Y7), RGB(255, 255, 255)
    If x > 0 Then Form1.Picture1.Line -(X70, Y70), RGB(255, 255, 255)
End If


'Fundamental trade volume distribution

'Form1.Picture1.PSet (X8, Y8), RGB(255 - CurveMemoryParameter * i * 150 / tcalc, 0, 255
- CurveMemoryParameter * i * 150 / tcalc)
'
'If x > 0 Then Form1.Picture1.Line -(X80, Y80), RGB(255 - CurveMemoryParameter * i * 150
/ tcalc, 0, 255 - CurveMemoryParameter * i * 150 / tcalc)


'Set previous values

X400 = X40
Y400 = Y40

X10 = X1
Y10 = Y1

X30 = X3
Y30 = Y3

X40 = X4
Y40 = Y4

X50 = X5
Y50 = Y5

X60 = X6
Y60 = Y6

X70 = X7
Y70 = Y7

X80 = X8
Y80 = Y8

Next x


Next j


'Draw grid

Form1.Picture1.DrawWidth = 1

XGridNumber = Prange
YGridNumber = 10

For x = 0 To xs Step xs / XGridNumber
    For Y = 0 To ys Step ys / YGridNumber
        Form1.Picture1.Line (0, Y)-(xs, Y), RGB(128, 0, 0)
```

```
        Form1.Picture1.Line (x, 0)-(x, ys), RGB(128, 0, 0)
    Next Y

Next x

Form1.Picture1.Line (0, ys / 2)-(xs, ys / 2), RGB(0, 128, 0)

DoEvents

Return

Finish:

End Sub


Option Explicit

Private Sub Command1_Click(Index As Integer)

    If Index = 0 Then

        Carbon

    End If

    If Index = 1 Then

        Picture1.Cls

    End If

    If Index = 2 Then

        End

    End If

End Sub

Private Sub Form_Load()
    Form1.Height = 11000
    Form1.Width = 15000
End Sub

Private Sub Form_Resize()
    Form1.Picture1.Height = Form1.ScaleHeight - Picture1.Top - Picture1.Left
    Form1.Picture1.Width = Form1.ScaleWidth - Picture1.Left * 2
End Sub
```

Appendix C - Reference Group Documents and presentation material

Appendix D – A Flexible Pollution Tax - Article