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Chapter 10

REASSESSING THE IMPORTANCE OF INITIAL ALLOCATION METHODS IN EMISSION PERMIT MARKETS

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Abstract

One of the most controversial aspects of tradable-permit markets is the initial allocation of pollution permits. Subject to a set of technical assumptions it can be shown that the equilibrium outcome is independent of the initial distribution of permits, meaning that the market-clearing permit price, individual firms' abatement efforts and overall compliance costs are the same regardless of whether grandfathering, auctioning or some other method is used to allocate permits. However, the assumptions required for this well-known result may be violated in practice. We review the recent literature that relaxes some of these benchmark assumptions and discuss if and to what extent the method of initial allocation affects the outcome. In each case we critically analyze the evidence for using auction and grandfathering approaches. We show that the choice between free allocation and auctioning depends on the specific allocation method used (e.g. pure grandfathering vs. allocation "updating", benchmarking, or output-based), the presence of market power and transaction costs, the use of auction revenue, and the political process through which the permit market is instituted.

1. Introduction

During the past 50 years economists have strongly advocated the use of market-based regulation as an efficient alternative to prescriptive 'command-and-control' policies (Kneese and Schultz, 1975; Schultz, 1977; Ackerman and Hassler, 1981; Anderson and Leal, 2001). One of the most innovative market-based mechanisms, and the subject of this chapter, is a tradable-permit market. The fundamental idea of a tradable-permit market is credited to Dales (1968a; 1968b) and Crocker (1966) who argued for a system of pollution regulation where firms can legitimately pollute when they hold a well-defined and tradable pollution right.[1]

To implement a tradable-permit market the regulator must determine (through discussions with the general public, scientists and industry) a desirable, or socially optimal, level of emissions. The target level of emissions is then partitioned into individual pollution rights, called permits, which allows the holder to emit a specified level of emissions of the pollutant within a certain time period (e.g. one ton of carbon dioxide in time period 2007-2012). The regulator creates trading rules for the permits and then allocates them to the regulated firms. After initial allocation, firms can freely trade permits.

Allowing for the transferability of pollution rights results in the environmental target being satisfied at the lowest social cost. A firm that finds pollution abatement relatively expensive has the opportunity to lower its compliance cost by purchasing allowances from the market. Moreover, firms that find pollution abatement relatively cheap have the ability to sell any excess permits to the market. In equilibrium, the lowest social cost will be achieved when each firm chooses a level of emissions (pollution reduction) such that their marginal abatement cost is equated to the permit price. Put differently, the social cost of a specified pollution reduction target is minimized when firms' marginal abatement costs are equalized—the level of abatement is efficiently distributed among the regulated firms.

Permit markets have become an increasingly common regulatory tool, most frequently used in the context of controlling air pollutants. Examples are the sulphur dioxide trading program or 'Acid Rain Program' (Ellerman et al. 2000; Carlson et al. 2000), NO_X budget program (Farrell, 2000; 2001), Regional Clean Air Incentives Market (RECLAIM) (Foster and Hahn 1995), Lead-phase down program (Kerr and Maré, 1998), Ozone depleting gases (CFCs) (Hahn and McGartland, 1989), volatile organic matter (Shannon; 1995), European Union Emissions Trading Scheme (EU-ETS) (Watanabe and Robinson, 2005), and the Regional Greenhouse Gas Initiative (RGGI) (Burtraw et al. 2005).

Although the application of tradable-permit markets to air pollution has been the most successful and well known application, others do exist. Permit markets have be discussed in water pollution and water supply (Eheart, 1980; Hanley and Moffat; 1993; Hanley et al. 1998), fishery quotas (ITQs) (Newell et al. 2005), waste disposal (Miranda et al. 1994), biodiversity conservation and land use (Mills 1980; MacMillan, 2004), forestry (Chomitz, 2004), recycling (Dinan, 1992), Energy (Berry, 2002) and even outer space (Scheraga, 1987).

The methods to initially allocate permits usually fall into two broad distinctions: either freely allocated or fee-based permits.[2] When permits are distributed for free, a number of possible allocation methods can be used. The most common type is the use of historical emissions to determine firms' free allocation, meaning that heavy polluters in the past will obtain more permits allocated for free in the current period than firms that emitted less. However, other alternative criteria are possible, such as basing permit allocation on a firm's output, energy (fuel) use, and so on (MacKenzie et al., 2008). The most common fee-based approach is the use of a multi-unit sealed bid auction, where polluters bid for permits (Cramton and Kerr, 2002).

We discuss the major contributions in the literature that have extended the analysis of

[1]The terminology 'right' is used loosely. As Raymond (2003) explains, this is not a property right as it is licensed to firms from the government. Instead, one might consider 'licensed property'.

[2]See MacKenzie et al. (2009) for a discussion.

the initial allocation of permits.[3] We begin the survey by illustrating the seminal work of Montgomery (1972), who proved that in a perfectly competitive and static market, the equilibrium outcome and thus market efficiency is independent of the choice of initial allocation (although it will affect the equity of the market). In policy terms, the perfectly competitive market will establish the least-cost outcome with *any* initial allocation vector. However, the independence between the initial allocation of permits and the least-cost outcome only holds due to a number of strong (and perhaps unrealistic) assumptions. We therefore discuss the major contributions in the literature that have advanced our understanding about the initial allocation process.

In particular, we focus attention on how (and to what extent) the initial allocation affects market efficiency when three assumptions are relaxed. We allow for (i) imperfectly competitive markets, (ii) the existence of transaction costs and (iii) dynamic permit allocation, and find that in these cases, efficiency is no longer independent of the initial allocation. Therefore, permits should not be allocated based on equity and distributional arguments alone. Instead, when regulators implement a permit market, they should consider the likely issues that may arise (e.g. strategic behavior of firms) in that permit market and devise an appropriate allocation mechanism. As permit market circumstances are largely heterogeneous, the initial allocation choice should be considered on a case-by-case basis. Aside from the issue of permit market efficiency we also consider how the use of revenue created from initial allocation mechanism as well as political activity can alter the desirability of free or auctioned permits.

Due to the vast selection of literature that, directly or indirectly, discusses the initial allocation process, our chapter is restricted in a number of dimensions. Probably the most important aspect that we do not consider here is that of uncertainty. Extending the benchmark model to allow for uncertainty regarding abatement costs, future caps and/or business-as-usual emissions can change things considerably. Uncertainty is central in the permit-vs.-taxes debate, in particular in the context of incentives for investment in irreversible abatement. However, the implications of uncertainty for initial allocation are less clear. Because we focus on various forms of allocation methods within a permit market but are not concerned with the prices-vs.-quantity debate, we will not consider uncertainty here.

We also keep the assumption of complete compliance in the permit market. Van Egteren and Weber (1996) and Malik (2002) consider the relevance of the initial allocation when firms may choose to be non-compliant. We feel that compliance is not an empirically relevant issue in the most important permit markets to date since emissions of CO_2, SO_2 and NO_X can be monitored relatively easily and/or computed based on fuel inputs. Furthermore, the high penalty for noncompliance in the EU ETS should largely eliminate the scope for noncompliance in this market.

The chapter is organized as follows. Section 2 details the benchmark case where efficiency is independent of the initial allocation, conditional on a set of assumptions. We relax some of these assumptions in Section 3 and discuss the resulting relationship between initial allocation and permit market efficiency. Section 4 deals with additional issues of allocation choice and Section 5 concludes.

[3] Other surveys relating to aspects of tradable permits include Tietenberg (1980) who discusses general implementation issues in permit trading and Koutstaal (1999) who discusses imperfectly competitive behavior and transaction costs in emissions markets.

2. Benchmark case: Equilibrium outcome independent of initial allocation

We begin the discussion of initial allocations by explaining the rationale for a property rights-based approach to pollution and show that under certain conditions, the permit market equilibrium outcome is efficient and independent from the initial assignment of permits. In this case, the method of allocation only has distributive consequences.

2.1. Theoretical background

Pollution is the quintessential example of an externality, as the polluter does not take the reduction in the sufferers' utility into account when making its production decisions because it occurs outside the market system. One method to counter the problem and hence reduce the effects of pollution on the environment is to define legal and enforceable property rights where an economic agent holds the right to pollute, or conversely the right *not* to be polluted.

One of the first expositions to define property rights for externalities was the seminal paper by Coase (1960). He argued that an efficient level of pollution can be achieved by relying on the polluter and sufferer bargaining over a given set of well defined property rights. Coase assumed a bargaining system for well defined property rights that was free from informational deficiencies, such as moral hazard and adverse selection, as well as transaction costs. Given these assumptions, a Pareto efficient bargaining equilibrium would exist independent of how the property rights were initially allocated.

Under an emissions trading program a similar logic applies. Permits are either given for free to polluting firms (in which case they obtain the right to pollute), or sold by the government (the case where the taxpayer retains the right not to be polluted). Montgomery (1972) used the analytical framework of an emissions trading scheme and formally proved Coase's result that the efficient equilibrium outcome is independent of the initial allocation of property rights. This is fortunate because Coasian bargaining is not a practical solution for situations involving multiple agents as in the case of air pollution, because transactions are prohibitively high.

2.2. The benchmark model

To provide a focus for discussion, we restrict attention to the simple case where the pollutant is uniformly mixed in the atmosphere. For alternative pollution types, the reader is referred to Baumol and Oates (1988), Hahn (1986), Krupnick et al. (1983), and Tietenberg (2006) for a comprehensive discussion.

To obtain the benchmark result that efficiency is independent of allocation, three key assumptions need to be made: (1) the product and permit markets are *perfectly competitive* so that there is no strategic behavior and all firms are price-takers; (2) there are no *transaction costs* involved in trading the pollution permits; and (3) the product and permit markets are *static* with regards to allocation and caps. This last assumption does not imply that pollution and emissions do not occur over time, but that the 'rules of the game' are fixed.

2.2.1. Social optimum

Let us assume firm i ($i = 1, 2, \ldots, n$) produces output q_i and, as a side-product, emissions e_i consisting of a single pollutant. Production costs vary across firms and are given by the function $C^i(q_i, e_i)$, which is twice differentiable and convex in both arguments, increasing in output and decreasing in emissions such that $C^i_q > 0$, $C^i_e < 0$, $C^i_{qq} > 0$ and $C^i_{ee} < 0$, where the subscripts refer to partial derivatives.[4] Furthermore, $C^i_e(q_i, e^*) = 0$, where e^* refers to business-as-usual emissions, i.e. emissions that the firm would choose in the absence of any regulation. This means that the first unit of abatement is costless.

Through the political process the regulator determines an emissions level that is not to be exceeded, denoted by $S = \sum_{i=1}^{n} x_i$. The regulator's goal is to achieve this emissions target at the lowest overall cost, which he obtains by optimally choosing a vector of emissions $E = (e_1, e_2, ..., e_n)$ subject to the overall emissions cap S:

$$\min_{e_i} \sum_i C^i(q_i, e_i) \quad s.t. \quad \sum_{i=1}^{n} e_i \leq S. \tag{1}$$

The first-order conditions for an interior solution are:

$$-C^i_e = \lambda \quad (e_i > 0), \tag{2}$$

$$S - \sum_i e_i \geq 0, \quad \lambda \geq 0, \quad (S - \sum_{i=1}^{n} e_i) \cdot \lambda = 0. \tag{3}$$

Equation (2) illustrates that at the least-cost solution, firms' marginal abatement costs $-C^i_e$ are equalized, and that they are equal to the shadow value of emissions λ_j . Equation (3) states that the level of emissions has to be equal or below the cap. If the cap is not binding, the shadow value of emissions is zero and as a consequence, firms do not carry out any abatement.

2.2.2. Market equilibrium

The socially optimal outcome can be decentralized by splitting up the cap into smaller units and require firms to hold a sufficient number of permits x_i to cover their emissions, where the sum of all permits in the market adds up to the cap S. Firms can freely trade these permits for emissions at a price σ. Each firm maximizes profits by choosing output, emissions and required permit holdings:

$$\max_{q_i, e_i, x_i} \Pi = p\, q_i - C^i(q_i, e_i) - \sigma(x_i - a_i) \quad s.t. \quad x_i \geq e_i, \tag{4}$$

where p refers to the output price and a_i to an initial free allocation that firms may receive. For price-taking firms and a binding cap, the first-order conditions for an interior solution (where $q_i > 0$ and $x_i = e_i > 0$) are:

[4] For this section, the dependence of costs on output is neglected. We chose to introduce output already here in order to facilitate comparison with later sections.

$$C_q^i = p, \tag{5}$$

$$-C_e^i = \sigma. \tag{6}$$

Comparing (2) and (6), it is clear that the market equilibrium coincides with the least-cost allocation when $\sigma = \lambda$, that is when the permit price is equal to the shadow value of an emissions reduction. If a firm's marginal abatement costs were below the price of a permit, it could make a profit by abating more and either selling more or buying fewer permits at a price of σ. Conversely, if marginal abatement costs are above the permit price, the firm could reduce costs by abating less and buying more permits on the market. As the market is perfectly competitive, this happens for all firms, which results in the necessary condition for the aggregate cost minimization problem (1) being satisfied. Perfect competition in the output market leads to an equalization of marginal production costs with the output price as shown in (5). This is the least-cost equilibrium.[5]

The crucial point of this derivation is that a_i, the initial free permit allocation, does not appear in (5-6). In other words, the conditions for optimality and therefore the resulting vector of emissions, abatement and output are independent of the initial permit allocation.

Equations (4-6) can also be used to illustrate that without uncertainty, emissions taxes and permits yield the same equilibrium outcome. To see this, set $a_i = 0$ for all firms and re-define σ as the emissions tax in (4). Now all firms equate their marginal abatement costs with the emissions tax, which again coincides with the shadow value of an emission reduction. The equilibrium outcome in terms of output, emissions and abatement are exactly the same. The two situations differ only in terms of wealth distributions embedded in the free permit allocation to firms.

The irrelevance of initial allocations for efficiency suggests a regulator can choose *any* initial allocation rule (or process) and be assured that the resulting equilibrium will be efficient. The choice of an allocation rule can therefore be based on equity considerations alone.

3. Relaxing the benchmark assumptions: Why allocation matters

The assumptions used to obtain the result of the previous section are quite stringent and arguably unrealistic for many tradable-permit markets. In this section, we survey the literature that relaxes the assumptions discussed above. The independence of initial allocation result described in the previous section no longer holds under these circumstances, such that the method and the distribution of the initial permit allocation generally impact both distribution and overall efficiency.

Throughout this section we will assess the importance of the type and level of permit allocation for efficiency in the permit market, as well as for overall efficiency. We define

[5] The second-order conditions are also satisfied: They are $-C_{qq} < 0$ and $-C_{ee} < 0$, as required for an optimum. As this is true throughout our model, we refrain from mentioning second-order conditions in what follows.

permit market efficiency as a situation where marginal abatement costs of all firms are equalized, which implies that overall costs to reduce emissions are minimized subject to a given cap and output level.

In contrast, by overall efficiency we refer to total welfare. In a model with only a permit market, the two definitions are the same. However, when taking into account other markets and their potential interactions with the permit market, overall efficiency can fail even when permit market efficiency holds. Conversely, in a second-best world where not all distortions can be removed, overall welfare may be maximized even if permit market efficiency does not hold.

3.1. Imperfectly competitive markets

In turn, we consider the three forms of imperfect competition: In the permit market only, in the product market only, or both.

3.1.1. Imperfectly competitive permit market

We begin with an imperfectly competitive permit market. In his seminal work, Hahn (1984) sets up a model with a single dominant firm and a price-taking fringe and showed that a dominant firm will take the effect of its permit purchases (or sales) on the permit price into account when minimizing compliance costs.[6] The dominant firm equates its marginal abatement costs $-C_e$ with the the total marginal cost of a permit, which consists of the permit price σ plus a second term that captures the price effect of the dominant firm's permit purchase decision (suppressing the subscript for convenience):

$$-C_e = \sigma + (x - a) \cdot \frac{\partial \sigma}{\partial x} \tag{7}$$

The second term is positive if the dominant firm is a net permit buyer, and negative if it acts as a net seller ($\partial\sigma/\partial x > 0$ reflects the assumption of market power in the permit market). For a net buyer, purchasing another permit costs the firm not only the price of a permit, but the resulting permit price increase is felt over the entire amount of permit purchases $x - a$. As a consequence, the dominant firm will not equalize its marginal abatement costs with the permit price, but over-abate and under-purchase permits relative to the fully competitive case. For a net seller, the situation is reversed. Because the fringe firms equate their marginal abatement costs with the permit price, not all firms' marginal abatement costs are equalized and thus permit market efficiency is not attained.

Figure 1 shows the effect of three different initial allocation levels for the same dominant firm.The downward sloping curve represents the firm's marginal abatement costs $-C_e$ as a function of its equilibrium permit holdings x. The upward sloping straight line reflects the assumption of market power and translates x into the permit price $\sigma(x)$. With no market power, this would be a horizontal line.

If the dominant firm receives a free initial allocation of a^b permits, its marginal abatement costs are greater than the permit price and the firm finds it optimal to buy permits in

[6] Sinn and Schmoltzi (1981) derived an equivalent result, but Hahn usually receives the credit, possibly due to a more intuitive exposition but probably also because Sinn and Schmoltzi published their work in German.

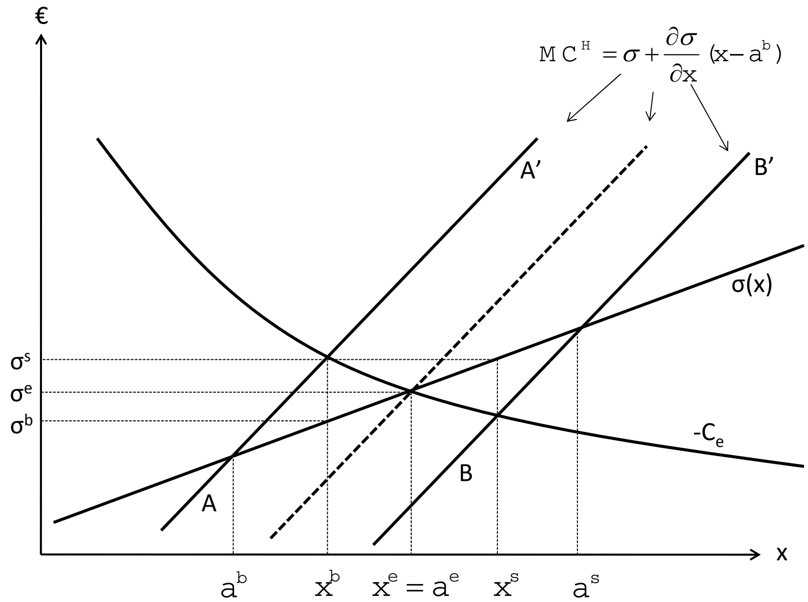

Figure 1. Market power in permit market only.

addition to its free allocation; in other words, the allocation a^b makes the firm a net permit buyer. If the firm were myopic and act as a price taker, it would equate its marginal abatement costs with the permit price and buy $(x^e - a^b)$ permits at a price of σ^e (where the superscript e stands for efficiency in the permit market). However, taking its influence on the permit price into account, the firm will equate its marginal abatement costs with the marginal cost of purchasing a permit defined by (7) and represented by the line BB' in the figure, and hold $x^b < x^e$ permits in equilibrium, with a resulting market-clearing permit price of $\sigma^b < \sigma^e$.

Conversely, if the firm is allocated a^s, its marginal abatement costs are below the permit price and the firm acts as a net seller. The firm equates its marginal costs with the marginal cost of a permit given by the line SS', keeps $x^s > x^e$ permits in equilibrium at a price of $\sigma^s > \sigma^e$ and sells the remainder on the market. The efficient solution consists of allocating the dominant firm exactly $a^e = x^e$ permits, at which point the marginal abatement cost curve intersects the marginal cost of a permit (dotted line) at the efficiency point. With this initial allocation, the dominant firm does not find it profitable to either sell or buy permits and will therefore cause no price distortion.

The intuition behind this result is that a dominant net buyer uses its market power to depress the permit price, and vice versa. The efficient solution consists in essentially taking the dominant firm out of the market, in which case marginal abatement costs of all firms are equalized and the permit market is efficient. Note that the allocation level to the fringe firms has no impact on the market outcome.

Hahn (1984) proves that aggregate compliance costs reach a minimum at the efficient allocation to the dominant firm, whereas both an under- or over-allocation relative to a^e result in increased costs. This is an alternative formulation of the result by Montgomery (1972) that a given emissions cap is reached at least cost if marginal abatement costs of all firms are equalized.

Initial allocation matters when markets are not perfectly competitive even if market power is not concentrated in a single actor. Westskog (1996) extended Hahn's model by applying it to the situation of an international permit market containing a number of Cournot-playing leaders, with the remaining countries acting as a competitive fringe. The results are similar to those obtained by Hahn in the sense that the efficient outcome is obtained by allocating the leaders the number of permits they would hold under perfect competition.

3.1.2. Imperfect Competition in Both Permit and Product Markets

The assumption of market power in the permit market alone simplifies the analysis and seems a natural choice when focusing on the effect of permit allocation on permit market efficiency. In the empirically relevant case of the electricity sector that faces no import competition, however, it is difficult to imagine a firm perceiving market power in the permit market but not in the output market. If the electricity sector is the only sector in the permit market (as in the SO_2 and NO_X markets in the USA), then a dominant firms will perceive a similar amount of market power in both markets. In multi-sector markets such as the EU ETS, the argument is even stronger: If a generator has market power in the permit market, then it follows that it perceives even greater market power in the product market, since the latter is a subset of the former. Naturally, this argument does not hold for sectors that do face competition from abroad, such as the cement or steel sectors, where it is possible that a firm has market power in the permit market but not in the global product market.

The issue of market power in both permit and output markets is closely related to the literature pertaining to raising rivals' costs (Salop and Scheffman, 1983; Rogerson, 1984; Krattenmaker and Salop, 1986a;b). The focus of this literature is that dominant firms may increase their market share and overall profits by artificially increasing industry costs, under the assumptions that these costs are lower for the dominant firm than for the fringe. The cost increase can have many sources, including the institution of mandatory standards, labeling, advertising etc; the key assumption is that the resulting costs are lower for the dominant firm than for its industry rivals. One particular version of raising rivals' costs is to over-purchase necessary inputs of production (Salop and Scheffman, 1987), which is a profitable strategy if the output price increase from this manipulation exceeds the firm's average cost increase.[7]

A number studies have applied raising rivals' costs theory to the context of a market for emission permits, which can be understood as a necessary input for production. The first of these is by Misiolek and Elder (1989), who set up a model where a dominant firm has market power in both markets, enabling it to increase rivals' costs in the output market via the permit price. This additional tool, which they call exclusionary manipulation, leads the

[7]This literature is somewhat ambiguous about the extent of direct price-setting power of the dominant firm in the output market. Whereas some studies allow for explicit "double" market power, others assume that the dominant firm is a price-taker in the output market in the sense that it equates its marginal production costs to the output price, but that it manipulates the output price indirectly through a manipulation of industry costs via the input market.

firm to buy more permits than it would if it were to focus on compliance cost minimization alone (i.e. Hahn's case). In the monopoly case (net permit seller), the increased permit demand unambiguously leads to an increase in permit price distortion and a decrease in overall efficiency. However, in the case of a net buyer, exclusionary manipulation may bring the dominant firm's permit demand closer to the efficient level than if it were focusing on cost minimization alone. If the exclusionary effect is very strong, it can lead the net buyer to push the permit price beyond the efficient level.

Von der Fehr (1993) extends the analysis to the case of two dominant firms that engage in Cournot behavior and focuses on exclusionary manipulation, whereas Sartzetakis (1997a) addresses positioning (predatory) behavior based on raising rivals' costs in emissions permit markets. He finds that the more stringent the environmental regulation, the more profitable the raising rivals' costs strategy will be, and that welfare implications are ambiguous and depend on the efficiency of the dominant firm relative to the fringe. In a different paper, the same author examines welfare implications under limited information and concludes that in spite of price manipulation, overall welfare is greater in a permit market than under command and control (Sartzetakis, 1997b).

More recently, this framework was adapted to illustrate the criterion needed for permit market efficiency. Assuming imperfect competition in the permit and product markets, Disegni Eshel (2005) and Hintermann (2011) prove that if the dominant firm is a net supplier of permits, it has an incentive to increase the permit price to raise the remaining firms' costs as well as to maximize profits in the permit market. The firm has an incentive to increase the permit price even if it is a net permit buyer provided that the increase in revenue due to an increased product price p outweighs the increased compliance costs, which are a function of the initial free allocation.

Taking the interaction between permit and product market into account, the dominant firm equates its marginal abatement costs to the total marginal cost of a permit which now includes an additional term related to the firm's output q:

$$-C_e = \sigma + (x-a)\frac{\partial \sigma}{\partial x} - \frac{\partial p}{\partial x} q, \tag{8}$$

The last term describes the marginal change in revenue in the product market from purchasing another permit . Under certain regularity conditions for the cost function, it can be shown that $\partial p/\partial x > 0$, such that for a net buyer, the last two terms of equation (8) pull in different directions (for a derivation of this result, see Hintermann, 2011). Whereas the increased compliance costs introduce an incentive to over-abate and under-purchase permits (the RHS is increased), the revenue effect in the product market leads to the opposite. Equation (8) can be solved for the level of free allocation a^* where the two last terms cancel out, and the dominant firm equates its marginal abatement costs with the permit price:

$$a^* = x - \frac{\partial p/\partial x}{\partial \sigma/\partial x} q < x. \tag{9}$$

If the dominant firm receives an allocation in excess of a^* it will increase the permit price upwards by over-purchasing permits and under-abating, and vice versa. From (9) it follows directly that in order to attain permit market efficiency, the dominant firm has to be allocated fewer permits than what it will hold in equilibrium. This differs from Hahn's

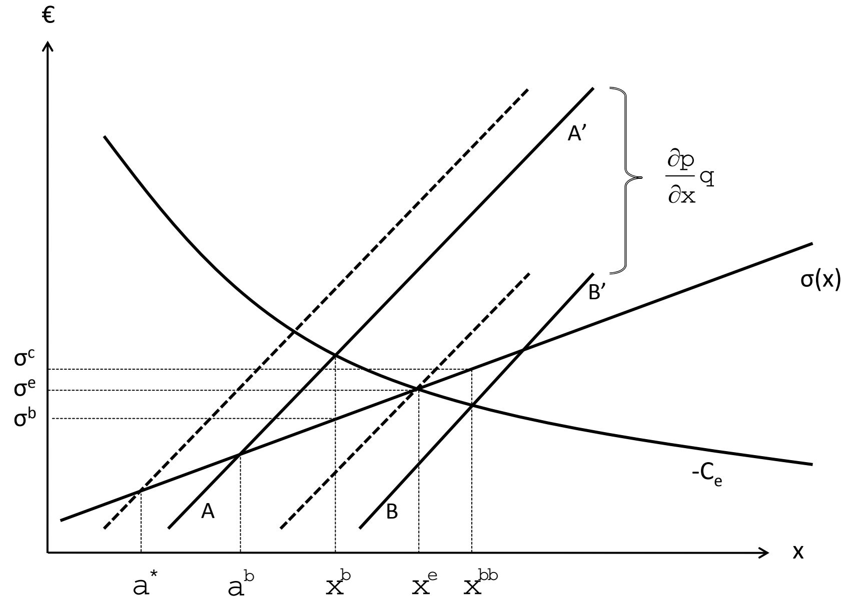

Figure 2.

prescription of full allocation to the dominant firm and is the consequence of including market power in the product market.

Figure 2 illustrates this result at the example of a dominant firm that receives a^b permits allocated for free. At this allocation the firm's marginal abatement costs exceed the permit price, making it a net permit buyer. If the firm were to ignore its market power it would move to the point x^e where no price distortion occurs. If it perceives market power in the permit market alone (Hahn's case), it equates its marginal abatement costs with the line AA', which represents the marginal cost of buying a permit as defined by the RHS of equation (7). In equilibrium it will hold $x^b < x^e$ permits and depress permit price to $\sigma^b < \sigma^e$. Introducing market power in the output market changes the marginal cost of buying a permit to the RHS of equation (8), represented by the line BB' in the figure, which is found by shifting AA' downwards by $q \cdot \partial p/\partial x$. Equating its marginal abatement costs with this shifted line leads the firm to demand $x^c > x^e$ permits, at a price of $\sigma^c > \sigma^e$. Thus, the same firm that finds it optimal to depress the permit price in Hahn's model now finds it optimal to inflate the permit price. Whether one assumes single or double market power really matters.

At an initial allocation of a^*, the total marginal cost of purchasing a permit (dotted line) intersects the firm's marginal abatement cost curve exactly at x^e, leading to permit market efficiency.

There exists an equivalent threshold of free allocation that leads to product market efficiency, defined as the situation where the dominant firm sets its marginal production costs equal to the product price:

$$a^{**} = x - \frac{\partial p/\partial q}{\partial \sigma/\partial q} q < a^{*}. \tag{10}$$

The fact that $a^{**} < a^{*}$ has important implications. First, efficiency in both markets cannot be obtained by means of permit allocation alone. This reflects a well-known result in economics: To correct for n distortions, an equivalent number of n instruments is required. Because there are three distortions in this model (an environmental externality and imperfect competition in two markets), three instruments are needed to obtain overall efficiency. The first is the institution of the permit market that requires firms to cover their emissions with permits. The second consists of the amount of initial allocation given to the firm. The missing instrument in this case could be an output subsidy to increase the dominant firm's production to the socially optimal level.

If reaching the "first-best" outcome (where all regulatory instruments are available and full efficiency is attained) is not feasible, we are in what is called a second-best policy situation.[8] If the dominant firm receives a free allocation of a^{*} in order to obtain permit market efficiency, output in the product market is too low and the product price p is too high relative to the social optimum. It follows that the socially optimal range of initial allocation must lie somewhere between a^{**} and a^{*}. Disegni Eshel (2005) derives a level of free initial allocation that maximizes social welfare in this situation as a function of the distortions in each market. Allocating the firm more than a^{*} or less than a^{**} cannot be optimal, because outside of this range, both markets are distorted in the same direction and no trade-off exists.

We would like to emphasize that a^{*} is a firm-specific threshold and depends on the magnitudes of the components in (9). It can be negative, meaning that the dominant firm would find it optimal to inflate the permit price even if it receives no free allocation at all. The empirical results by Hintermann (2011) imply that a^{*} was most likely negative for a number large electricity firms in Germany, the UK and the Nordpool market.

The threshold that restores efficiency in the product market, a^{**}, is almost certainly negative, as the profits from output market distortions (e.g. in electricity markets) tend to outweigh costs and profits related to permit markets, at least at the magnitude of permit prices observed to date.

3.1.3. Competitive permit market and imperfectly competitive product market

The third scenario in this section involves a competitive permit market combined with an imperfectly competitive product market. As argued above, this could be the case in a multi-sector permit market, where a firm may perceive market power in its product market but is not large enough to influence the permit price in the larger permit market.

Given perfect competition in the permit market, abatement effort will be redistributed so that firms' marginal abatement costs are equalized. A firm that finds abatement cheap relative to the permit price (a 'low-cost' firm) will increase its abatement and sell any surplus permits to the market whereas a firm that finds it relatively expensive to abate (a 'high-cost'

[8] Although it is often useful to discuss particular market failures and policies under the assumption of first-best, all real-world situations are essentially second-best in nature. To our knowledge, no existing permit market simultaneously adjusts for market power in both markets.

firm) will reduce its abatement whilst purchasing permits in the market. As a consequence, permit market efficiency holds and the aggregate cost of reducing pollution to the desired cap is minimized.

However, due to imperfect competition in the product market, overall efficiency cannot be achieved. Output is below the socially optimal level, and the product price is above marginal production costs. Depending on whether the dominant firm has low or high marginal abatement costs, overall welfare can improve or decline with the introduction of the permit market. Malueg (1990) shows that the extent to which social welfare can improve depends on the distribution of cost reductions. In particular, if the permit market 'evenly' ('unevenly') distributes cost reductions among firms then social welfare will rise (fall). Intuitively, an 'even' distribution of cost reductions means that the relative effect on output choice is negligible whereas an 'uneven' distribution results in 'high-cost' firms altering their output relatively more than 'low-cost' firms.

In theory there is scope for using the level of free allocation to the dominant firm to increase overall efficiency, for example through the use of an implicit output subsidy in the form of output-based allocation updating (see below). However, this seems a somewhat unnatural choice of instruments to correct for the output market distortion. In general it is best to use the regulatory instrument that is most directly linked to the market failure the regulator seeks to correct. In the case of market power in the product but not the associated permit market, this implies that efficiency should be restored by directly subsidizing output or otherwise regulating the product market, rather than by using the level of free allocation as an indirect instrument.

3.1.4. Scope and Empirical Relevance of Market Power in Permit Markets

Market power in the permit market clearly changes the theory reviewed in Section 2: Allocation matters. The extent of the distortion, however, and whether market power is in fact present in existing permit markets, are a different issue.

Maeda (2003) proposes a rather strict condition for market power in a permit market, namely the requirement that the excess permit supply of the monopolist exceed the net permit demand of the market as a whole. This condition confers potential market power only to a dominant net permit seller (but not a net buyer) and is practically impossible to attain.[9]

But it is not clear that this is indeed a necessary condition for market power to occur. Even if a firm is not able to freely choose any permit price to maximize its profits, it may still find it feasible to affect demand or supply and nudge the permit price upwards or downwards. A less strict tool of assessing the likelihood of market power would be the use of the Herfindahl-Hirschman (or similar) index.

[9]Suppose that a permit market is set up to decrease emissions by 100 Mt CO_2 relative to business-as-usual emissions. According to Maeda's condition, a dominant net permit seller only yields market power if it has excess permit holdings of more than 100 Mt. But there seems to be no reason for a regulator to hand out such a generous allocation to the dominant firm considering the overall emissions reduction goal. Instead, the government would probably find it optimal to reduce the dominant firm's allocation and either tighten the overall cap in order to obtain a greater environmental benefit, or to distribute more permits to the other market participants for equity reasons.

Moreover, comparing a large firm's permit holdings relative to the total cap may be an imperfect measure of the price-setting power of such a firm. In practice, it may not be the total number of permits in the market that matters, but the number of permits that is held by firms that are active in the market. During the first phase of the EU ETS, it appears that many smaller firms were not interested in selling their surplus permits,[10] with the result that the sustained permit demand from a few large buyers (mostly electricity firms) constituted the majority of the permit demand and drove the price to very high levels. Once it became clear that the market was over-allocated, the price fell to half of its value but remained relatively high for another 6 months. If all firms with a permit surplus brought their permits to market, the price should never have been positive, given the fact that the cap was not binding.[11]

Market thinness or lack of potential traders may also occur due to the geographical boundaries of an emissions scheme where very few firms have the opportunity to participate in the scheme (e.g. Hanley and Moffat (1993)). Even if a large number of firms participated in the market, trading restrictions (used mainly for non-uniformly mixed pollutants) may restrict the number of potential traders, as argued by O'Neil et al. (1983).

Lastly, it is at least possible that firms within the same sector collude. In this case, a group of firms may have market power together, even if the individual firms within the group would not be expected to have market power by themselves.

The issue of the size of the distortion in permit market and/or overall efficiency due to the presence of market power is even more difficult to address empirically. Price distortion and welfare loss are a function of the degree (not just the presence) of market power, which is almost impossible to assess. To make matters worse, marginal abatement costs and even output and load factors per generator are often treated as proprietary information.[12]

The evidence about the quantitative importance of market power that does exist is based on laboratory experiments. Brown-Kruse et al. (1995) is one of the first experiments to address the issue of market power. They find that market power matters in terms of permit market as well as overall efficiency, and the results were especially strong when the dominant firm was given market power in both the permit and the product markets. In some treatments they found that overall efficiency was even decreased relative to the command-and-control benchmark, implying that the gains from equalizing marginal abatement costs among fringe firms through permit trading were more than dissipated by the efficiency losses arising from market manipulation on behalf of the dominant firm.

Similarly, Godby (2000; 2002) carried out an experiment involving a small number of firms, including one that had market power. The results from altering the magnitudes of the initial allocation to the traders suggested that allocation mattered, but that the size of the distortion was relatively small when restricting market power to the permit market. If,

[10] Jaraite et al. (2010) examine the participation behavior of all Irish firms covered by the EU ETS and find that many of them were not prepared to sell their surplus or simply did not take this option into account. This is closely related to the discussion about transactions costs in the last subsection.

[11] For a discussion of the permit price dynamics during phase 1 of the EU ETS, see Rickels et al. (2007) and Hintermann (2010).

[12] In the EU ETS, it is generally not known which firms abated emissions to what extent nor who traded how many permits, all of which is necessary information when comparing the actual situation with a theoretical first-best outcome. Some firms only publish total electricity sales, which includes electricity bought from third parties, but keep actual own generation confidential.

on the other hand, the dominant firm was able to jointly manipulate both the permit and product market, the impact of initial allocation on the outcome was significant.

Böhringer and Löschel (2003) simulated an international carbon trading scheme where one country had a dominant position due to an excess allocation of permits. The excess permits are known as *hot-air*: An allocation given over-and-above the expected emissions of a country (the former Soviet Union countries are likely to experience this in an international permit market due to a dramatic economic downturn after the Kyoto baseline period). They found the initial allocation of permits can affect the efficiency of the market. More recently, Klepper and Peterson (2005) discussed different institutional and permit allocation designs in *hot-air* economies. They found, in agreement with the theory presented in this subsection, that the permit allocation choices in *hot-air* economies were important in determining the equilibrium outcome.

3.2. Transaction Costs

The benchmark model of a tradable-permit market assumes that participating firms can trade permits at no additional cost (other than the permit price). Yet this assumption is often unrealistic as transaction costs occur in a variety of forms. Prior to the exchange of permits, firms may find it costly to search for potential traders. Transaction costs may continue to pose a problem even after a trading partner has been found as trade negotiation may be costly (which also includes the cost of time spent bargaining). Transaction costs can also occur due to the existence of informational deficiencies in the permit market, such as the imperfect and asymmetric information on the location of traders, the availability of permits for purchase or sale, and so on.

With this in mind, Stavins (1995) analyzed the relationship between the initial allocation, transaction costs and market efficiency. By associating a cost with exchanging permits of the form $T = T(x - a)$, he showed that transaction cost created a wedge equal to the marginal transaction cost between a firm's marginal abatement cost and the permit price:

$$-C_e^i = \sigma + T'. \tag{11}$$

Simplifying the case for two sources, he then showed that the choice of emissions reduction was no longer independent of the initial allocation. In particular, the effect of the initial allocation on permit market efficiency depends on the functional form of the transaction cost (specifically, on the the second derivative of the transaction cost function). When the marginal transaction cost is constant (second derivative is zero), the initial allocation does not alter the efficiency at the equilibrium in the sense that output, emissions and abatement of each firm are unchanged. The only difference to a situation without transactions costs is that the market-clearing permit price will be the sum of the shadow value of emissions reductions and the wedge and thus above the social optimum. The higher permit price will have distributional effects plus some second-order efficiency effects (see section 4), but it will not affect permit market efficiency as defined in this chapter.

For non-constant marginal transaction costs, the resulting vector of abatement is altered and thus permit market efficiency is not achieved. If marginal transaction costs are increasing (decreasing), then a movement of the initial allocation away from the efficient equilibrium allocation level will increase (decrease) the departure from the least-cost equilibrium.

The intuition behind this result is that when marginal transaction costs are increasing, the cost of additional transactions increases at an increasing rate. Therefore it will be relatively expensive to reach the efficient market equilibrium with an allocation level that is further away from the efficient level. Conversely, decreasing marginal transaction costs allow scale economies to occur in transactions and make it relatively easier for a firm to reach the efficient equilibrium with an allocation that is further away from the least-cost equilibrium level.[13] Cason and Gangadharan (2003) experimentally tested the effect of initial allocation under transaction costs in a laboratory experiment and found results consistent with the theory of Stavins (1995).

Trading can also be costly when individual trades are subject to (ex-ante uncertain) approval by the regulator. This can be an important issue in non-uniformly mixed pollutant markets where regulatory trade approval is necessary due to the increased likelihood of the ambient environmental target being violated. Hahn and Hester (1989a) develop a model where each firm in the emissions market has the option to trade. If a firm decides not to trade then no transaction costs occur and the emission/abatement choice is the only required action. However, if the firm does trade then it will incur transaction costs associated with searching for potential trading partners and the possibility that the trade will not be approved.[14]

It is debatable whether transaction costs are a significant barrier to market efficiency in existing permit markets. The successful design of current schemes can be, in part, put down to the experience gained under emissions trading schemes almost three decades ago. Moreover, to find evidence of large transactions costs, one must revisit the first implemented markets, where knowledge of emissions trading and the potential traders in the market was highly uncertain. Hahn and Hester (1989a; 1989b) found evidence of large transaction costs (and a resulting reduction in market efficiency) due to the large amount of trading and administrative restrictions in the EPA's Emissions Trading Program and in the permit program for the Fox river, Wisconsin.[15]

The existence of transaction costs was also supported by Foster and Hahn (1995), who analyzed the trading activity in the Los Angeles basin (RECLAIM) and found transaction costs significantly altered behavior in the permit market. Gangadharan (2000) econometrically tested the existence and severity of transaction costs in the RECLAIM emissions program. Transaction costs appeared to be most influential in the earlier periods of the program, suggesting that as the market develops, firms learn and as a consequence, the search and informational costs diminish. This argument is supported by evidence from the SO_2 emissions trading program. Doucet and Strauss (1994), Conrad and Kohn (1996), Joskow et al. (1998), Schmalensee et al. (1998) and Ellerman et al. (2000) provide evidence that transaction costs declined throughout time as firms gained more experience with trading permits. A fundamental reason for the successful development of this market was the improved market information and price discovery experienced by firms through the annual auction mechanism.

[13]In practice, any transactions cost are likely constant or decreasing but probably not increasing.

[14]Montero (1998) extended the Stavins' (1995) transaction cost model to include a firm's uncertainty over trade approval. His model assumes that firms place a probability on the success of an approved trade.

[15]See also Atkinson and Tietenberg (1991) for a discussion about the Emissions Trading Programs divergence from the cost effective allocation.

3.3. Dynamic permit allocation (updating)

Up to this point we have reviewed the relationship between the initial allocation and permit market efficiency in markets with one compliance period (although this could consist of several years). However, many tradable-permit schemes have multiple compliance periods, each with a potentially different allocation method and level of free allocation (e.g. the EU-ETS and the US SO_2 market).

The presence of a series of compliance periods alone does not necessarily imply dynamic permit allocation. A regulator can choose to allocate the same number of permits at the start of each compliance period, which is sometimes referred to as 'one-off' grandfathering. Alternatively, he can change the amount of free allocation by a general rule that is independent of firms' decisions. Examples are a gradual reduction of the aggregate emissions cap as in the RGGI market, or a movement away from free allocation towards permit auctioning, as in later phases of the EU ETS. The change of the cap and/or the level of free allocation does not have to be determined before the first market phase, as long as the same proportional allocation reduction applies to all firms.

Even though fixed allocation or uniform allocation changes are preferable on efficiency grounds, governments may find it necessary to include information gathered during the market for fairness reasons[16]

In this subsection we discuss the relationship between the initial allocation and market efficiency when permit allocation is dynamic in the sense that it depends on firms' decisions after the market had started. In keeping with the literature we refer to this as allocation *updating*.

Allocation updating creates a link between a firm's current decisions about output, emissions and abatement, and current or future permit allocation. It is sometimes referred to as the 'ratchet effect' (see for example, Freixas et al. 1985; Harrison and Radov, 2002).

There are various forms of allocation updating that are being used (or at least considered): (i) emissions-based updating, (ii) output-based updating, (iii) intensity targets and (iv) benchmarking. We consider the effect of these types of updating in turn.

3.3.1. Emission-based allocation updating

Emissions-based updating is perhaps the purest form of allocation updating, because the observed performance (i.e. emissions) and the free allocation are part of the same market.

Böhringer and Lange (2005) develop a simple but very insightful model to show the effect of allocation updating. Every year, firms receive a_{it} permits lump-sum. In addition, they receive free permits proportional to emissions and output during the preceding J years. Abstracting from discounting, firms' profit maximization problem over time becomes

$$\max_{q_i,e_i} \sum_t \Pi_t = \sum_t \{p_t\, q_{it} - C^{it}(q_{it}, e_{it}) - \sigma_t[e_{it} - (a_{it} + \sum_{j=1}^{J} \kappa_{ie}^{t,t-j} e_i^{t-j} + \kappa_{iq}^{t,t-j} q_i^{t-j})]\} \quad (12)$$

[16]For example, there was very little information about historic emissions levels in the EU. Countries based their National Allocation Plans (NAPs) on a combination of available data, forecasts and information supplied directly by the regulated firms. When actual emission levels were observed for the first time after the first year of the market, many countries found it very difficult to ignore this new information when defining the second-phase NAPs.

where we substituted the constraint that all emissions must be covered by permits into the problem. The constant $\kappa_{ie}^{t,t-j}$ linearly translates firm i's emissions in year $t-j$ to free allocation in year t, and $\kappa_{iq}^{t,t-j}$ is the equivalent factor for output. The first-order condition with respect to emissions is

$$-C_e^{it} = \sigma_t - \sum_{j=1}^{J} \sigma_{t+j}\ \kappa_{ie}^{t+j,\,t}. \tag{13}$$

The updating rule drives a wedge between firms' marginal abatement costs and the permit price, defined by summation term on the RHS of (13). Intuitively, emissions-based updating makes abatement more costly: In addition to marginal abatement, every unit of abatement carries an additional cost in the form of a reduction of future free allocation. Since abatement are negative emissions, emissions-based updating constitutes a subsidy on emissions. Also note that lump-sum allocations a_{it} do not appear in (13), implying that non-updated allocation has no impact on efficiency, as in the benchmark model.

An important thing to keep in mind is that within an enforced permit market, emissions are capped. The effect on permit market efficiency depends on the uniformity of updating within the market. If all participants face the same updating rule for emissions (i.e. $\kappa_{ei}^{t+j,\,t} = \kappa_{el}^{t+j,\,t}\ \forall\ i,l$) and the market is closed to permits generated outside the system, the market-clearing permit price is above the shadow value of emission reductions, but permit market efficiency itself holds: Firms' emissions and abatement levels are the same as under one-off grandfathering or under auctions and thus independent of the initial allocation. The enforcement of the emissions cap leads to an increase in the permit price to the level where it is equal to the sum of the shadow value of an emissions reduction and the disincentive to abate due to updating.

With a uniform updating rule, the effect of emissions-based allocation updating is qualitatively similar to the presence of transactions costs: The market-clearing permit price is inflated relative to the first-best solution, but permit market efficiency as defined in this chapter holds. The only efficiency loss occurs due to second-order effects stemming from the too high permit price.

If the market is open to permits from outside, allocation updating causes firms within the system to abate less whereas more abatement occurs outside, relative to the situation without updating. Marginal abatement costs are equalized across firms within the system, but they are lower than marginal abatement costs outside, where no penalty for abatement exists. Thus, permit market efficiency holds within, but not between markets.

If updating rules differ across firms, as is the case in the EU ETS where the individual member countries determine firms' free allocation levels for each phase using different allocation rules, permit market efficiency fails to hold even within the permit market (Martiney and Neuhoff (2005)). Firms equalize their marginal abatement costs plus the (firm-specific) penalty of abatement to the market-wide permit price, leading to different marginal abatement costs across the system and increased overall compliance cost. Sterner and Muller (2006) derive a similar result and find that allocation updating decreases overall welfare.

One important special case of emissions-based updating is the new entrant reserve (new entrants to the market receive free allocation, even though they don't have historic emissions) coupled with the other side of the same coin, the canceling of allocation to installations that are shut down. Åhman et al. (2007) show the efficiency implications of these extreme forms of updating. A firm that might have built a low-emission installation if it had to pay for all its permits can find it optimal to build a high-emissions plant, provided that the difference in free allocation from the new entrant reserve is large enough. Likewise, a firm may keep an installation running when otherwise it would have found it profitable to shut it down if free allocation is lost when shutting down a plant. In both cases, the firm faces an incentive to increase emissions relative to the case without updating.

Although new entrant reserves and canceling of allocation of closed plants affect efficiency negatively, both policies are almost unavoidable on equity grounds. Not giving new entrants any free allocation when all incumbent firms do receive one seems seems quite unfair to the former and may even be legally challenged, whereas handing out free permits to installations or firms that no longer operate may be very difficult to justify to the public. To address this problem, Åhman et al. (2007) advocate a time lag of ten years before a new entrant receives a free allocation or an exiting firm loses its allocation, arguing that this compromise would dampen the distortionary incentives of allocation updating.

Martinez and Neuhoff (2005) investigated the link between market efficiency and emissions-based allocation updating when banking and borrowing of permits across time is allowed and find that borrowing with updating causes emissions to move from the second period to the first, which could be a concern in the context of flow pollutants. Rehdanz and Tol (2007) derived very similar results. Intuitively, borrowing allows firms the option to increase current period emissions and as a result obtain a larger future period allocation. In particular, there is net borrowing when future emissions reduction obligations are large relative to the current period.

3.3.2. Output-based allocation updating

Fischer (2001) considered environmental policy schemes (tradable performance standards, taxes and tradable permits) that rebated revenues based on output market shares. For a tradable-permit market this translates to output-based free allocation. Fischer found that using such an allocation process provided an implicit output subsidy. This conclusion was supported by Burtraw et al. (2001; 2002) and Burtraw et al. (2005; 2006) who investigated the cost-effectiveness of alternative allocation mechanisms in the electricity sector subject to a tradable-permit scheme. Moreover, Fischer (2003), Fischer and Fox (2004) and Bernard et al. (2007) extend the basic model to include imperfect competition in the output market and a general equilibrium analysis, respectively.

To show this result analytically, we again refer to the model by Böhringer and Lange (2005). The first-order condition of (12) with respect to firms' output is

$$C_q^{it} = p_t + \sum_{j=1}^{J} p_{t+j}\ \kappa_{iq}^{t+j,\,t}. \tag{14}$$

The wedge between marginal production costs and the product price p constitutes the output subsidy. Because of this, Böhringer and Lange (2005) argue that using an updated output-based allocation will never obtain the least-cost equilibrium outcome. Jensen and Rasmussen (2000) supports this outcome by creating a dynamic general equilibrium numerical model that used auctioning and allocations based on output and emissions to distribute pollution permits and found output-based allocation is more costly than either auctioning or 'one-off' grandfathering. None of these studies take market power in the product market into account. If output is restricted due imperfect competition, an output-based updating rule may lead the system closer to overall efficiency.

Edwards and Hutton (2001) used a computable general equilibrium model of the UK to investigate a number of possible allocation mechanisms and found an output-based allocation improved GNP and welfare in the economy (encourages a switch to domestically produced goods). Similarly, Haites (2003) finds this type of mechanism can be used in a tradable-permit markets to reduce the output decline of industries that are adversely affected by international competition.

Neuhoff et al. (2006) numerically examine the consequences for the EU-ETS electricity sector updating output-based allocation and found clear evidence of implicit output subsidies and noticed that the number of plant closures falls when using an output-based allocation and accelerated construction of plants occurs for new entrants. Demailly and Quirion (2006) find similar results for the cement sector. [17]

4. Revenue recycling and rent-seeking

So far we have addressed direct distortions in the permit and/or product market that may arise, and/or be corrected by, the type and level of allocation chosen. However, there remain issues that are independent of the distortions that we have discussed in Section 3. The method of allocation may matter even if the benchmark assumptions hold.

In this section we focus on two issues that, in our view, are particularly important: Recycling of permit revenue, and dissipation of rents in a political economy context.

4.0.3. Revenue recycling

The obvious difference between selling permits and handing them out for free (by whatever method) is that the government receives revenue in the latter, but not in the former case. This has efficiency implications because the government can choose to use revenue to decrease existing distortionary taxes, such as taxes on labor or capital. [18] With free allocation, no revenue accrues and therefore no welfare-improving recycling of revenue can take place.

The importance of revenue recycling from corrective taxes (i.e. taxes introduced to correct an inefficiency rather than to raise revenue) is discussed in the literature about what has become known as the 'double dividend hypothesis" (Bovenberg and de Mooj, 1994; Parry, 1995; 1997; Parry et al., 1999; Bovenberg and Goulder, 1996; goulder et al. 1997;

[17] Under intensity targets, it is not absolute emission levels but emissions per unit of output (the emission intensity) that is capped. The use of updated intensity targets has similar effects as output-based allocation in the sense that it constitutes an implicit output subsidy (Dewees, 2001; Ellerman and Wing, 2003; Kuik and Mulder, 2004). The noticeable difference between the two types concentrates on the cap. In output-based allocations, the aggregate emissions cap is generally fixed so that average allocation per unit of output has to be altered to take into account (changing) total output. Whereas under a rate-based mechanism, allocation per unit of output is held constant and instead the aggregate emissions cap is altered. It is not in the scope of this review to consider these types of mechanisms in detail (See, Sterner and Höglund, 2000; Fischer, 2001; Fischer 2003).

[18] This is an issue that only arises in second-best settings. In a first-best world, taxes are lump-sum and thus there would be no scope to decrease pre-existing distortionary taxes.

1999). Goulder (1995) gives an excellent review over this topic and separates the various claims into three hypothesis, which he labels the weak, intermediate and strong double dividend.

Briefly, the weak version of the double dividend hypothesis states that by using revenue from an environmental tax to finance reductions in marginal rates of existing distortionary taxes, there are efficiency gains relative to the benchmark case where the revenue is recycled to taxpayers lump-sum. This is equivalent to the claim that replacing, at the margin, a lump-sum tax with a distortionary tax entails a positive welfare cost. But of course this is precisely the meaning of a *distortionary* tax, which makes the weak double dividend hypothesis relatively uncontroversial.

According to the intermediate double dividend hypothesis it is always possible to find a distortionary tax such that the revenue-neutral substitution of the environmental tax involves zero or negative gross costs, where gross costs are defined as the welfare costs of introducing the environmental tax without taking into account the environmental benefits that accrue (the reason for the environmental tax in the first place). The strong double dividend hypothesis goes one step further and claims that the revenue-neutral substitution of the environmental tax for a *typical* or *representative* tax leads to zero or negative gross costs.

Bovenberg and de Mooij (1994) show that for the intermediate and strong forms of the double dividend hypothesis to hold in a model with labor as the sole factor of production, the wage elasticity of labor supply has to be negative, i.e. the society must be at a point where the labor supply curve is backwards-bending. Although this is possible in theory, it has not been found to be the case empirically. When allowing for other factors of production in the model, the results become more complicated, but it can generally be said that the intermediate and strong forms of the double dividend hypothesis only occur if the existing tax system is far from being optimal, and if the burden of the environmental tax in question primarily falls on the factor of production with the lowest marginal efficiency cost. [19]

To gain some intuition it is convenient to split up the effect an new corrective tax into two parts. For one, the tax revenue can be used to lower pre-existing distortionary taxes, thereby increasing welfare. This is sometimes referred to as the *revenue-recycling effect*. Second, the presence of pre-existing distortionary taxes increases the gross cost of the corrective tax, which is known as the *tax interaction effect*. Under plausible parameter assumptions, the tax interaction effect outweighs the revenue recycling effect, which is the reason why the strong form of the double dividend hypothesis generally fails to hold. [20]

The crucial point in the context of selling permits vs. free allocation is not whether the intermediate or strong versions of the double dividend hypothesis hold, but that the tax interaction effect occurs *regardless* of the type of allocation. Even if firms do not have to pay for their permits under free allocation, there is still an opportunity cost attached to each permit because surplus permits can be sold on the market. The inherent value of a permit

[19]Under optimal taxation, the marginal efficiency costs are equalized across all factors of production.

[20]The intuition behind this result is the following: The corrective tax on the good that causes the externality (e.g. pollution) lowers the after-tax wage through an increase in the price vector and thus creates a distortion in the labor market. This distortion is at least as great in magnitude as the reduction in distortion due to a revenue-neutral decrease of the labor tax. In addition, the introduction of the pollution tax shifts consumption away from the dirty towards cleaner goods, eroding the tax base of the environmental tax (this is where the environmental benefit occurs). As a consequence, the labor tax cannot be lowered to the extent that the gross cost of the policy is zero.

leads firms to include permit (opportunity) costs in their production decision the same way they would include permit costs if they had to purchase them in an auction. Depending on the price elasticity of consumer demand and the extent to which a sector is exposed to competition from outside the permit market area, firms will price between zero and 100% of permit costs through to consumers. For the case of the electricity sector in the EU ETS that received over 90% of its historic emissions allocated for free, it appears that carbon costs are being priced through completely (Sijm et al., 2008; Fell, 2008), leading to large "windfall profits" (Vollebergh et al., 1997; Grubb and Neuhoff, 2006; Hepburn et al., 2006; Neuhoff et al., 2006). Although sometimes described as inappropriate profiteering in the popular press, cost pass-through is nothing but profit maximization on behalf of rational firms who realize that emission permits have an economic value.[21]

Permit cost-pass through means that the prices of the externality-generating products (e.g. electricity) increase *as if* they were taxed, giving rise to the tax interaction effect. Thus, giving permits away for free leaves the tax interaction effect unchanged but eliminates the revenue-recycling effect (because there is no revenue to be recycled). Since this effect is unambiguously welfare-increasing, the results from the double dividend literature indicate that permits should be sold rather than given away for free, and that the resulting revenue should be used to decrease the most distortionary taxes in the tax system.

Finally, even if the government were to recycle the revenue from permit sales lump-sum, it still has the opportunity to use the revenue to address distributive concerns as it sees fit, whereas free permit allocation implies a specific wealth transfer from taxpayers to producers.

4.1. The Effects of Political Activity

Auctions are the preferred choice over free allocation on efficiency grounds from the point of view of a social planner or benevolent government. In this subsection, we consider the choice of free or auctioned permits with respect to vested interests and political activity.

A large amount of literature explains why free allocation has been favored over auctioned permits (e.g., Keohane et al, 1998; Aidt and Dutta, 2002; Oates and Portney, 2003). Generally, free allocation has been the prominent allocation mechanism as polluting industries have been more accepting of a free allocation system than any other instrument. This is a result of the industries obtaining rents in the form of permits, for free, which can be used or sold on the market. Industry acceptance and support is sometimes crucial when a permit market is implemented. However, this debate does not consider which allocation process *should* actually be used.

Cramton and Kerr (2002) and Hepburn et al. (2006) have argued in favor of auctioning as opposed to free allocation. They argue that free permit allocations provide rents to polluters, which are politically contestable. As the costs of political activity, in terms of negotiation time bureaucratic costs, and so on, may be substantial, it is often argued that auctioning should be used to prevent this from occurring. Indeed, Hanley and MacKenzie (2010) show the explicit incentives for polluting firms to rent seek for freely allocated pollu-

[21] Suppose a generator receives a delivery of gas for free. No one would expect it to not include fuel opportunity costs in its electricity price, because instead of using the gas for generation, it could sell it on the market. The same logic applies to emission permits, which can be understood as a necessary input for production.

tion permits. They find firms' incentives to rent seek fundamentally depends on the market value of the permits, whereas the impact depends on the responsiveness of the regulator to aggregate rent-seeking effort. Furthermore, they show that depending on the government's responsiveness to rent seeking, in some cases, welfare may improve due to the reduction in the per-unit value of permits from rent seeking outweighing any increase in damages experienced from the additional emissions.

Although political activity has played an important role in free permit allocation, it is still an open question as to whether an auction system would do any better in this respect. MacKenzie and Ohndorf (2010) compared the incentives to expend political activity under alternative market-based mechanisms when rents were created from the process of regulation (value of free allocation and auction revenue). They took into account the potential for a revenue recycling effect from auctioned permits as well as the feasibility that some of the rents created from regulation are preassigned (e.g., to energy efficiency programs, forestry sequestrations administrations costs, and so on). They showed that non-revenue raising regulations are in many cases preferable over revenue raising regulations. First, an increase in the revenue recycling effect may result in even larger (net) costs from political activity. Second, free permit allocations often tend to be pre-assigned. Free allocation based on historical emissions, by their definition, are not usually as contestable as revenue from an auction. Therefore, under the assumption that grandfathered permits are less contestable than auctioned revenue, the free allocation of permits results in a larger level of social welfare.

5. Policy Recommendations and Conclusions

The most basic model of a permit market implies that the initial allocation of permits does not matter for efficiency but only for distribution. As we show in this chapter, the economics literature has proceeded well beyond the relatively simple models that underly this conclusion. Surprisingly, the "fact" that allocation does not matter is still widely cited in the popular press and sometimes even in academic papers, without qualification.

The main point we would like to make in this chapter is that *permit allocation can impact efficiency*. Even if permit market efficiency holds (marginal abatement costs are equalized across firms), there may be second-order effects due to the presence of the weak double dividend hypothesis. Finally, there are political economy considerations to be taken into account.

Many of the potential permit market inefficiencies related to permit allocation that we discuss can be resolved by means of full auctioning. With zero free allocation at all times, none of the issues related to dynamic permit allocation discussed in section 3.3 can arise, as neither emissions nor output is subsidized due to allocation "updating".

Full auctioning also minimizes overall distortions taxation because it allows the regulator to use the auction revenue to reduce existing distortionary taxes, or, equivalently, to avoid having to raise distortionary taxes.

In the presence of market power, welfare may be maximized by distributing a certain number of permits for free. Earlier results from the literature prescribed full free permit allocation to firms that potentially have price-setting power. This is the appropriate policy if market power is only a concern within the permit market. However, if market power exists in both the permit and the product market (which, in our view, is no less likely as market power in the permit market alone for some sectors), then firms with market power should be allocated fewer permits than what they will hold at the end, thus making them net permit buyers. In determining whether a firm (or a colluding group of firms) has market power, the regulator should rely on a wide array of information and all available institutional knowledge, not only narrow definitions of technical market power, which tend to underestimate the degree to which firms can influence market prices.

Likewise, free allocation should not be used as a means to level the playing field for export-oriented domestic firms relative to rivals from outside the permit market area. Whether or not firms receive a free permit allocation, the value of permits enters their profit maximization problem and will be priced through accordingly. It is true that free allocation to exporting firms would in theory allow them to reduce prices below marginal costs on the international market, but firms may not choose to do so as it could be more profitable to produce less and sell the surplus permits on the market. In order to protect domestic industry from outside competitors, border-tax adjustments or other more direct measures rather than free permit allocation should be used.

If some free allocation is either politically unavoidable or economically desirable it should be of the "one-off"-type, i.e. they should not depend on current decisions by firms as this introduces a distortion. Whether such a one-off allocation is based on historic emissions, output or other considerations is purely a distributive issue. The crucial requirement is that the allocation be not updated based on current, firm-level data. This does not necessarily translate to a fixed allocation over time. Free allocation levels that decline uniformly across firms are not distortionary and can be used to decrease the overall cap over time and/or to capture an increasing proportion of the weak double dividend by a commensurate increase of auctioning.

Where some form of updating is seen as unavoidable as when accommodating new entrants and canceling free allocation to installations that are shut down, some form of mitigating measure (e.g. the ten-year-rule proposed by Åhman et al., 2007) should be used to counteract some of the distortions brought on by such extreme forms of allocation updating.

Allocation updating could in theory be used to correct for, or at least mitigate, existing distortions in other markets. For example, output-based allocation updating could be used to boost output when the latter is contracted due to imperfect competition or for other reasons. However, we believe that in these instances it would be preferable to use a different to address the pre-existing distortions directly, rather than relying on an indirect instrument such as free permit allocation. For one, choosing the policy instrument that is most closely related to the inefficiency the regulator seeks to correct is generally preferable. And second, even full allocation (or, in the extreme, over-allocation) may not ensure efficiency, especially if the value of a permit and thus the rent that comes with free allocation is small relative to the pre-existing distortion.

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