Eur J Law Econ (2007) 24:29–70
DOI 10.1007/s10657-007-9020-z

CO_2 emission allowance allocation mechanisms, allocative efficiency and the environment: a static and dynamic perspective

Stefan Weishaar

Published online: 1 August 2007
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Abstract The object of this paper is to place allocation mechanisms into a framework of Emission Trading Systems and thereby to establish a typology. It analyses how various assignment mechanisms deal with issues such as price determination, allocative efficiency and environmental considerations in a static and dynamic economy model. It analyses how allocation mechanisms are to be ranked and whether they serve the attainment of the general equilibrium. First the paper examines how market-based allocation mechanisms (auctions) perform in light of the above issues. Second the paper distinguishes between the two types of administrative allocation mechanisms: (1) financial administrative allocation mechanisms, combining payment schemes with bureaucratic expertise, and (2) free administrative allocation mechanisms, based inter alia on industrial policy considerations and on passed emission records (grandfathering). In particular, the value added of relative performance standards, which are for example included in the "Performance Standard Rate" (PSR) Emission Trading System, are examined as a means to provide allowances. The overall finding is that in a closed static economy and in the presence of an efficient trading market, different allocation methods produce equally efficient outcomes in allocative and environmental respects. With regard to an open dynamic economy, the impact of initial allocation mechanisms resembles those of a static closed economy. In such an economy the upper limit to the internalisation of negative externalities is given by operator's costs of environmentally harmful relocation and hence the cost burden placed upon operators is crucial. Auctions and financial administrative allocation mechanisms perform less well than free administrative mechanisms. Relative standard base mechanisms, constituting an important element of the PSR Emission Trading System, perform better than grandfathering schemes

S. Weishaar (✉)
Metro, Faculty of Law, University of Maastricht, P.O. Box 616, 6200 MD Maastricht,
The Netherlands
e-mail: Stefan.Weishaar@facburfdr.unimaas.nl

because they take into account abatement possibilities of industries, minimise stranded costs and do not give rise to time shifting of abatement projects. It is therefore concluded that allocation mechanisms merit more attention than the discussion relating to capped trade and trade without a cap.

Keywords Allocative efficiency · Allocation systems · Emission trading · CO_2 · Environment · Performance Standard Rate (PSR) · Grandfathering · Auction theory

JEL Classification K32 · Environment · Health and Safety

1 Introduction

Since 1991 the European Commission has taken various climate related initiatives to limit CO_2 emissions and improve energy efficiency. Measures included the promotion of electricity from renewable energy, voluntary commitments by carmakers and proposals on the taxation of energy products. In order to meet the European Greenhouse Gas[1] reduction goals committed under the Kyoto Protocol,[2] the European Commission launched the European Climate Change Program (ECCP). The ECCP aims at identifying and developing all necessary elements to implement the Kyoto Protocol,[3] and to attain the committed average annual reduction of 8% below 1990 levels during the years 2008–2012 (binding upon the old 15 EU Member States).

One element of the ECCP is the so-called European Emission Trading System. The theoretical idea to reduce pollution by emission trading is by no means new. It was already proposed by Dales (1968) and has been discussed in a European context for years.[4] In accordance with Directive 2003/87/EC[5] all Member States of the European Union were obliged to establish an emission-trading scheme as of 1st of January 2005. Around 5000 operators with approximately 12.000 installations participate in this multi-jurisdictional attempt to reduce CO_2 emissions from four broad sectors: energy (electric power, oil refineries etc.), the production and processing of ferrous metals (iron and steel), minerals (cement, glass and ceramics), pulp and paper.[6] The program is implemented in two phases: the first ranging from 2005 to 2007, and the second from 2008 to 2012 and then following 5 year periods,

[1] Greenhouse gases covered by the Kyoto Protocol are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), hydrofluorocarbones (HFCs), perflurocarbons (PFCs) and sulphur hexafluoride (SF_6).

[2] When reports indicated that mere stabilisation of Greenhouse Gas emissions were insufficient to prevent a climate change, members to the ''UN Framework Convention on Climate Change'' committed themselves in 1997 to emission reductions, the so-called Kyoto Protocol. Following the ratification by Russia in November 2004, the Kyoto Protocol entered into force in February 2005.

[3] The Council of the European Union approved the Kyoto Protocol on 25 April 2002. See Council Decision 2002/358/CE.

[4] See Dales (1968) and Peeters (1993, pp. 117–134).

[5] The Directive entered into force on 25 October 2003.

[6] See Annex I of Directive 2003/87/EC.

which resembles the Kyoto Protocol compliance period. The first EC trading phase should allow Member States to make progress towards meeting their particular CO_2 goals committed under the Burden Sharing Agreement[7] with respect to the Kyoto protocol. The trading system may be extended to incorporate other greenhouse gases and other installations in subsequent periods.[8]

Even though much has been written about the advantages and disadvantages of Emission Trading Systems, one element of crucial importance that needs to be addressed in depths is emission allowance allocation.[9] The issue of how to allocate emission allowances has been addressed in the debate whether allowances should be auctioned or freely distributed (grandfathered). A good example reviewing the benefits of auctions over grandfathering schemes is presented by Cramton and Kerr (1999).[10] They find that auctions are superior because auction revenues can be recycled to reduce distortionary taxes (double dividend hypothesis), provide incentives for innovation and avoid market distorting awarding of politically contentious windfall profits. Despite their enthusiasm, the authors note that auctions may not be a first choice because vested interests are much in favour of free allocation. In contrast to this Stavins (1997)[11] presents a good discussion why grandfathering has been widely accepted. The author cites greater political control and distributional impacts of free allocation as reasons why grandfathering systems are more readily accepted.

Some works have explicitly included market distortions in their analysis of initial allocation mechanisms. Parry et al. (1999)[12] apply analytical and numerical general equilibrium models to analyse the efficiency impacts of revenue-recycling carbon taxes and CO_2 grandfathering allocation schemes in the presence of pre-existing distortionary labour taxes. For such an environment they find that the tax interaction effect (stemming from higher output prices and falling real wages' impact on labour supply) considerably inflates the efficiency costs of CO_2 abatement policies, in particular for grandfathering allocations, which does not generate government funds. They suggest that revenue-recycling could be a necessary condition for CO_2 emission abatement policies to enhance social welfare as long as the environmental benefits of CO_2 abatement are positive.

Frequently, comparisons between initial allocation mechanisms are examined within a closed economy setting. Some authors have, however also examined implications of initial emission allowance allocation systems at international level.

[7] The Council of the European Union agreed upon the contributions of each Member State to the overall Community reduction commitment in the Council conclusions of 16 June 1998. Document 9702/98 (Annex I) of 19 June 1998 of the Council of the European Union reflects the outcome of proceedings of the Environment Council of 16 – 17 June 1998. It should be noted, however, that unlike the new Member States who are also parties to the Kyoto Protocol, both Malta and Cyprus were qualified as ''developing countries'' within the meaning of the UNFCCC and therefore do not have any qualified greenhouse gas emission targets (see Malta 2004, p. 5; Cyprus 2004, p. 3).

[8] Article 2 of Directive 2003/87/EC relates to installations listed in Annex I and to the Greenhouse Gases listed in Annex II.

[9] Gayer (2005, p. 1).

[10] Cramton and Kerr (1999).

[11] Stavis (1997).

[12] Parry et al. (1999).

Helm (2003)[13] for example recognises the problem that there is no central authority charged with the power to determine initial allocation of tradable emission allowances on international level. In his article the author compares endogenous choices of tradable and non-tradable emission allowances by countries, which are participating in an Emission Trading System and finds that environmentally concerned countries tend to choose fewer allowances under a trading system. This positive effect may, however, be offset by incentives of less environmentally concerned participants to demand more tradable allowances. Maeda (2003)[14] examines the implications of market power and initial allocation between participants of the Kyoto Protocol. The author finds threshold levels that give rise to competition distorting market power.

Academic articles addressing the relative standards as a basis for initial permit allocation are still scarce. Gielen et al. (2002)[15] compare emission trading with absolute and relative targets in a partial equilibrium model with an absolute emission cap. They find that abatement efficiency is safeguarded by a relative standard, while operators benefit from scarcity rents as well as an output subsidy. The authors note that deadweight losses cannot be reduced since no funds are raised, emission constraints are more uncertain and monitoring costs are higher under a relative system. The high political acceptability of relative target systems is based upon firms' ability to expand production within certain limits without having to pay for additional emissions, less severe competitive pressure vis-à-vis third countries and the ease of combining relative target systems with existing regulation.

This paper adds to the existing literature in two ways. First by placing a coherent typology of emission allowance allocation mechanisms into an emission trading model and secondly by analysing how various assignment mechanisms deal with issues such as price determination, allocative efficiency[16] and environmental considerations in a static and dynamic model, how they are ranked and whether they serve the attainment of the general market equilibrium. The most important multiunit auction systems, financial allocation mechanisms as well as free allocation mechanisms are compared with each other. The analysis goes beyond the traditionally analysed auctioning and grandfathering allocation mechanisms and pays particular attention to relative standard allocation and specifically the new Performance Standard Rate Emission Trading System, which is being applied in the Dutch NO_x Emission Trading System. It examines the differences between various allowance allocation mechanisms with regard to allocative efficiency and the environment. At first a perfectly competitive static closed economy provides the framework of analysis. In a subsequent part it is examined how the findings change if one relaxes the strict theoretical assumptions and allows for a dynamic open economy setting in which only one economy has introduced emission trading.

13 Helm (2003).

14 Maeda (2003).

15 Gielen et al. (2002, p. 5 ff).

16 Allocative efficiency can be defined as a condition in which all possible gains from exchange are realised. See Frank (1997, p. 350). This implies that those market participants valuing a good most have been able to attain it.

Besides determining which allocation mechanism is more desirable, an important finding is that here allocation mechanisms have a strong impact on environmental effectiveness. This impact may merit more attention than the discussion relating to capped trade and trade without a cap. In the course of the analysis parallels are drawn to existing Emission Trading Systems such as the Dutch NO_x or the European Emission Trading System where convenient.

Before placing allocation mechanisms in a theoretical framework of Emission Trading Systems (Sect. 2.3), a general reappraisal of the economic intuition behind emission abatement and Emission Trading Systems will be presented in Sects. 2.1 and 2.2. Thereafter problems incurred in the context of initial allocation of CO_2 emission allowances are reviewed (Sect. 3).

Section 4 discusses allocative efficiency and environmental impacts of initial allowance allocation mechanisms within a static closed economic setting. After introducing the static closed economy model (Sect. 4.1) various allocation mechanisms are reviewed (Sect. 4.2). Because of the symmetry of findings, environmental considerations with respect to all reviewed allocation mechanisms are addressed jointly in Sect. 4.3. Section 4.4 presents the findings of this section.

Thereafter the restrictive theoretical assumptions are relaxed and allocative efficiency is examined in an dynamic open economy setting in section 5. After the introduction of the model (Sect. 5.1) allocation mechanisms are examined with regard of their allocative efficiency (Sect. 5.2). Subsequently environmental considerations are treated (Sect. 5.3). Section 5.4 summarises the main findings. Section 6 presents an overall conclusion of the paper.

2 Basic economic intuition for abatement and emission trading

2.1 Why abatement?

Economic theory predicts that if a good is under priced, more of it will be used. This proposition becomes particularly important if its ‘‘excessive’’ use reduces the standard of living of other market participants. CO_2 did not have a market price and entrepreneurs did not take into account the ‘‘negative externalities’’ i.e. the negative effects they inflicted upon the environment. This ‘‘market failure’’ can be overcome by internalizing the negative effects i.e. by bringing the good into the market price mechanism. The basic intuition behind this is that the price of the good private parties pay should be inflated to adequately reflect social costs in order to create incentives to use less of the good. This can be achieved by levying adequate taxes for each level of usage of the under priced good.[17] Figure 1 provides a graphical representation of this. The introduction of a so called ‘‘Pigou Tax’’ which equals the vertical distance between a firm’s marginal production costs (Private Marginal Costs) and the total costs inflicted upon society (Social Marginal Costs), leads to a price increase of the product from P1 to P2. Because consumers demand less at a higher price, the quantity of demanded contracts decreases from Q1 to Q2 and brings about a full reduction of the loss to society.

[17] This referred to as the ‘‘Pigou tax’’. See Pigou (1949) Chapter 8.

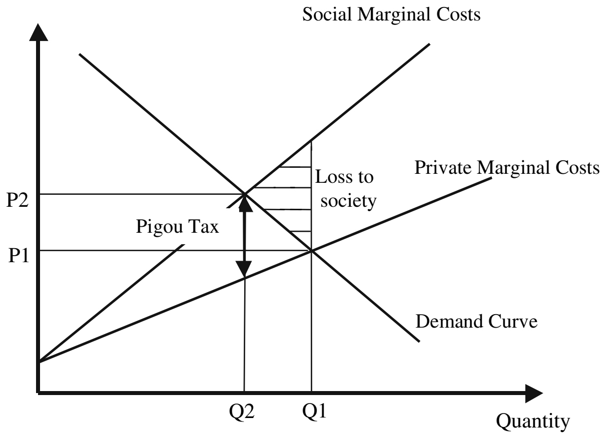

Fig. 1 Internalisation of negative external effects. *Sources*: Based on Pigou (1949), Chapter 8

Besides market-based instruments to internalise negative external effects, there are other means to change behaviour of private parties. Private law instruments such as tort law liability schemes or public law regulations, which can be sanctioned by administrative and criminal law, can be used.[18] The instruments employed in the European CO_2 Emission Trading System are a combination of public law rules, administrative sanctions and the price mechanism.

With regard to the introduction of CO_2 emission allowances, a contraction of the gross domestic product (GDP) is expected. Despite the reduction in overall economic output, or rather, precisely due to this contraction, society is better off. The absolute loss to society that stems from the excessive use of scarce resources is reduced to a socially desirable level. Since the GDP only takes into account economically quantifiable data, it does not take into account the destruction of the environment and is thus not a viable measurement instrument for social wealth.

2.2 Why emission trading?

After having reviewed the basic intuition why abatement benefits society, we now examine how emission trading can reduce CO_2 abatement cost to society.[19] The optimal quantity of CO_2 emission should be reduced until Social Marginal Benefits from CO_2 emissions equal Social Marginal Costs from emissions. In Fig. 2A, society's welfare is maximised when emissions are restricted to 20 units of CO_2.

In a ''command and control'' setting, society could order firms to reduce their emissions by an equal amount. Figure 2B shows CO_2 abatement cost structures of firms A and B, which produce 20 units of CO_2 each. Under a command and control

[18] See Faure and Skogh (2003) particularly Chapters 14 and 16.

[19] Since allocation mechanisms and not emission trading systems are the focal point of interest of this paper, I will restrain myself to merely depict the underlying intuition of such trading systems.

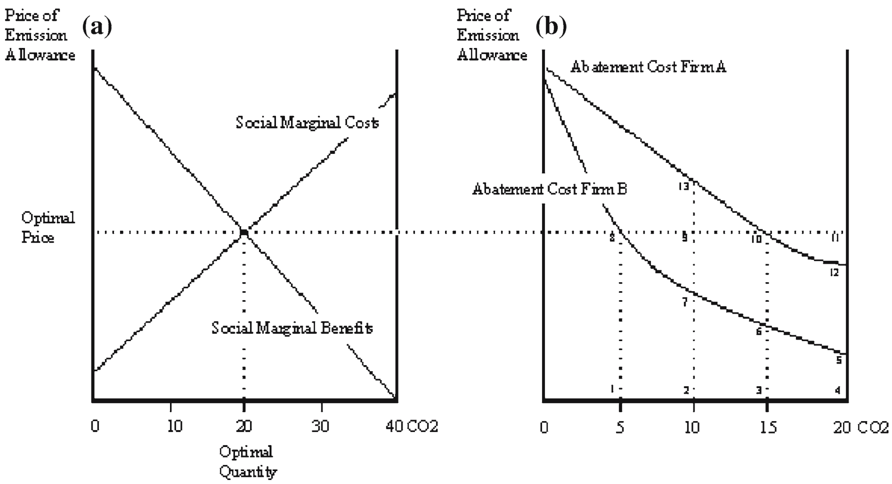

Fig. 2 Abatement costs. *Source*: Own representation

system, abatement costs for 10 units of CO_2 of firm A are given by the area 2, 4, 12, 13 and of firm B by the area 2, 4, 5, 7.

An Emission Trading System allows firms to freely exchange CO_2 emission allowances.[20] Firms are thereby enabled to determine themselves which firm will in fact abate emissions. Because it is cheaper for firm A to buy emission allowances from firm B, rather than to invest in abatement technology, firm A has an incentive to buy allowances. If, as in the previous example, allowances are restricted to 20 units, firms will review their marginal abatement costs and engage in trade. Firm B will reduce its emission by 15 units (costs are given by area 1, 4, 5, 8) while firm A will only reduce its emission by 5 units (costs are given by area 3, 4, 12, 10). Such an Emission Trading System generates the same abatement result at a lower cost than a command and control system. This can be seen in the fact that area 2, 3, 10, 13, representing the costs of firm A abating five additional units, is bigger than area 1, 2, 7, 8, which represents the costs of firm B abating five more units. Thus the overall cost savings of the CO_2 emission reduction is the difference between firm A's cost to abate CO_2 units 10–15, (area 2, 3, 10, 13) and firm B's cost to abate CO_2 units 5–10 (area 1, 2, 7, 8).

According to the European Commission's own assessment[21] the EU's cost of climate policy of the Emission Trading System will be between 2.9 and 3.7 billion euros. In the absence of a trading system, the environmental costs would amount to 6.8 billion euros.

[20] This finding has long been proposed by scholars. For a similar explanation see Tietenberg (1994, p. 222 ff).

[21] European Commission, (2004, p. 8).

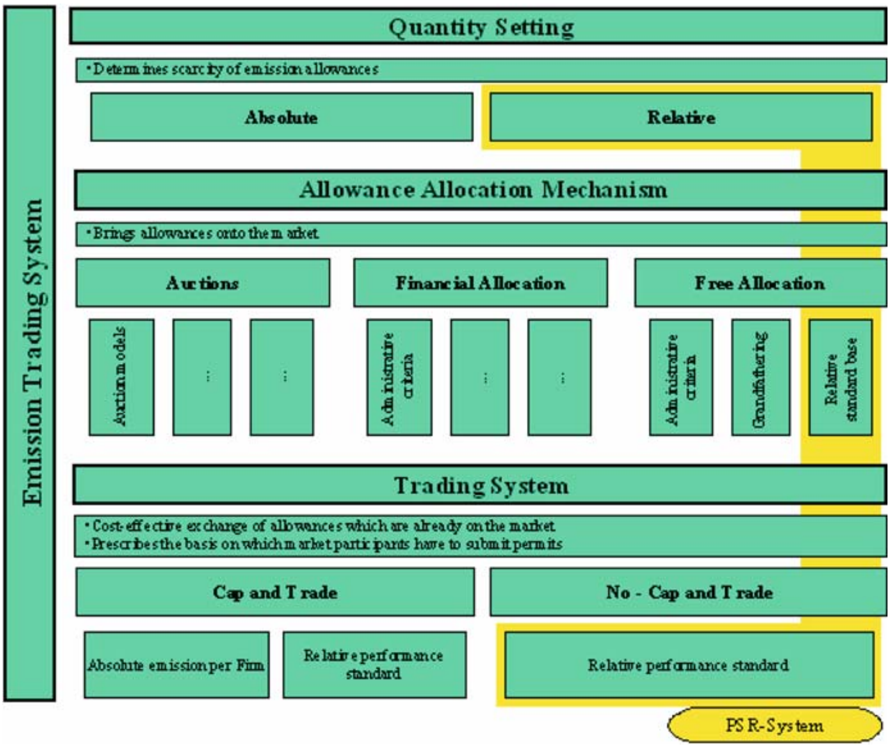

Fig. 3 Emission trading system. *Source*: Own representation

2.3 Emission trading systems

After having presented the general economic rationale behind CO_2 emission allowances and emission trading, the conceptual framework on which the current paper is based will be introduced. With regard to Emission Trading Systems, three different elements can be distinguished: these elements are the Quantity Setting, the Allowance Allocation Mechanism and the Trading System (see Fig. 3).

On the first layer, ‘‘Quantity Setting’’, society determines to what extent it wishes to reduce CO_2 emissions.[22] The scarcity of the emission allowances can be expressed in absolute terms, setting an absolute amount of emission allowances, or

[22] To motivate the United States and major developing countries to effectively control their greenhouse gas emissions is a core challenge for the international climate ‘‘regime’’ beyond the Kyoto Protocol. Studies addressing problems related to international emission allowance allocation include Lecocq and Crassous (2003) and Böringer and Welsch (2004). It should be noted that determining the socially desirable level of pollution is a non-trivial task in the presence of imperfect information about present and future benefits and damages of pollution and the problem of collective action. Some economic models have addressed these problems by treating emission as an endogenous variable. See for example Smith and Yates (2003).

in relative[23] terms. Relative scarcity can be expressed as being dependent on prescribed industry standards or on a certain tonnage of CO_2 emission per unit of GDP. Independent of the basis on which scarcity is measured, an absolute amount of CO_2 emission permits has to be determined so that they can be allocated in the next stage. With regard to the European Emission Trading System, Directive 2003/87/EC requires Member State governments to set absolute quantities of CO_2 emission allowances in their National Allocation Plans.

An ‘‘Allowance Allocation Mechanism’’ serves to initially allocate a predetermined amount of emission allowances. It therefore deals with the initial distribution of emission allowances amongst market participants but not with the operation of the emission trading market. Figure 3 shows a number of different generic formats of allocation mechanisms. All of them will be reviewed in this paper. Auctions and financial allocation systems require market participants to pay for emission allowances. The difference between the two is that auctions allow market participants to determine the price they will pay in accordance with the prescribed auction rules while other financial administrative allocation mechanisms allow administrative bodies more discretion[24] in price determination and final distribution. In contrast to the two preceding mechanisms, free allocation mechanisms do not require payment. Administrative bodies can base their allocation decision on historic production data (grandfathering), on relative production standards or any other administrative criteria. ‘‘Trading Systems’’ do not deal with issues of initial allocation. They treat the allowances that are on the market as given. Trading systems provide a cost-effective system of exchange and determine the criteria on which market participants are allowed to emit CO_2.

A ‘‘cap’’ prescribes the maximum amount of CO_2 emission that a country is willing to emit. Under a ‘‘cap and trade’’ system a maximum emission ceiling is installed. No emissions are permissible beyond that ceiling. Each firm has to submit at the end of a time period enough CO_2 allowances to comply with its prescribed obligations. These obligations can be based on the absolute emission per firm or a relative performance standard. Firms will also have to comply with their obligations under a trading system that does not have a cap. The difference between a cap and a non-cap trading system is that in the former the absolute amount of CO_2 emission is prescribed, while in the latter it is not. Yet also in the absence of a cap emission reduction goals can be set on environmental production standards.

One particular emission-trading system merits special attention: the so-called ‘‘Performance Standard Rate System’’, in short PSR. In this system emitting entities are free to produce but have to compare their actual emission level per unit of output with that prescribed by the government’s benchmark. The emitting entity has to account for every emitted ton in excess of the benchmark and pay a punishment if it cannot attain CO_2 emission allowances via the Emission Trading System or benefit

[23] One successful example of an allowance trading program which applies such relative criteria is the American lead trading program. The program provides incentives for the diffusion of cost-saving technology, see Kerr and Newell (2003). For a brief review of the program see Kerr and Newell (2003, p. 320 ff) and UNEP, UNCTAD (2002, p. 9 and p. 23).

[24] It should be noted that through the selection of auction rules administrative bodies are also able to influence prices.

from past or future savings. One important specialty about the PSR trading system, which distinguishes it further from ordinary relative standard base benchmark allocation systems is that the emission allowances are not created by the government and distributed to emitting entities. A legal act obliges emitting entities to meet particular emission targets, to have them accredited by third parties and to report them to the government. While the government takes an active role in monitoring the compliance to the law, it is not participating as an actor. Government takes a laissez faire approach limiting itself to creating the rules to be followed by emitting entities. In this sense, the PSR system is operated by private entities who are able to sell their accredited savings to other market participants via a cost effective trading system.[25]

As already indicated the field of interest of this paper does not encompass the entire Emission Trading System but is restricted to allowance allocation mechanisms. Therefore it suffices to note that Emission Trading Systems have been subject to research[26] and that the European Emission Trading System has been drawing from past experience.[27]

3 What is the problem of initial allocation?

From a socio-economic perspective, there are three important considerations with respect to initial allocation mechanisms. These regard price determination, allocative efficiency and in accordance with the overall objective of the Emission Trading System, environmental considerations. Each will be discussed in turn.

3.1 Why do we need prices?

The economic problem at hand is that an allocation mechanism has to allocate CO_2 emission allowances to firms in such a way as to distort markets in the least possible way. From a social welfare point of view, the operator placing the highest value on an emission allowance should be able to use it. Due to the fact that in reality, true CO_2 abatement cost structures of the individual installations are only known to operators themselves, the true value they place on CO_2 emission allowances is unknown to the allocating entity. Quite naturally firms would like to buy emission allowances for less than they are worth to them and are therefore reluctant to reveal their true value to the allocating entity. Market prices are able to overcome such problems of information asymmetry where one party knows more than another. In accordance with the law of demand and supply, prices reveal individuals' preferences. In particular, market prices fulfil two important functions. First, prices serve to redirect existing supplies of a product to those users that value the good most; this is also referred to as the ''rationing function of prices''.[28] Second, prices

25 This passages draws from European Commission (2003).

26 For a recent summary of market-based policies see Stavins (2001, 2003).

27 Kruger and Pizer (2004, p. 6).

28 See Frank (1997, p. 43).

redirect resources from less productive uses to more productive ones. This is called the ‘‘allocative function of prices’’.[29]

With regard to the initial allocation of CO_2 emission allowances, however, the problem is that there is no such market price. In order to ensure both the rationing as well as the allocative functions of the price, there are two possibilities. Either a well functioning trading system can reduce inefficiencies stemming from the initial allocation of emission allowances or the employed allocation mechanism leads to the revelation of ‘true’ values of allowances.[30] Both will be examined below.

An efficient trading scheme would allow all market participants to trade emission allowances at minimal costs. In the presence of a trading system with sufficiently low transaction costs, an optimal resource allocation will result on the market irrespective of how allocation mechanisms distribute emission allowances.[31] Thus if an operator values an allowance higher than another operator which has been awarded a permit, both would engage in trade. Hence, the absence of a market price does not create severe economic obstacles to the attainment of a market equilibrium if a trading system is present.

An efficient trading system can, however not ensure the attainment of a special market equilibrium: the general market equilibrium. At this equilibrium the production market gives rise to an optimal product mix and consumers have also realised all gains from exchange. Only if an allocation would be sufficiently close to this special market equilibrium, it could be reached through market exchanges. It can, however, also be reached directly if market operators would be forced to reveal their ‘‘true’’ values of allowances,[32] such as through an auctioning allocation system.

To summarise, the relevant criteria to be assessed are the revelation of operators’ valuations of emission allowances (price determination), whether those market participants who value the CO_2 emission allowance most will be able to attain it (allocative efficiency) as well as adverse effects on the efficiency of the Emission Trading System. In principle, if either an efficient price determination mechanism or an efficient allocation of emission allowances can be ensured, the absence of a price will not per se constitute a problem from an allocative efficiency point of view. Yet only an allocation mechanism that leads to a true revelation of preferences will be able to attain the general equilibrium of the economy with an optimal production mix.

3.2 Allocative efficiency

The preceding section has shown that CO_2 emission allowance allocation mechanisms can be equally desirable from an allocative efficiency point of view, but they do not necessarily lead to the same equilibrium outcome. When an allowance with no intrinsic value is introduced into the market price mechanism, real value is created[33]

[29] See Frank (1997, p. 43).

[30] Auctions can lead to such desirable revelation of private values.

[31] Coase (1960).

[32] Auctions can lead to such desirable revelation of private values.

[33] This is analogous to the concept of ‘‘seigniorage’’ when a government exploits the monopoly power of the central bank to create money as a means of raising real resources.

due to market participants' willingness to attribute value to such an allowance. Windfall profits accrue to the issuing entity if emission permits are sold to the market participants. If allowances are allocated free of charge or below their true market value, windfall profits accrue to the recipients. The discussion who should be awarded a windfall profit can be led on a (scientific) welfare economic level or on a (normative) social choice level.

With respect to the scientific dimension of this question, there may be a strong rationale to allocate wealth to those groups of society who invest it most wisely[34] or to those who create the strongest impulse for economic growth.[35] Costs and benefits should be compared and resources should be allocated in such a way as to maximise social welfare.

From a societal point of view, however, there may be strong normative grounds to prefer a different allocation. Society may refer to normative principles such as the ''polluter pays'' principle in order to determine how emission allowances should be distributed.[36] Besides such general principles, society could decide that consumers, producers or taxpayers should benefit the most from an allocation mechanism. Or society could, for example, decide that CO_2 emission allowances should be allocated to small and medium-sized enterprises in order to reward them for their labour-intensive production.[37] In such a case large operators, which are not awarded allowances, will have to acquire them. The monetary transfer constitutes a pecuniary, i.e. a redistributive, effect[38] to the extent that it does not have a bearing on the overall social welfare. To the extent that such measures do affect the size of the overall economy[39] or distort competition on the merits and lead to a different market equilibrium, they create undesirable effects from an economic point of view.

If particular firms may be put in a position of comparative disadvantage because their competitors benefit from a subsidy in form of CO_2 emission allowances which effectively reduces their production costs, or if their production costs are unduly inflated, this can lead to strong market distortions and even adversely affect the common market. In this context state aid implications of initial allocation schemes under Article 87 EC Treaty[40] and distortions of competition created by Member States that could fall within the ambit of Articles 81 and 82[41] are relevant.

To summarise, the overall social welfare should be as large as possible, and mere redistributive effects of initial allocations can be ''rationalised'' by social choice

[34] Here industrial policy issues come to mind.

[35] A ''multiplier effect'' denotes a phenomenon whereby some initial increase or decrease in the rate of spending will bring about a more than proportional change in national income.

[36] For an early statement of the strong acceptance of the ''polluter pays'' principle see OECD (1974) Recommendation C (74) 223. The ''polluter pays'' principle is inscribed in Article 174 (2) of the EC Treaty.

[37] It may be noted that many economists are critical of such arguments. Economists tend to emphasise overall social welfare and production efficiency and tend to prefer to leave such normative standpoints to politicians.

[38] Cullis and Jones (1998, p. 133).

[39] Through, for example, multiplier effects.

[40] See Weishaar (2006a).

[41] See Weishaar (2006b).

arguments. To the extent that market distortions caused by certain social choices give rise to competitive disadvantages and distort the general equilibrium, however, they should be subject to severe scrutiny.

3.3 Environmental considerations

Even though scholars have been arguing that the initial allocation of emission allowances as such does not affect their use,[42] the above discussion has shown that initial allocations are important. If operators are maximizing their profits and the Emission Trading System works efficiently[43] reallocation of emission allowances will occur over a certain range. In such circumstances market participants valuing an emission allowance the most will attain it, irrespective of its initial allocation and give rise to allocative efficiency. From an environmental point of view, however, it does, not matter who will eventually ‘‘use’’ the emission allowances, i.e. in which sector of the economy CO_2 is produced. It is the atmospheric CO_2 concentration dependent on the absolute amount of CO_2 emission and the timing of emissions, which is of importance in terms of environmental effects.

4 Static closed economy

This part of the paper consists of three parts. After introducing the concept of a static closed economy, the allocative efficiency of various initial allocation mechanisms within the framework of a closed static economy is examined. Subsequently the environmental impacts of these mechanisms are reviewed.

4.1 Static closed economy model

Because reality is very complex, models are used to gain a better understanding of intricate relationships between variables. Models construct an artificial framework of analysis based on assumptions how reality could look like. In this section, a static closed economy model is introduced. Unlike an open economy, a closed economy is not influenced by any form of international trade. Nothing can be exported or imported because there is only one economy within this analytical framework. For the sake of analysis, this assumption simplifies the complex interactions within the economy to analyse the circular flow of national income. In this paper we are, however, not interested in national income as such but rather in the allocative efficiency of CO_2 emission allocation mechanisms and its environmental impacts. Therefore only these issues are being analysed. In this part of the paper I have chosen a static economy which presents only a snap-shot but does not allow for

[42] Tietenberg (2002, p. 3).

[43] This again implies that transaction costs are sufficiently low so that the operator with the lowest abatement costs has every incentive to sell its CO_2 emission allowance on the market, rather than using it. This is again an application of the Coase theorem.

strategic firm behaviour. In the second part of this paper these assumptions are relaxed to allow both dynamic firm reaction and trade.

4.2 Comparison of allocation mechanisms and allocative efficiency

Having introduced the static closed economy model and presented the importance and function of initial allocation mechanisms, the next section will provide a comparison of allocation mechanisms. Criteria used for comparison are price determination, allocative efficiency and possible adverse effects of allocation mechanisms on trading systems.

This section consists of two parts. The first part addresses auction mechanisms, the second examines other financial allocation mechanisms and free initial allocation mechanisms, including grandfathering and ‘‘relative standard base’’ systems.

4.2.1 Auctions as an allocation mechanism

Auctions have become enormously popular and are being used in a large number of economic exchanges both in the public and private sector. Just two prominent examples are mobile phone licenses and the decentralisation of electricity markets.

There are four reasons rendering this allocation mechanism attractive. First, an auction is designed to lead to self-revelation of the bidder's private values. In the presence of inherent information asymmetry, in which a potential seller is unable to determine the market value of a particular object, an auction mechanism can yield higher revenues than simply quoting a price or repeated negotiations with potential buyers. While this is very desirable from a theoretical point of view, it should be noted that bidders are generally reluctant to reveal their preferences because they fear that competitors could take advantage of it—protection of such information is crucial for firms. Second, auctions can be designed in such a way as to ensure allocative efficiency. It should be noted that efficiency here is to be understood as to award the bidder with the highest valuation for an object with the tender.[44] Third, auctions legitimise transfers which would otherwise be suspect. Prior knowledge of the auction rules provides bidders with a transparent framework of how their bids will be assessed while at the same time ensuring bidders that selling agents have clear and indiscreet tender selection criteria.[45] Fourth, since no time consuming negotiation has to take place, auctions are fast allocation mechanisms. Though it should be noticed that the development of an auction mechanism depends on the object being auctioned and can be a non-trivial, time consuming process.

This section of the paper is subdivided into two parts. The first part introduces general auction formats. Drawing from that, the second part will present auction

[44] Implicitly assuming away the possibility of credit rationed bidders. See Milgrom (2004, p. 57). Maximisation of social welfare, defined as the maximisation of the sum of producer surplus and consumer surplus can be reached if side-payments (in the presence of budget balance constraints) are possible. In such cases Pareto optimal allocations are feasible in which one person is better off without someone else being worse off.

[45] See Rothkopf and Harstad (1994, p. 368).

Table 1 Standard auction types

Open auctions	Closed auctions
Ascending price auctions (English auction)	Second-price sealed-bid auction (Vickrey auction)
Descending price auction (Dutch auction)	First-price sealed-bid auction

theory's contributions to CO_2 allocation mechanisms. A conclusion will summarise the main points.

Auction formats. An auction can be understood as a set of rules, which translates information revealed by bidders by means of an allocation rule, and a payment rule into efficient outcomes. The challenge of auction theory is to develop auction rules which are tailored to the preferences of bidders in such a way as to provide Pareto optimal[46] allocations. Auctions do not only differ with regard to allocation and payment rules but also with respect to the amount of information they require bidders to reveal.

There are numerous possibilities to design auctions. These models fall into several categories, or formats. A standard auction is an auction in which the highest bidder amongst potential buyers, or the lowest bidder amongst potential sellers wins. Since there is an almost perfect correspondence in results,[47] it is quite unimportant to distinguish between both forms.[48] Standard auctions are commonly distinguished into ''open'' and ''closed'' auctions. In open auctions bidders are aware of their competitors' bids while in closed ones they are not. Two examples of open auctions are the ascending price auction, also called the English auction, and the descending price auction, also known as the Dutch auction. Two examples of closed auctions are the second-price sealed-bid auction, frequently referred to as Vickrey auction,[49] and the first-price sealed-bid auction. The four standard auction types are presented in Table 1.

In an open ascending price (English) auction, the price is raised by the auctioneer or by bidders themselves until only one bidder remains. At any particular point in time bidders know the level of the current best bid.[50] Such auctions are often used by auction houses like Sotheby's. In the open descending price (Dutch) auction the price decreases continuously until one bidder accepts the current price. A well-known example where (sequential) open descending price (Dutch) auctions are used is the flower auction in Aalsmeer (the Netherlands). In a closed sealed-bid auction

[46] Pareto optimality describes situations in which it is impossible to make one person better off without making at least someone else worse off. In the absence of side payments between bidders, i.e. when bidders are unable to compensate each other, Pareto efficient but suboptimal allocations can occur.

[47] With the possible exception of the invalidity of reserve prices and treating zero as an implicit limit to acceptable bids. Despite the intuitive appeal of the later argument, Shubik (1983, p. 39 ff) cites Herodotus reporting on Babylonian marriage markets which did include auctions starting at negative bidding values.

[48] Rothkopf and Harstad (1994, p. 366).

[49] Named after Nobel laureate William Vickrey, who first presented this auction in his seminal paper on auctions. Vickrey (1961).

[50] McAfee and McMillan (1987, p. 702).

bidders are only allowed to enter one bid, thus they are unable to react ex post to their rivals. In the closed first-price sealed-bid auction the highest bid wins, while in the closed second-price sealed-bid (Vickrey) auction, the highest bidder is only required to pay a price equal to the second highest bid.

After having reviewed the four standard auction types, the following section examines auction mechanisms, which could be used to initially allocate CO_2 emission allowances.

Multiunit auctions. Under Directive 2003/87/EC each tradable permit is defined as 1 ton of CO_2 equivalent over a designated period of time.[51] Later the trading may be extended to other greenhouse gases with an equivalent global-warming potential of 1 CO_2 ton.[52]

Because the benefit derived by operators from attaining one CO_2 equivalent ton is the same irrespective of the greenhouse gas they purchase, the good is clearly a substitute[53] and can thus be treated as a homogeneous i.e. a similar good, from an auction design point of view.

Surprisingly little is known about efficiency properties of multiunit auctions. A lot of the conventional wisdom comes by analogy from single-unit auctions[54] but a sound understanding of how equilibria respond when assumptions about values and information change are not yet answered at any level of generality.[55] Since participants to an emission trading auction will generally acquire larger quantities of allowances, multiunit auctions are of core interest. As in the case for single-unit auctions, auction designers strive to reach two goals. They try to ensure an efficient outcome and to maximise revenues. Even though these goals are closely related, here we merely focus on efficiency criteria as the relevant benchmark because revenue maximisation focusses on redistribution of wealth rather than the maximisation of consumer and producer surplus.

In this section, two general multiple auction methods that could be used to allocate CO_2 emission allowances are reviewed. First, sequential auctions in which one allowance would be sold after the other and secondly, simultaneous auction models in which multiple CO_2 emission allowances are sold at the same time. The later group is subdivided into open and closed auction formats. Because strategic firm behaviour such as e.g. demand reduction, undermines allocative efficiency a short review is presented whenever appropriate.

Sequential auctions are easy to implement for auctioneers but are not very much favoured by bidders. One reason is the strategic complexity of bidding decisions and the inevitable price variation of sequential auctions of homogeneous goods.[56] Ashenfelter (1989) has termed this ‘‘declining price anomaly’’[57] and

[51] Defined in Article 3 (a) of Directive 2003/87/EC.

[52] Defined in Article 3 (j) of Directive 2003/87/EC.

[53] If obtaining one good makes the bidder willing to pay more for a second good, the goods are complements, if the bidder is willing to pay less, they are substitutes.

[54] Ausubel and Cramton (2002, p. 1).

[55] See Börgers and Van Damme (2004, p. 43).

[56] Inefficiencies from synergies and complementariness of goods appear to be smaller if goods are homogeneous.

[57] Ashenfelter (1989, p. 29 ff).

explained a falling price in subsequent auctions[58] in terms of bidder's necessity to acquire particular quantities, risk aversion[59] and uncertainty.[60] From an allocative efficiency point of view, auctions ensuring a single market price as e.g. uniform-price auctions are preferred over sequential auctions because they mitigate the 'price risk' of paying too much for the same good.[61] In general, an auction format that cannot ensure that the bidder with the highest valuation always receives the good cannot be allocative efficient, and hence not be a viable first-choice option as a CO_2 emission allocation system. If such auction schemes were to be chosen, allocative efficiency would have to be established on an efficiently operating emission trading market.

After having reviewed sequential auctions, simultaneous multiunit auctions are reviewed. At first, simultaneous closed sealed-bid auction models are examined. Thereafter simultaneous open ascending price auctions models are treated.

Due to their importance, three simultaneous closed sealed-bid auction models are discussed here.[62] These are pay-as-you-bid, uniform-price auction and multiunit Vickrey auction. Each will be discussed in turn.

The pay-as-you-bid[63] is a closed sealed-bid auction in which bidders simultaneously submit demand schedules[64] for goods. Bidders win the quantity demanded at the clearing price and pay the particular price for each unit as indicated in their submitted demand schedule. In order not to pay unnecessary high amounts for emission allowances, bidders have to estimate the market clearing price and bid slightly above it. This exposes less informed bidders to the strategic risk of misjudging the clearing price and pay ''more'' for identical goods. This increases the transaction costs to the parties of participating in a bid and may even deter potential bidders from participating, which in turn reduces the competitiveness of the entire market and hence its efficiency.

The uniform-price auction is a closed sealed-bid auction in which bidders simultaneously submit demand schedules for goods and pay the clearing price for every unit demanded at that particular price. In contrast to the pay-as-you-bid auction, this auction format has two advantages. First, every bidder pays the market-clearing price, which is equal to the overall marginal valuation. Second, in the absence of the danger of paying too much for the same good, less informed bidders are more inclined to participate in such auctions.

Both, the pay-as-you-bid auction and the uniform auction format can be expected to be inefficient in the presence of market power or collusion. In such cases they

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58 See Ashenfelter and Graddy (2002, pp. 34–36) and Table 8 for a review of subsequent research.

59 Risk aversion implies that bidders dislike taking fair bids. McAfee and Vincent (1993) show that risk aversion can create declining prices.

60 See Neugebauer and Pezanis-Christou (2005).

61 Milgrom (2004, p. 256).

62 See Krishna (2002) and Ausubel and Cramton (2002).

63 Also called ''discriminatory auctions'' or ''multiple price auctions''.

64 In this section all demand schedules are assumed to be downward sloping, i.e. more is being demanded if the price decreases.

may give rise to inefficiency[65] inducing ''demand reduction'' strategies.[66] In multiunit auctions dominant players recognise the interdependence of their bidding strategy and competitors' bidding behaviour. A strategy of self restricting the quantity demanded while bidding the minimum price to indicate interest in a number of units can generate large consumer surpluses. The inherent inefficiency stems from the fact that users with the highest value for a good do in fact prefer not to attain it; large bidders win too little and small bidders win too much. Salmon (2003)[67] points out that if such behaviour is strictly unilateral, this does not amount to collusion. However, if it does involve strategic considerations exemplified by trigger strategies, such behaviour would amount to (tacit) collusion.[68]

The third sealed-bid multiunit auction format reviewed here does not suffer from demand reduction in private-value environments.[69] The closed second-price sealed-bid auction system (a multiunit Vickrey auction), is an auction in which bidders simultaneously submit demand schedules for goods. Bidders win the quantity demanded at the clearing price and pay an amount equal to the highest losing bid for each unit. Since sincere bidding is a dominant strategy, allocative efficiency distorting demand reduction will not occur.

In contrast to closed auction formats, in open multiunit auctions the price and the allocation of emission allowances are determined by open competition. In cases of considerable uncertainty with regard to future market development and future technological developments, bidders' valuations may depend on information held by other bidders. The ''feedback'' that bidders get in the process of bidding in ascending auctions formats renders them more efficient than sealed-bid auction formats when it comes to solving complex allocation problems.

The open uniform-price ascending auction is the dynamic version of the closed sealed-bid uniform-price auction. For each slowly increasing price quoted by a fictitious auctioneer, bidders are allowed to observe and respond by quoting quantities they wish to purchase. Quantities demanded are added horizontally in order to determine the market demand. As long as demand exceeds supply, the price will be increased. Unlike in the closed sealed-bid uniform-price auction, in the open ascending-price auction bidders can be informed about other bidders' demanded quantities.

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[65] Inefficiency is created by ''differential bid shading'', i.e. when bidders with identical marginal values reduce their bids by different amounts so that awarding the bidder who values the item most is impossible. See Ausubel and Cramton (2002, p. 4).

[66] For examples see Weber (1997) and Ausubel and Cramton (2002).

[67] Salmon (2003, p. 5).

[68] Distinguishing between tacit collusion and pure strategic firm behaviour is complicated if not impossible. In a multiunit auction both bidders could, for example, independently decide to pursue a ''demand reducing'' strategy. The outcome would be identical to tacit and indeed outright collusion.

[69] In private-value models bidders are assumed to have knowledge, which is strictly private to them such as for example the price they would be willing to pay in a tender. Common-value models in contrast, assume that the actual value is identical to all participants, but bidders do have diverging private information about this value. Unlike in private-value environments, in common-value environments Vickrey auctions do not always produce efficient equilibria. To the extend that emission allowances depend on the operators abatement costs, emission allowances are probably best thought of as depending on private values.

Open ascending-price auctions are easily implemented since bidders will only have to quote the quantity demanded and observe simple activity rules. As the simultaneous ascending (multiunit) auctions, which can be applied in contexts when goods are not identical, this auction format is vulnerable to demand reduction and collusion. In cases where market power is limited, inefficiencies from standard ascending-price auctions are also expected to be low.

Kagel and Levin (2001) suggest that demand reduction can be stronger under the open ascending-price auction than under the closed sealed-bid uniform-price auction.[70] With respect to (tacit) collusion in multiunit open ascending price auction environments, Ausubel and Schwartz (1999)[71] postulates the existence of a unique cooperative equilibrium if bidders are able to use backward induction.[72] If bidders fail to immediately reach a low price outcome, signalling[73] can be employed to ‘‘negotiate’’ a mutually acceptable allocation. In a simultaneous ascending price bid auction environment with a limited number of participants and known limit prices of fringe firms, Grimm et al. (2001)[74] cite a powerful example of how effectively signalling can be used to reach an almost immediate mutually acceptable strategic demand reduction.

While signalling and demand reduction certainly are strong points of critique of open multiunit ascending-price auctions, there are two factors which complicate effective collusion. First, Brusco and Lopomo (1999)[75] show that the collusion becomes more difficult as the number of bidders relative to the number of items rises. Weber (1997)[76] presents a vivid example of how difficult it can be to reach a mutually acceptable allocation of heterogeneous permits when the number of participants is large. Second, Brusco and Lopomo (1999)[77] show that considerable externalities or synergies across items negatively impact prospects of collusion.[78] The authors conclude that due to signaling,[79] collusion is possible, even in the presence of a high ratio of bidders to objects and under some complementarities in bidders' utility functions.

For its favourable efficiency properties the Ausubel auction deserves particular mentioning. Ausubel (2002)[80] proposed an efficient ascending auction design for homogeneous goods that eliminates incentives for demand reduction[81] and rewards

[70] See Kagel and Levin (2001).

[71] See Ausubel and Schwartz (1999).

[72] Bidders are assumed to imagine how the auction will be developing and to derive from this a mutually acceptable offer at the beginning of the auction.

[73] By for example using the financially inconsequential digits of their bids, parties can signal their identity or indicate the market for which they are retaliating.

[74] Grimm et al. (2001).

[75] Brusco and Lopomo (1999).

[76] Weber (1997).

[77] Brusco and Lopomo (1999).

[78] For an analysis of externalities in single-unit auctions, the interested reader is referred to Caillaud and Jehiel (1998).

[79] See Cramton and Schwartz (2002) for an insightful analysis of FCC spectrum auctions.

[80] Ausubel (2002). Earlier versions of this paper date back till 1997.

[81] For an experimental assessment see Kagel and Levin (2001).

the revelation of true values.[82] As in the ascending-price auction, quoted prices continuously increase until demand equals supply. The bidder demanding the highest quantity when the collective demand of all other bidders is one unit less than the total quantity supplied, will be rewarded one unit at the current price. Consequently the bidder with the highest valuation for a particular unit is able to secure it and pay the price indicated in the demand schedule. Notwithstanding the notable efficiency properties which the Ausubel-auction demonstrates in both private-value and common-value environments, Manelli et al. (1999) find that this auction format generates incentives for bidders to engage in strategic overbidding to mislead competitors.[83]

The above can be summarised as follows. Sequential multiunit auctions are easy to implement but due to the complexity of bidding strategies they require and their inability to ensure allocative efficiency, they will not serve as an efficient means to allocate CO_2 emission allowances.

With respect to closed multiunit auctions, simultaneous sealed bid uniform-price auctions are likely to be more allocatively efficient than pay-as-you-bid auction schemes because the costly strategic burden of misjudging the clearing price is not placed upon firms. Even in the presence of demand reduction, small firms would benefit from it and consequently have every incentive to participate in the auction which in turn would mitigate effectiveness of demand reduction strategies. Auction rules in both auction formats are easy to understand for bidders but the strategic complexity of placing bids is non-trivial. If one, however, would only consider efficiency from an auction theoretic point of view, the efficiency ranking of pay-as-you bid auctions and uniform-price auctions is ambiguous.[84]

In the presence of market power on emission allowance markets, the multiunit Vickrey auction is clearly more efficient since it does not give rise to demand reduction. In the absence of market power, a uniform-price auction is similarly efficient and due to the simplicity of the auction rules and price uniformity at first sight it may generate even more desirable results.[85] Since it is difficult for firms to develop good bidding strategies, multiunit Vickrey auctions, in which true bidding is a dominant strategy, may be socially more desirable. This will be the case if—and only if—firms could be convinced that the information they reveal is kept secret at all times.

With regard to open multiunit auction formats, it has been shown that open ascending auction systems are allocatively efficient if there is no market power. In those cases where there is market power on the emission trading market, the Ausubel auction may be a viable option.

One can therefore conclude that auction mechanisms can be used effectively for the allocation of CO_2 emission allowances. Auctions do solve the problem of price determination by allowing bidders to ''reveal'' (at least part of) their preferences. Auctions are therefore capable of attaining the general equilibrium of an economy.

82 Ausubel replicates the intuition of the Vickrey auction in a dynamic context.

83 Manelli et al. (1999, p. 3).

84 Ausubel and Cramton (2002, p. 16 ff).

85 Cramton and Kerr (1999, p. 6).

Auctions can, however, also give rise to strategic behaviour of bidders. Allocative inefficiencies stemming from e.g. demand reduction could, however, be corrected ex post, if large bidders are able to acquire emission allowances through efficient trading systems.

4.2.2 Administrative allocation mechanisms

After having reviewed how auctions can be used as an emission allowance allocation system, we turn to two different mechanisms. Both have in common the relative importance of administrative bodies. First financial administrative allocation mechanisms will be briefly reviewed before free administrative allocation mechanisms will be introduced.

Financial administrative allocation mechanisms. In the preceding section auction mechanisms have been reviewed. In contrast to these fully market-based instruments, other financial emission allowance allocation mechanisms can be considered. Such instruments are more akin to ''command and control'' mechanisms to the extent that they attribute an active role to bureaucrats.

All or part of the emission allowances could be sold. Either on the basis that society wants to recoup expenses for the establishment of an Emission Trading System or because it would like to grant industries preferential access to emission allowances at a price which lies below a competitive market price.[86]

From an allocative efficiency point of view, it is certain that bureaucrats will perform less efficiently than purely market-based financial allocation mechanisms. First because civil servants are likely to be less well-informed about the particular needs of an enterprise than entrepreneurs themselves. And second because firms do have an incentive to misstate their true valuation in order to attain more allowances.[87] Thus due to bureaucrats' inability to determine the optimal price correctly, any interference in the allocation mechanism will lead to less efficient allowance allocation. In other words it is unlikely that bureaucrats are able to allocate emission allowances in such a way as to reach the general equilibrium of the economy. In the presence of an efficient trading system, however, inefficient initial allocation of emission allowances can be remedied by the market[88] and an efficient allocation is safeguarded. Yet this efficient allocation can but does not have to be equal to the general equilibrium.

While administrative financial allocation mechanisms are certainly undesirable from a general equilibrium point of view, it should be noted that society would only be worse off if the resulting allocation would not be reflecting its preferences. Even if there are normative grounds (such as equity considerations), which would justify

[86] With regard to such schemes, state aid considerations under Article 87 of the EC Treaty are relevant.

[87] Such an incentive will be present as long as the expected rewards outweigh costs placed upon violators. Becker (1968, pp. 169–217), shows that disutility from trespassing legislation can be modelled as being a function of the detection probability, the level of punishment and the risk averseness of the violator.

[88] This is again subject to the assumption that transaction costs are sufficiently low and that markets operate efficiently.

an administrative influence in financial allocation mechanisms, it should be examined whether the positive effects cannot be created in a less distortive manner.

Free administrative allocation mechanisms. A free administrative allocation mechanism does not require payments for emission allowances. Based on administrative criteria, allowances are distributed to market participants. There are numerous possibilities of how to distribute emission allowances. They may differ as much with regard to the social group they set at a comparative advantage as to the criteria they apply as a basis for allocation. Society may distribute allowances to virtually anybody. Firms may be rewarded for their labour intensiveness of production or families for having many children. Promising economic sectors, low-income families, art galleries etc. are other examples. It is obvious that in free administrative allocation mechanisms normative distribution justifications based on society's preferences or industrial policy considerations prevail over general equilibrium and allocative efficiency considerations.

In the presence of an efficient trading market those market participants who value an emission allowance most are able to attain it. Provided, of course, that there is no significant leakage of allowances because some recipients prefer to save rather than to use or sell them. Furthermore, the liquidity of the emission trading market may be undermined if transaction costs for initial recipients may be high. This would unduly increase the financial burden, which is placed upon those market participants which value emission allowances most and constitute a real waste to society. If society would like to support particular groups, it should consider using more direct means such as tax cuts or direct monetary transfers accruing from auction proceeds.

There are, however, two incompatible free allocation mechanisms, which merit particular attention. These are the so-called grandfathering and the relative standard base allocation system. Each will be discussed in turn.

(a) *Grandfathering*. Bureaucrats can allocate emission allowances for free on the basis of historic data. There are three bases, which can be used to allocate allowances. First, input-based (used historic energy input); second, output-based (e.g. kilowatt-hours of electricity production); or, third, emission-based (direct or indirect i.e. total emission from emitting facilities).[89] Furthermore, the base period for historic data has to be determined. As can be seen from these choices, allocating emission allowances is a non-trivial matter that is likely to generate a high administrative burden and provoke both strong opposition from disadvantaged parties and welfare reducing lobbying.[90]

As other free allocation mechanisms, grandfathering systems cannot be expected to generate an allocatively efficient initial distribution of emission allowances and for the reasons highlighted above may also fail to establish a general equilibrium. Since grandfathering systems will allocate allowances to operators directly and therefore to a societal group which naturally has a high valuation for CO_2 emissions, it is obvious that grandfathering mechanisms can be allocatively superior to other

[89] Harrision and Radov (2002, p. 60 ff).

[90] Cullis and Jones (1998, p. 93 ff).

free allocation mechanisms.[91] Since allocation is based on historic emissions and is not based on abatement cost structures of firms, they will always be less efficient than auction models, even in the presence of perfect information.

(b) *Relative standard base mechanisms*. As discussed above, there are many possible criteria on which emission allowance allocation can be based. One can also envisage a free allocation on the basis of industry specific CO_2 emission standards. Such standards can be quoted, for instance, in CO_2-ton per production unit or in terms of CO_2 efficiency per amount of GDP produced. Such relative standard base allocation systems form part of the Dutch National Allocation Plan of the European Emission Trading System, the Dutch NO_x Emission Trading System and are also underlying the PSR-Emission Trading System presented in Fig. 3.[92]

The Dutch National Allocation Plan[93] (Dutch NAP) allows for a sector-specific correction factor, which takes into account the relative energy efficiency of installations. Government intends to encourage operators to further improve their already notable technology and to attain world best practice standards by means of the so-called benchmarking covenants schemes.[94] Besides the relative energy efficiency, historic emission data (base period 2001–2002) and sector growth (2003–2006) as well as an overall correction factor ensuring compliance with the emission ceiling, are variables in the allocation formula. Thus, the Dutch NAP can be viewed to combine elements of the grandfathering allocation with the relative standard base allocation mechanism. Research into both the importance and the effectiveness of the relative standard base element in the Dutch NAP and the emission development under the covenant benchmarking system can generate interesting insights as to how industry would operate in the absence of a strict per-firm cap. It should be noted however, that the Dutch NAP has specific quantities allocated for the industry which—depending on society's preferences—may be altered with regard to other CO_2 emitting sectors or the tax payer.

While the Dutch NAP represents a hybrid form of allocation mechanisms, the mechanism applied in the Dutch NO_x trading system is generic in nature. The Netherlands intends to introduce a relative standard base system,[95] and, more precisely, a PSR-System[96] for emitters of NO_x gases. There are four reasons why the Dutch government opted for relative standards. First, the high emission reductions, second, the strong differences in NO_x efficiency between operators in the same industry, third, compatibility of the relative standard with existing legislation,

[91] How grandfathering schemes compare to relative standard base allocation systems (discussed below) has to be determined on a case by case basis.

[92] The particularities of the PSR system will be discussed below.

[93] The Netherlands (2004a).

[94] The Netherlands (2004a, p. 17 and p. 20). The Dutch government has decided to reward energy-efficiency performance with the allocation of allowances and to prevent infliction of punishments on first movers. More than 80% of total industrial energy use is now covered by covenants. In exchange for compliance with the covenant plans, Government has promised not to impose further national measures on participating businesses, which are directed towards CO_2 reductions. See also The Netherlands, (2004b).

[95] Tweede Kamer der Staten-Generaal (2004, p. 4 ff).

[96] VROM (2003, p. 17).

fourth, that the relative standard does not impede growth of firms since they are not required to buy additional emission allowances when their production increases.[97]

Whether such a ''provision'' system[98] is allocatively efficient is, however, subject to the same reservations as the above-mentioned free allocation mechanisms. Because emission allowances are created free of charge, politicians will have to estimate abatement cost structures and industry abatement potential in order to ensure a welfare maximizing allocation. This is equally difficult to attain as under a grandfathering system but similarly not a problem if the trading system functions effectively. In this case an allocative efficient solution will result if transaction costs are zero. Yet as was the case under grandfathering, the likely hood that a PSR system will give rise to the overall general equilibrium is low.

With regard to grandfathering, relative performance base allocation mechanisms have the important normative advantage that ''early movers'' will automatically be rewarded for having invested in abatement technology. Furthermore, in the presence of upward sloping abatement cost curves ''early movers'' will have an above average valuation for CO_2 allowances if compared to firms in a grandfathering system. In such environments relative performance allocation mechanisms are allocatively superior to grandfathering systems.

4.3 Environmental aspects

A major objective of Emission Trading Systems is the creation of incentives for operators to apply environmentally friendly means of production. With respect to the European Emission Trading System, it is clear that a cap-and-trade system is intended,[99] which in effect strives to restrict the absolute amount of CO_2 emissions to prescribed levels. Operators who are not able to surrender CO_2 allowances for all their emissions on every 30th of April are subject to an excess emission penalty and to the obligation to surrender them in the following year.[100]

In a trading system, emission reduction is achieved by those operators who's marginal abatement cost is less than, or equal to, the emission allowance market price. It is thus the scarcity of the CO_2 emission allowances that inflates the market price of CO_2 allowances and that eventually determines which firms will be selling and which firms will be buying allowances on the market. From an environmental point of view, it is irrelevant which firms emit CO_2 but decisive how the concentration of CO_2 in the atmosphere changes. CO_2 concentration and

[97] Tweede Kamer der Staten-Generaal (2004, p. 5 ff).

[98] As explained in Sect. 2.3 of this paper, emission allowances under the PSR system are created by an administrative act based on relative standard bases for specific industries but are not transferred from the government to enterprises. Therefore they are ''provided'' but not allocated.

[99] Articles 3(1) and 3(2), in conjunction with Annex B of the Kyoto Protocol, impose a specified absolute emission target upon Member States. Even though ''the cap'' is not explicitly introduced in Directive 2003/87EC, it can be inferred from Article 11(1) requiring Member States to decide upon the total quantity of allowances they will allocate during the three-year period to the operators of each installation. Although it is not explicitly stated in the Directive, it is a general assumption that Member States impose specific absolute emission caps on industries.

[100] Article 16 (3) and 16(4) of Directive 2003/87EC.

hence environmental performance is dependent on the absolute number of emission allowances and the timing of emissions brought into circulation and independent on their particular market price. Therefore it can be concluded that all initial allocation mechanisms operating under an absolute annual emission cap are logically separable from environmental effectiveness considerations. The absolute amount of environmental allowances is exogenously determined and is thus not influenced by such allocation mechanisms. This dichotomy can be seen in Fig. 3, which clearly distinguishes between the Quantity Setting decision and Allowance Allocation Mechanisms.

With respect to the operation of abatement, there are some subtle differences between the initial allocation mechanisms, which do not, however, give rise to different environmental effects. In auction systems, market operators will monitor allowance prices and decide on the spot if they buy CO_2 allowances or if they commit themselves to install abatement technology. Similarly with regard to financial administrative allocation mechanisms, the decision to buy or sell emission allowances is determined by the market price. Similarly, with regard to free allocation mechanisms such as grandfathering, firms will decide on the basis of the market price and their CO_2 abatement cost structure to buy or sell emission allowances and to install abatement technology. In allocation mechanisms based on relative industry standards, firms are awarded or provided with allocation permits on the basis of their relative CO_2 production efficiency but the decision to use them or to sell them does also depend on the market price.

Allocation mechanisms applying a ‘‘relative standards base’’ do merit further attention. Such allocation mechanisms do form part of the PSR-Emission Trading System, which expressly operates in the absence of a cap.

In the Dutch NO_x trading system, allowances are created on the basis of relative industry standards and government requires firms to submit additional emission allowance if they do not fulfil the ‘‘best practice’’ NO_x efficiency standards per produced unit. This places environmentally minded ‘‘early movers’’ at a comparative advantage with respect to those operators which have not been willing to invest in abatement technology.

The Dutch NO_x Emission Trading System combines both, a ‘‘relative standard base’’ benchmark system that provides emission credits by reference to the actual emissions of the operator, with a trading system that operates in the absence of a direct cap for national industry and is therefore referred to as a PSR System.[101] The Dutch NO_x trading system, which only extends to industrial operators, does not have a direct emission cap. The overall amount of Dutch national NO_x emission and thus environmental effectiveness is theoretically safeguarded by the Dutch ratification of the Gothenburg Protocol.[102] The Netherlands have agreed to restrict themselves to a maximum NO_x emission of 266 kton in 2010, and in accordance with the NEC directive[103] committed themselves to reduce this amount even further to 260 kton. In accordance with society’s preferences

[101] VROM (2003, p. 17).

[102] The Gothenburg Protocol was signed in 1999 and will enter into force on 17 May 2005.

[103] Directive 2001/81/EC.

emission reduction measures can be allocated to the sectors concerned; however, a nation-wide emissions trading system which includes every NO_x polluter has not been established by law.[104]

If society decides not to expand the allowances of the NO_x Emission Trading System, also and in particular in the presence of increasing industry output, one may speak of a de facto emission cap. This will highlight the essential positionality[105] of environmental protection standards. Thereby an environmentally beneficial ''race for top environmental standards'' is created. Whenever the Dutch government determines that the overall use of emission allowances of a particular industry is sufficiently close to the maximum amount allocated to it, it will sharpen environmental-friendly production standards to create incentives for firms to invest in abatement technology. Thus with regard to the Dutch NO_x trading system, it can be concluded that environmental effectiveness, measured in terms of NO_x emissions produced within one country,[106] can be ensured by a fixed amount of emission allowances on national level without setting a precise cap for industry.[107]

The above discussion has shown that allocation mechanisms cannot influence the environmental effectiveness of Emission Trading Systems because allocation mechanisms are charged with the task to bring an externally determined and prescribed amount of emission allowances onto the market. Reservations, however, do arise when allocation mechanisms are combined with ''relative Performance Standard Rate'' trading systems, which are not subject to any form of cap.

Here the absolute amount of emission allowances in circulation and hence the overall amount of emission can vary with respect to the total output of the economy. Whether a lowering of the social marginal costs of CO_2 emissions in Europe can tip the balance towards a conscious and normative preference of additional economic output is not only subject to societal preferences but also a question of both legal and economic considerations.

Whether a relative Performance Standard Rate system can work in parallel with a cap and trade system, its potential environmental and legal aspects—in particular state aid reservations, is an interesting subject to further research.

[104] The transportation sector, receiving about 60% of the emissions allocations, is expected to encounter severe difficulties in meeting its emission target. Government will hold a security reserve to ensure compliance with the NEC Directive and strives to maintain the sectoral distributions. VROM (2003, p. 14 and p. 29).

[105] Frank (1997, p. 169) defines a ''positional good'' as "a good whose value depends strongly on how it compares with similar goods consumed by others;..." and also referred to it as a ''status good''.

[106] This assumption is relevant because it may be possible that as a reaction to increasing environmental standards, production is shifted to countries with lower environmental standards. This reservation is, however, not peculiar to the NO_x system, but in fact relevant for all emission trading systems which do place a cost burden on firms.

[107] Assuming here expressly that government monitoring and action is well timed, that implementation time of abatement technology is either immediate or that overshooting effects of excessive NO_x emission and periods of less NO_x use counterbalance each other over time.

4.4 Summary

This part of the paper has outlined the importance of initial allocations in an Emission Trading System. The comparison of various allocation mechanisms has shown that auctions are best to solve the problems of price determination and can thus give rise to a general equilibrium. Yet if auctions give rise to strategic behaviour of bidders efficient transaction mechanisms are needed to ensure allocative efficiency and the general equilibrium. Due to the inherent information asymmetry bureaucrats cannot be expected to allocate emission allowances to those market participants that value them the most and consequently cannot ensure an allocative efficient distribution of emission allowances. In the presence of efficiently operating trading markets, however, this does not pose a problem because allocative efficiency can be ensured via market exchanges on such markets. In all administrative allocation mechanisms normative distribution considerations prevail over allocative efficiency and it cannot be ensured that the resulting allocation will give rise to a general equilibrium. Whether a society is better off under such systems strongly depends on its preferences. With regard to free allocation mechanisms, it should be noticed that ''relative standard base'' allocation mechanisms—in accordance with the ''polluter pays'' principle—directly reward environmentally pro-active producers, while a grandfathering system does not have the same advantage. In the presence of increasing abatement costs ''early movers'' will have higher abatement cost structures and hence also a higher valuation of CO_2 allowances. Consequently the relative standard base allocation mechanisms are allocatively superior to grandfathering systems in such environments.

From an environmental perspective, the discussion in a static closed economy has shown that the impact on the environment is dependent on the atmospheric CO_2 concentration and hence the amount and timing of emissions. The amount of allocated emissions is external to allocation mechanisms. Therefore all mechanisms reviewed can perform equally well. It should be noted, however, that this finding only holds as long as additional CO_2 emissions generated by economic growth do not offset positive environmental effects stemming from relative standards. In the latter case, environmental standards would have to be strengthened in order to attain identical emission targets.

5 Dynamic open economic setting

This section of the paper consists of three interrelated parts. The first will give an overview of the assumptions of an open dynamic economy. The second part examines how allocative efficiency in an open dynamic economy differs from a static closed economy. The third addresses environmental considerations. This last part is further divided into two sections. The first reviews variables that influences firm's production decision and hence the environment. The second analyses the environmental impact of the various initial allocation schemes.

5.1 Dynamic open economy model

After having examined allocative efficiency and environmental considerations in a static closed environment, some of the underlying assumptions are relaxed. We stop assuming that the world consists of only one economy but allow for international exchanges. An open economy allows for international trade through both import and exports. Examination of an open economy, particularly of a dynamic one, is important because it allows the analysis of firm's reaction to initial allocation mechanisms. Since the focal point of interest is the allocative efficiency and its environmental impacts of initial allocation mechanisms, Joint Implementation Mechanisms,[108] Clean Development Mechanisms,[109] economic growth and demand issues will not be discussed here. The model allows for strategic firm reactions to the implementation of an emissions trading system such as the European ETS. Firms can react to the introduction of such systems by reducing output, investment in abatement technology and by shifting production abroad. The model expressly assumes that foreign environmental requirements are negligible or non-existent and that the only relevant variables influencing firms' relocation decisions are transport costs and profit opportunities abroad.

5.2 Comparison of allocation mechanisms and allocative efficiency

Having introduced the dynamic open economy model, the next section will provide a comparison of initial allocation mechanisms. In particular, the differences to the static closed economy model are emphasised. This section consists of two parts. The first addresses auctions while the second deals with financial and free initial allocation mechanisms, including grandfathering and ''relative standard base'' systems.

5.2.1 Auctions as an allocation mechanism

The findings made in a dynamic open economy are very similar to those made in the static closed economic model discussed earlier. There are, however a number of additions which need to be addressed. At first collusion will be treated. Thereafter declining price anomaly is reviewed.

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[108] The Joint Implementation (JI) mechanism is established by the Kyoto Protocol and allows parties listed in Annex I of the Kyoto Protocol to receive emissions reduction units for co-financing projects that reduce net emissions in an Annex I country. Article 30(3) of Directive 2003/87/EC contains the possibility to incorporate JI mechanisms into the European Emissions Trading System.

[109] The Clean Development Mechanism (CDM) is established by the Kyoto Protocol (definition in Article 12) and allows Parties listed in Annex I of the Kyoto Protocol to finance emission-reduction projects in countries which are not listed Annex I. Annex I parties are awarded certified emission reductions (CERs) for doing so. The goals of the CDM are two-fold: firstly to assist non-Annex I parties in pursuing sustainable development policies and in contributing to the ultimate objective of the convention and secondly to assist Annex I parties in meeting their emission targets. Article 30(3) of Directive 2003/87/EC contains the possibility to incorporate CDM mechanisms into the European Emissions Trading System.

As presented in the static model, in-auction collusion is of particular importance in multiunit auctions.[110] Such issues as demand reduction and signalling have already been addressed in this paper. Since the same negative effects hold true for a dynamic environment, they will not be repeated here. There is, however, an important addition: in a dynamic model one does not only take into account in-auction collusion but also collusion occurring in a multi-sequential auction setting. Repetitive interaction of bidders provides the opportunity to retaliate against non-cooperating cartel members in later auctions.[111] In the presence of market power, an increased expected profit from collusion will distort the emission allowance market and thus allocative efficiency. Such form of collusion is beyond the reach of auction design theory and is dealt with in a competition law context.

Similarly, the problem of ''declining price anomaly'' which occurred only in a sequential auction framework in the static model is exacerbated in the dynamic economic setting. Here the temporal scope of simultaneous multiunit auctions is cast into a number of subsequent auctions over time. Hence bidders are forced to predict the evolution of market prices. A higher degree of uncertainty[112] is associated with demand and supply estimates in the more distant future and expected to exacerbate the strategic complexities firms will have to deal with. The degree of uncertainty firms are exposed to in both sequential and simultaneous multiunit auctions is expected to be higher in a dynamic environment than in a static one. High uncertainty may induce risk averse bidders to overbid even more in early auctions. Consequently strong declining price anomaly distorts allocative efficiency.

If Competition law would work suboptimally and fail to contain collusion occurring outside auctions, ceteris paribus, allocative efficiency would be worse than in a closed static environment and the general equilibrium may not be attained. Similarly a higher degree of uncertainty associated with larger prediction errors of forecasts is expected to exacerbate declining price anomaly and hence negatively affect allocative efficiency and the prospects to reach the general equilibrium in comparison to the static model. If allocative efficiency cannot be attained through auctions, efficient secondary markets on which bidders can cost effectively exchange emission allowances are needed.

5.2.2 Administrative allocation mechanism

After having reviewed how the allocative implications of auctions in an open dynamic economy differ from a closed static economy, we now turn to a set of different allocation mechanisms. Subsequently, the changes of both financial administrative and free administrative allocation mechanisms with regard to the dynamic model will be analysed. Allocative efficiency is the relevant criterion.

Financial administrative allocation mechanisms. The allocative effects of a financial administrative allocation mechanism are dependent on its particularities, but some general aspects can be highlighted. As in the static model, allocative efficiency is expected to be suboptimal and the general equilibrium may not be

[110] Salmon (2003, p. 10).

[111] See Martin (1994, p. 163).

[112] See Neugebauer and Pezanis-Christou (2005).

attained because bureaucrats will normally not be fully informed about the needs of operators nor are entrepreneurs willing to reveal their true preferences.

Due to societal considerations, a financial administrative allocation mechanism can be created to cross-subsidise specific operators. Through the granting of more favourable prices, operators can be awarded windfall profits.[113] Independent of initial allocation, profit-maximizing firms will take the opportunity costs[114] of the awarded emission allowances into account and rationally decide to use or to sell them. Therefore the same finding as in the static model prevails: efficient secondary markets have to ensure efficient allocation of emission allowances.

Free administrative allocation mechanisms. Unlike auctions or financial allocation mechanisms, free administrative allocation mechanisms do not require payments for emission allowances. As in the static economy, in a dynamic one the normative distribution justifications routed in societal preferences or industrial policy prevail over allocative efficiency and general equilibrium considerations. Allocative efficiency is subject to the same reservations concerning leakages and transaction costs as presented in the static environment and has to be ensured on secondary allowance markets. Below two particular forms of free administrative initial allocation mechanisms are being discussed: (a) grandfathering, and (b) relative standard base initial allocation systems.

(a) *Grandfathering.* As already outlined in the static model, grandfathering systems cannot be expected to generate an allocatively efficient initial distribution of emission allowances and may not lead to the attainment of the general equilibrium. As in the static environment, grandfathering in the dynamic environment can be allocatively superior to other free administrative allocation mechanisms because the former distributes allowances to a set of market operators who can be expected to have a high valuation for emission allowances. Given, however, that grandfathering is based on historic emissions and not on abatement cost structures, this allocation mechanism will always be less efficient than auction models.

(b) *Relative standard base mechanisms.* Similarly to other free allocation mechanisms, the relative standard base systems, including the PSR system, are not allocatively efficient and may not give rise to a general equilibrium. This is because emission allowances are allocated for free, leaving politicians to estimate abatement cost structures and industry abatement potential in order to ensure a welfare maximizing allocation. This is as difficult to achieve as under a grandfathering system and can only be remedied via an effectively functioning Emission Trading System. As already indicated in the static economic model, ‘‘early movers’’ are rewarded for investing in abatement technology. If ‘‘early movers’’ have higher abatement cost structures,[115] a relative standard base allocation system will not only be more allocatively efficient but also be in line with the ‘‘polluter pays’’ principle. The finding of the closed static economy model is thus repeated.

[113] Windfall profits are unexpected profits that accrue to the recipient and are beyond his control. Such windfall profits may give rise to State aid considerations under Art. 87 EC Treaty.

[114] Opportunity costs are commonly understood as the cost of something measured in terms of the benefit forgone by not using it for a different purpose.

[115] This will be the case in the presence of an increasing abatement cost curve.

This section has generated the results analogous to those in the closed static economy setting. Free administrative allocation systems are not allocatively efficient because bureaucrats are unable to award those market participants who have the highest valuation with emission allowances and may not give rise to a general equilibrium allocation. In the presence of upward sloping abatement cost curves, however, relative standard base allocation systems are allocatively superior to grandfathering systems and in conformity with the polluter pays principle.

5.3 Environmental aspects

This part consists of two sections. The first reviews variables that influence firms' production decisions and hence the environment. Subsequently the environmental impact of the various initial allocation schemes is analysed.

5.3.1 Dynamic interaction of firms and the environment

This part of the paper describes the complex interaction of an open economy in which emission allowances are introduced. Here it is assumed that from an environmental point of view it is irrelevant where in the world CO_2 emissions are reduced. Unlike in a static model, a dynamic setting allows for strategic firm behaviour and the adaptation to its business environment.

Due to the liberalisation of international investment flows and the advances in transportation and communication, capital has become more mobile than ever before. In the 1990s globalisation intensified when firms engaged in stronger vertical disintegration of production processes through outsourcing and process fragmentation. The ratio of global trade in goods and commercial services to world GDP has increased strongly from 8% in the 1950s to 19.8% in 1990. In the few years till 2002 this ratio increased by another 10%.[116] An important motivation underlying globalisation is the desire to benefit from international price differentials of production inputs.[117]

Rising environmental standards will increase production costs and lower the rate of return on domestic capital, leading to a reduction of the competitive edge of production sites and thus eventually to capital outflows. This in turn will impact private income and government's ability to finance its expenditure via taxes. At present the knowledge on the direction and magnitude of the interdependences between environmental cost internalisation and international competitiveness is limited.[118] Therefore the following discussion is restricted to a theoretical review of relevant strategic implications of firm behaviour.

As already presented in this paper, the economic intuition behind emission trading is the internalisation of negative externalities. Incentives to produce in a socially and environmentally desirable way are created via the market-price

[116] See Van den Bossche (2005, p. 8).

[117] Jones and Kierzkowski (2001) and Ethier (2002) for detailed discussions.

[118] Alanen (2003, p. 1112).

mechanism by increasing costs of production. In the following a firm's profit maximizing reaction to increases in production costs and its associated environmental implications are reviewed.

The obligation to submit allowances on a predetermined date in accordance with specified criteria can entail budgetary consequences for operators. Whether these consequences will be positive or negative depends on CO_2 abatement costs, the prevailing market price of emission allowances, operating costs and stranded costs.[119]

Budgetary impacts will be positive if the market price of emission allowances exceeds the cost of CO_2 abatement to such a degree that an operator is able to profitably sell emission allowances on the market. Positive effects of emission trading are enhanced by mitigating the impact on operating costs by saving on expensive CO_2 intensive energy consumption.[120] There will also be a positive (or less negative) budgetary effect if an operator receives part of the needed CO_2 emission allowances for free or below their true market value. This is generally referred to as windfall profit.

On average, however, negative budgetary implications are to be expected, given the environmental objective of reducing anthropogenic CO_2 emissions. Besides the direct costs of emission allowances, administrative and operative costs are non-negligible. In addition to these costs, firms will incur accounting losses if existing investments will be rendered unprofitable through increases in variable operating costs. These costs are referred to as stranded costs. Particularly energy and thus CO_2 intensive sectors will be subject to considerable increases in production costs and may not be able to withstand competitive pressure.[121]

The above discussion shows that an important determinant to induce behavioural change of operators is to increase their production costs. Whether the introduction of a regional Emission Trading System such as the European Emissions Trading System will indeed lead to the intended reduction of global CO_2 emissions, is a different issue. Profit maximizing operators can reduce CO_2 emissions within the economy by investing in abatement technology, or by reducing production output. This is precisely the same finding as was discovered in the static setting. Allowing for dynamic interaction, however, one should also note the strategic reaction of firms. Firms have two options. First, they can outsource abatement or secondly they can outsource production. Each will be treated in turn.

Firstly, in an open dynamic economy such as the one of the European Union, firms can ‘‘outsource'' CO_2 abatement. This can be done via Joint Implementation[122] and

[119] Existing investments which are rendered unprofitable due to the introduction of environmental regulations are commonly referred to as stranded costs.

[120] Fossil energy sources are particularly rich in CO_2.

[121] For a recent study addressing this issue see Reinaud (2005).

[122] The Joint Implementation (JI) mechanism is established by the Kyoto Protocol and allows parties listed in Annex B of the Kyoto Protocol to receive emissions reduction units for co-financing projects that reduce net emissions in an Annex B country. Article 30(3) of Directive 2003/87/EC contains the possibility to incorporate JI mechanisms into the European Emissions Trading System.

Clean Development Mechanisms.[123] Both mechanisms allow firms to benefit from lower abatement costs abroad. This in turn mitigates the cost burden placed upon domestic firms and hence the pressure to rely upon other means to contain CO_2 emission. Critics argue that this may create significant leakage and thus is not desirable from an environmental point of view. It should, however, also be noted that a lowering in the abatement cost structure enables operators to produce within the domestic economy and avoid additional CO_2 emissions associated with a shifting of production abroad.[124]

Second, in an open dynamic economy firms can outsource production. A restriction of CO_2 emissions in one region can lead to increases in production costs which trigger changes in relative prices and shifts in trade patterns which work to offset positive CO_2 reductions.[125] The mere suspicion that higher production costs may reduce profitability may lead to a redirection of investments ex ante, i.e. before the introduction of cost internalisation measures. It will, however, certainly lead to a redirection of future investments.

The profitability and hence occurrence of such outsourcing and the redirection of trade flows depends on transportation costs and profits reaped on the foreign market.[126] If it is more profitable to produce in the absence of any environmental cost internalisation measures abroad and to serve the foreign and domestic market at the same time by shipping goods to the EU, profit maximizing firms will do so in the long run. Particularly so if growth prospects are more favourable abroad and transportation costs are expected to be declining over time. Production relocation would entail an increase of CO_2 emissions abroad with potential negative effects for the environment. Not only would the apparent EU emission be understating its true CO_2 consumption, but ceteris paribus even lead to a rise in CO_2 emissions due to an increase in the average transportation distance of goods marketed in the EU. This negative impact on global CO_2 emissions would be exacerbated if foreign producers used more carbon intensive production techniques.

This section has shown that the introduction of an Emission Trading System can have significant distributional effects for particular firms. These can be exacerbated or mitigated through the selection of an initial allocation mechanism. Allowing the procurement of CO_2 abatement abroad lowers the overall cost burden on enterprises and permits domestic firms to continue their operations. Distributional effects within

[123] The Clean Development Mechanism (CDM) is established by the Kyoto Protocol (definition in Article 12) and allows Parties listed in Annex B of the Kyoto Protocol to finance emission-reduction projects in countries which are not listed Annex B. Annex B parties are awarded certified emission reductions (CERs) for doing so. The goals of the CDM are two-fold: firstly to assist non-Annex B parties in pursuing sustainable development policies and in contributing to the ultimate objective of the convention and secondly to assist Annex B parties in meeting their emission targets. Article 30(3) of Directive 2003/87/EC contains the possibility to incorporate CDM mechanisms into the European Emissions Trading System.

[124] See discussion below.

[125] Such effects have long been addressed in multi-regional studies. See for example Pezzy (1992), Edmonds et al. (1995), Burniaux and Oliveira Martins (2000) and Munskgaard and Pedersen (2001).

[126] In reality there are of course other political and socio-economic factors taken into account before a production decision is taken. For the sake of simplicity, only transportation costs and profit opportunities on the foreign market are taken into account.

the domestic market as such do not induce firms to relocate. The decisive factor for relocation and the generation of associated negative environmental effects is the existence of a cost differential between environmental cost internalisation on one hand and transportation costs on the other. Profit opportunities in foreign markets are also taken into account and counterbalance high transportation costs. Positive predictions of the evolution of transportation costs and profits earned abroad and dim prospects of permit prices can tip the balance towards relocation decisions.

5.3.2 Initial allocation mechanisms and the environment

After having reviewed general firm behaviour that can be triggered by production cost increases due to the introduction of an Emission Trading System, the following section reviews qualitative environmental differences stemming from the selection of different initial allocation mechanisms. Systems considered include auctions, financial administrative allocation systems as well as free administrative allocation systems. Here particular attention is devoted to grandfathering and relative standards.

Auctions. Unlike in the static closed economy setting, auction mechanisms used in an open economy are capable of impacting the environment. Due to the mere fact that in auctions CO_2 emission allowances are sold, auctions do generate the strongest distributional effect of all initial allocation mechanisms. The cost burden placed upon firms will lead to a reduction in CO_2 due to investment in abatement technology and the reduction of output to a socially desirable level. From an environmental point of view the critical element is the change in the production decision. The reduction on the rate of return of domestic capital can trigger the relocation of domestic production plants and lead to a rise in CO_2 emissions. This will be the case if an increase in transportation distance of goods is associated with more CO_2 emissions and if production abroad is more CO_2 intensive.

One interesting opportunity provided by auction systems is that they generate government funds in a non-distortionary manner. These funds can be channelled back to operators. Investment shifts will not occur if the collected funds are redistributed in form of tax cuts in such a way as to fully compensate operators for the expenses they incur.[127]

If funds are distributed via tax cuts to other groups of society, an increase in disposable income will lead to an increase in demand and hence to more overall world emissions. This will particularly be the case if foreign direct investment stimulates foreign economic growth and profitable business opportunities in the host country.

The threat of the occurrence of declining price anomaly and collusion will distort the equilibrium market price. The declining price anomaly gives rise to an

[127] The substitution of distortionary taxes on labour or profit could be substituted by the levy of non-distortionary taxes on CO_2 emissions. Ballard et al. (1985) estimate that one dollar raised through distortionary taxes can cost society one dollar 30 cents. Thus society, including operators, can be made better off by levying taxes through auctions. Such overcompensation is also found by Bovenberg and Goulder (2000).

overshooting effect in the sense that the market price will at the beginning lie above its true equilibrium. This could, however, lead to short run overinvestment in abatement technology. Such positive environmental effects, may be partially depleted during the price adjustment towards its true equilibrium. Collusion will not lead to an overstatement but to an understatement of bidder's true valuations. This leads to adverse environmental effects to the extent that the lower market price for emission allowances gives rise to suboptimal investments in abatement technology and increased market penetration of foreign competitors.

Administrative allocation mechanisms. After having reviewed the environmental impact of auction mechanisms, this section reviews the impact of administrative allocation mechanisms on firm behaviour and consequently, its impacts on CO_2 emissions. First financial administrative allocation mechanisms are being reviewed. Subsequently free administrative mechanisms, including grandfathering and relative standard base mechanisms are examined.

(1) *Financial administrative allocation mechanisms*. As already indicated, environmental effectiveness in a dynamic open economy does not only depend on the absolute emission cap but also on how operators adapt to changes in their business environment. Emission reduction in a trading system is only achieved by inducing operators to take externalities into account. This is achieved by inflating the price of an earlier under-priced good.

Even profit maximizing operators who have been awarded windfall profits under a financial administrative allocation mechanism have every incentive to reduce emission if their production costs with regard to CO_2 increased. This leads to a reduction in output, an increase in CO_2 efficiency or to a transfer of production abroad. If transportation costs are sufficiently low as to allow a firm to produce abroad and import goods at a profit, a profit maximizing operator has every incentive to do so. This is rational behaviour irrespective of any windfall profits, which are granted to particular operators or sectors. This may lead to a furtherance of the wedge between CO_2 production and CO_2 consumption within the EU.

(2) *Free administrative allocation mechanisms*. Similarly, even in the case where all emission allowances are distributed for free, overall scarcity is determined by the quantity supplied. Since in all cases reviewed the initially allocated amount is assumed to be the same, the degree of scarcity and hence also the prevailing market price will be the same. Firm's strategic reaction to the introduction of emission allowances is similarly dependent upon transportation costs and expected profits from abroad. Since the actual costs incurred by operators are lower than under auction and financial administrative allocation mechanisms, *ceteris paribus*, less relocation will occur.

(a) *Grandfathering*. Free allocation based on historical input, output or emission data gives rise to strategic firm behaviour. Overall CO_2 emission will depend on the market price of emission allowances, abatement costs, transportation costs and expected profits abroad. If it is profitable firms will shift production sites abroad and prefer to import rather than to produce within the EU. This entails negative environmental consequences. Grandfathering, however, differs from other free allocation mechanisms because it gives rise to additional strategic firm behaviour. Before the base year is being set, firms do have every incentive to emit more CO_2 and to postpone emission reduction programs in order to increase their future allocation. How such negative environmental effects compare to other allocation mechanisms is subject to further research but it appears clear that grandfathering based on actual historic emissions is less preferable than free allocation mechanisms based on e.g. market share, which do not give rise to such self-defeating incentives.

(b) *Relative standard base mechanisms.* As has been shown in the static economy setting, a relative standard base allocation system can be applied to attain a predetermined emission cap provided that the industry standards are adjusted in accordance to increases in production. The costs accruing to particular operators are expected to reflect their abatement possibilities. Therefore the threat that existing investments will be transformed into stranded costs appears to be lower. Similarly, if transportation costs and potentially higher monitoring costs[128] were indirectly taken into account by assessing an industry's competitive position, relocation will be limited and consequently, environmental effects will be limited. This will, however, only be the case if monitoring costs are sufficiently low and uncertainty about bureaucratic action to raise prevailing environmental standards to maintain the CO_2 cap are not such as to induce firms to relocate. Since PSR systems reward early movers, they penalise late movers. This creates the danger that if standards are set too high, late movers bearing the relatively higher costs will have stronger incentives to relocate. Whether relocation can be limited through the introduction of relative standards that can contain adverse global CO_2 effects depends not only on the standard setting institution's ability to determine abatement capabilities but also on the stringency of the selected emission cap. If the abatement target is so large as to exhaust all possibilities to burden domestic industry, relocation will necessarily take place.

In the absence of a fixed emission cap, it is argued that CO_2 emission will rise more than under an absolute emission cap. While this is a valid reservation under a closed economy setting if decision makers are inclined to follow social considerations and lobbyists not to increase relative standards, this is not so evident in an dynamic open economy. Here, similarly, the reservations regarding decision makers' determination to adhere to goals committed to under international treaties are valid. Independent of the decision maker's resolution to contain CO_2 emissions, feasibility of CO_2 abatement is determined by profit opportunities abroad and transportation costs. Firms who can operate more profitably in a country which does not internalise negative externalities and still sell products in the domestic economy, will do so. The only means for the domestic economy to push internalisation of externalities beyond the level of transportation costs is to shift existing taxation away from current tax sources[129]

[128] Gielen et al. (2002, p. 11) assert that monitoring costs for particular industries under a relative standard base mechanism will be higher if no existing relative standards can be referred to.

[129] One could think about increasing the tax burden on CO_2 while reducing the taxation for labour by an equal amount so that it is rational for firms to adjust to the new taxation rules by reducing the amount of CO_2 emission without having incentives to relocate production facilities.

or to levy an import tax[130] to take the differences in CO_2 intensity of production attributable to particular goods[131] into account.

5.4 Summary

This part of the paper has shown that allocative efficiency, and potentially also the general equilibrium, are more difficult to attain in an open economy. Allocative efficiency of auctions in a dynamic setting is complicated by collusion occurring outside the auctions and can only be contained via the application of Competition law. Similarly a higher degree of uncertainty associated with larger prediction errors of forecasts is expected to exacerbate declining price anomaly and hence negatively affect allocative efficiency. If allocative efficiency cannot be attained through auctions, efficient secondary markets are needed. As in the static closed economy model, allocative efficiency cannot be attained via administrative distribution systems, which emphasise normative distribution considerations. Efficiently operating secondary markets allow operators to realise the windfall profits they have been awarded via financial or free administrative allocation mechanisms. In the presence of upward sloping abatement cost curves, however, relative standard base allocation systems are allocatively superior to grandfathering systems and in conformity with the ‘‘polluter pays’’ principle. Thus the finding made with respect to the static model has been confirmed.

In a dynamic model firm’s reactions to an increase in production prices has an important bearing on the environment. The decisive factor for international competitiveness and the decision to relocate production and the generation of associated negative environmental effects is the existence of a cost differential between environmental cost internalisation on one hand and transportation costs on the other. Profit opportunities in foreign markets are also taken into account and counterbalance high transportation costs. Positive predictions of the evolution of transportation costs and profits earned abroad and dim prospects of permit prices can tip the balance towards relocation decisions.

Distributional impacts on particular firms can be exacerbated or mitigated through the selection of an initial allocation mechanism. Auctions generate the strongest cost burden on particular firms and thus also the strongest incentives for firms to relocate if the funds that are levied in a non-distortionary manner are not redistributed to bidders. If other parts of society are awarded parts of the funds, it can be expected that an increase in disposable money will lead to increased demand and CO_2 emissions. While collusion will not generate adverse environmental effects, declining price anomaly may lead to a temporary overinvestment in abatement technology. The cost burden placed upon firms is less severe under a

[130] Import taxes serve to protect producers’ surplus at the expense of consumers’ surplus. While the overall social welfare effect is ambiguous, it is assumed to be lower for small economies. See Krugman and Obstfeld (1997, p. 193 ff).

[131] An “import tax” is the same as an import tariff, or customs duty. Tariffs on most products are bound in the schedules of the WTO Members. Unilateral increases in tariffs are generally a violation of WTO law (Article II GATT) and are permitted only in certain very restricted cases (e.g. anti-dumping, countervailing, safeguards).

financial administrative allocation mechanism than under auctions since permits are assumed to be marketed below their true market price. Free administrative allocation systems place the lowest direct cost burden on enterprises and thus generate the least incentive for firms to engage in environmentally unfriendly production relocation. Yet it should be noticed that grandfathering systems can induce operators to postpone emission reduction projects in order to be awarded more emission allowances. Such incentives are not present for relative standard base mechanisms. In addition stranded costs are expected to be limited. Under a cap and trade system—or in case of its absence if a given emission quantity is observed—and assuming that the set relative standards take into account abatement costs and industry's competitive position, and that monitoring costs and uncertainty costs are limited, relative standard base systems can perform in the most environmentally efficient manner.

In a dynamic open economy the upper boundary for the internalisation of environmental externalities is dependent upon the international competitive position of domestic firms and not determined by domestic regulation prescribing absolute emission targets. In such cases the existence of a cap or its absence is not of practical relevance since this differentiation does not affect firm's production decisions. Hence, both from an environmental and competitiveness point of view the most cost effective system is most desirable. Depending on the particular mechanism design, this might be a relative standard base system, which may be an element of a PSR Emission Trading System.

6 Conclusion

This paper has placed various initial CO_2 emission allocation mechanisms into a typology and analysed them within a static closed and a dynamic open economy setting according to their price determination and allocative efficiency in order to determine if the EU ETS promotes or hinders allocative efficiency and whether allocative efficiency can be safeguarded. In light of the overall objective of the Emission Trading System, particular attention has been given to environmental aspects of allocation mechanisms.

With regard to the static closed economy the chapter shows that only auctions are capable to solve the problem of price determination and to attain allocative efficiency and the general equilibrium. In the presence of collusion or declining price anomaly, however, they have to rely upon efficient secondary markets for the attainment of these goals. It is however not certain if a general equilibrium will result. Since in administrative allocation mechanisms normative distribution considerations prevail over allocative efficiency, they too have to depend upon efficient secondary markets to ensure allocative efficiency and still may fail to ensure a general equilibrium. Relative standard base mechanisms award ‘‘early movers'' in accordance to the ‘‘polluter pays'' principle and thus are allocatively superior to grandfathering schemes. Relaxing the strict model assumptions towards a dynamic open economy confirms the above findings with only one qualification. Due to an exacerbated risk of collusion and a declining price anomaly due to a larger degree of uncertainty, auctions perform less well in the dynamic closed economy than in a static closed economy. Therefore it can be concluded that only the auctioning mechanism is capable of ensuring allocative efficiency with general equilibrium characteristics and that the other allocation formats that can be applied under the EU ETS do rely on cost effective exchange systems to safeguard allocative efficiency.

With regard to environmental aspects, initial allocation mechanisms under a static closed economy are unable to affect the environment as long as a strict dichotomy between the quantity setting decision and the distribution issue of CO_2 prevails. This, however, is not the case for a dynamic open economy setting. The introduction of an emission allowance trading system increases production costs of operators. In the framework considered transportation costs and profit opportunities abroad constitute the upper limit of the internalisation of negative environmental externalities because operators may relocate production facilities abroad if it is profitable for them to do so. Global CO_2 emission will rise due to relocation if the average transportation distance increases[132] or if production abroad is not subject to equivalent environmental regulations.

In the absence of compensation schemes auctions generate the highest burden on operators and thus perform worst from an environmental perspective. Its performance may only partially be mitigated by short-term positive environmental effects stemming from declining price anomaly. The relocation-inducing burden under financial administrative systems is less severe than under auctions but not as low as under free administrative allocation systems. Due to the non-existence of time shifting incentives and low stranded costs, relative standard base systems are more environmentally friendly than grandfathering mechanisms. This will be the case in a cap and trade system as well as in the absence of a cap as long as the overall emission quantity is not increased provided that standards are set in such a way as to take abatement costs and industry's competitive position into account and that monitoring costs and uncertainty costs are sufficiently low. Irrespective of the existence of an emission cap, the upper limit of the costs to the internalisation of environmental costs is given by operator's ability to evade such costs. Therefore it can be concluded that indeed initial allocation mechanisms have a bearing on the environment and that its impact may even be more relevant than the discussion of the necessity of emission caps may suggest.

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[132] Here the underlying assumption is of course that CO_2 emissions are positively correlated with transportation distance, implying that emissions increase as distance increases.

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