TRADEABLE CO₂ EMISSION PERMITS IN EUROPE
A study on the design and consequences of a system of tradeable permits for reducing CO₂ emissions in the European Union

Proefschrift

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Straatsburg

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Samenvatting

Bibliography
STELLINGEN

1 Een systeem van verhandelbare emissierechten is een uitvoerbaar, efficiënt en effectief instrument voor het terugdringen van de CO₂ emissies.

2 Een systeem van verhandelbare emissierechten kan in theorie de toetreding van nieuwe bedrijven belemmeren, maar in praktijk zal dit effect beperkt zijn.

3 De nuttigste besteding van het geld dat beschikbaar is voor milieu-onderzoek is een studie naar het milieurendement van deze uitgaven.

4 Complexiteit is geen rechtvaardiging voor een gebrek aan creativiteit.

5 De belastingverhogingen die Diocletianus (Romeins Keizer van 284 tot 305 AD) heeft ingevoerd om de Romeinse legioenen te versterken zijn één van de oorzaken van de uiteindelijke militaire ondergang van het Romeinse rijk.

6 Het standaard-gebruik om verschillende single cask malt whisky’s samen te voegen, is een verspilling.

7 Binnen de Europese Unie behoeft men niet bevreesd te zijn voor een culturele eenheidsworst, omdat regionale specialiteiten het lekkerst smaken in de regio van produktie.

8 Invoering van het Latijn als enige officiële taal in de Europese Unie is de historisch meest verantwoorde oplossing voor het talenprobleem in de Unie.

9 Het schrijven van een dissertatie is geen monnikenwerk, indien men bij het werk begeleid wordt door Gregoriaanse muziek.

Paul Koutstaal

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CHAPTER 1
INTRODUCTION

On the agenda of environmental problems, the enhanced greenhouse effect has nowadays acquired a prominent place. Although there is still much uncertainty about its extent and its consequences, there is an important rationale for addressing the possible problem of climate change now: whatever the specific consequences may be, they are to a large extent determined by the actions we take (or do not take) today. Emissions from greenhouse gases will determine the atmospheric concentrations of these gases for centuries to come. Because of the increase in anthropogenic CO₂ emissions, starting with the industrial revolution and the rise in the use of fossil fuels which it has caused, the concentration of CO₂ in the atmosphere has risen by 25 percent since 1750. If we want to limit the increase of CO₂ concentrations, action must be taken now.

Within the broad area of research on climate change, one specific strand of economic research has focused on the problem of how to reduce emissions from greenhouse gases, especially the emission of carbondioxide, which is the main greenhouse gas. Taking as a starting point the assumption that a CO₂ emission reduction target has been set, the objective of these studies is to determine the optimal way of reducing these emissions.

From the start, it has been pointed out by environmental economists that economic instruments are suitable for implementing a policy of reducing emissions of greenhouse gases. With economic instruments, emissions will be reduced in an efficient manner, according to the theory. This has been argued and illustrated in a large number of studies which deal with economic instruments like taxes or charges and tradeable emission permits (see e.g. Barrett 1992, UNCTAD 1992, OECD 1992a and 1992b, Smith 1992). In this study, the instrument of tradeable carbon emission permits (TCP’s) is studied in more detail. The central issue is: the design of a feasible system of TCP’s and the study of the consequences of implementing such a system.

Up till now, the focus of research in this area has been predominantly on the efficiency of reducing CO₂ emissions by means of tradeable emission permits or taxes.
Less attention has been paid to the design of such a system, which is the subject of chapter 2. In this chapter the outlines are sketched of a feasible system of tradeable emission permits for the European Union. The proposed system is in essence a system of (carbon in) fuel rationing with tradeability of quota between citizens. Points under consideration are a.o. the characteristics of the fuel permit, the distribution of the permits (either the government sells them or gives them away for free), the market allocation of the permits, the time path by which the number of permits available is reduced, monitoring and enforcement of the system and the consequences which a system of tradeable emission permits might have for business location choice. Moreover it is studied whether a system of TCP’s can operate on a national base in one member state of the European Union or if it should be implemented at the European level. Last, the requirements of a EU-wide system are sketched.

A study of the implications of reducing CO₂ emissions by means of TCP’s (or any other instrument) can not be complete without studying the economic consequences of such a system. To predict some of the consequences of introducing an instrument like TCP’s in an industry a micro-economic approach is necessary in which the influence on one or more facets of economic behaviour is studied in detail. For example, attention has been given to the potential misuse of market power in the permit market (see Tietenberg 1985 and Hahn 1984). On the other hand hardly any attention has been paid up till now to the possible effects of tradeable emission permits on entry into industries. This is especially interesting because it has been practice to grandfather permits to existing sources while new sources, potential entrants, have to buy them. Many people, and even economists have the intuition that in particular such a system of grandfathering will erect barriers to potential entrants, whereas a system of auctioning permits to all firms, established ones and entrants, would not have such an impact, or at least a much weaker negative effect on entry. In chapter 3 and 4 it is analyzed how far this idea is true. The question is addressed whether, how and to what extent a system of tradeable permits might create barriers to entry in the product market. Several forms of entry barriers which might be caused or increased by tradeable permits are identified and analyzed. Subsequently, it is studied whether these forms of entry barriers are likely to occur in the system of TCP’s which is outlined in chapter 2. An effort is made to determine to what extent entry will be affected when
entry barriers are raised due to the TCP system.

The above questions are important, not only from a static point of view, but also if a dynamic view is taken. If a TCP-system for reducing CO₂ emissions raises entry barriers, it will affect the whole economy, affecting long-term industry dynamics. This in turn might reduce the efforts on research and development and reduce economic activity and efficiency in the longer run in the whole economy. The approach taken here is to study the micro-economic consequences of a system of tradeable carbon permits with respect to entry barriers, both with grandfathering and with auctioning of CO₂ emission permits. The results will be compared with the results achieved under two other instruments, taxes and standards. The possible occurrence of entry barriers is analyzed both theoretically and empirically.

A salient feature of the greenhouse problem is that it occurs worldwide, irrespective of the place where CO₂ and the other greenhouse gases are emitted. While this facilitates the design of a TCP system considerably (see chapter 2), it does pose the additional problem of coordination of policies. It is important to examine whether and how countries cooperate in reducing emissions and what the role of the instruments of taxes and tradeable permits can be in an international setting. This is the subject of chapter 5 and 6.

The approach taken is more general than in the earlier chapters. The model used 'pictures' the whole economy but in a very simplified way. The economy is assumed to consist of one representative consumer who can consume two goods, one of which causes pollution when it is consumed (the pollution represents CO₂ emissions). In addition, the consumer chooses how much of his time he will spent working (and earning an income) and how much leisure he takes. The consumer does not take this pollution into account when he makes his consumption decision, therefore the government has to use instruments like taxation (or TCP’s) to limit emissions. In the first sections of chapter 5, the optimal levels of CO₂ emission reduction are not taken as given; instead they are a result of the analysis. In addition to reducing pollution, the government also has to raise an exogenously given amount of revenue. The government maximises a (social) welfare function which includes damage from pollution under constraint of its revenue requirement. Its instruments (the variables in
the model) are the taxes it can levy on the two goods, labour is not taxed. The taxes must serve two purposes: reducing pollution and raising revenue. This reflects the complicating factor that fossil fuels, the main source of CO₂ emissions, are already taxed in most countries. In this model it can be determined how an emission reduction policy should be combined with these existing taxes, as has originally been done by Sandmo (1975).

Our approach differs from earlier literature on the subject by extending the model to an international context. The extended model includes two countries which are assumed to be equal in all respects except in the damage suffered from pollution and the amount of revenue which has to be raised. The object of the analysis is to answer the following questions:

- How will the tax structure in both countries change when they cooperate in reducing emissions and use taxes as instruments of coordinated emission reduction?
- What is the consequence of such cooperation for the welfare level (or worded differently for the economy) and the level of pollution in both countries?
- Can coordination be improved (made more efficient) and total emission reduction raised by allowing for Joint Implementation, that is by allowing one country to pay another country which in return increases its emission reduction by increasing its tax on the polluting good? In our model sidepayments have to be raised by taxation on the two goods, which further complicates the analysis.
- How are the tax structures and the pollution levels affected by this form of Joint Implementation?

In addition to the formal analysis a less general functional form is used in simulations to get more specific answers to the questions posed above.

Instead of a damage function from which the optimal level of pollution is derived an exogenously determined emission ceiling can be used. This better reflects the current practice of CO₂ emission reduction policy. In chapter 6 the model is modified to include such emission ceilings instead of damage functions. It is studied how different government budgets and different initial emission quota influence the tax structures in both countries when they cooperate.

It might be an interesting exercise to determine the optimal tax structures when
countries coordinate in reducing pollution, it is also important to determine which institutional arrangements and instruments can be used to achieve the optimal conditions. It is studied whether international agreements have to specify in detail the level of taxes which each country should levy or whether it suffices to agree on emission limits and sidepayments and leave it to the countries themselves to set taxes. Moreover it is analyzed which role TCP’s can have in international agreements to limit CO$_2$ emissions. Conventional wisdom is that trade in emission quota between countries will lead to a cost-efficient and welfare maximising solution. It will be studied whether this is also the case in our model in which governments have to reduce emissions and raise revenues at the same time.

A last question which is addressed is the role of grandfathering. Selling the permits will raise revenue for the government while grandfathering means that taxes have to be used to meet the government’s budget constraint. The question arises whether grandfathering and auctioning have the same welfare effects or whether they differ in their consequences.

In the outline sketched above, two themes are recurrent. First, the choice between grandfathering and auctioning the permits. This is a central element in the design of a system of tradeable emission permits. Experience with tradeable emissions shows that up till now it has been practice to grandfather the permits to existing sources whereas new sources have to buy the permits they need. A main reason for this policy is that grandfathering permits reduces resistance from (industrial) polluters considerably as compared with auctioning the permits or imposing emission charges. The outlays of polluters on permits can be large compared with their abatement costs when they have to buy permits to cover their remaining emissions. While this does not mean that the use of the permits is without costs (the firms forego the opportunity to sell the permits, therefore they bear the opportunity costs), receiving the permits for free is equivalent to receiving a lump-sum capital transfer. However, while grandfathering is attractive from the point of view of the existing sources, it might be a drawback to entrants. This possible negative influence of grandfathering is considered in the third chapter on entry barriers. Furthermore, in chapter six the role of grandfathering is analyzed in a model in which governments have to reduce pollution and raise revenue at the same time. The
welfare implications of grandfathering are compared with those of auctioning of the permits (chapter four).

The second recurrent theme is the comparison of the instrument of tradeable emission permits with other instruments: a charge on CO$_2$ emission (the so-called carbon tax) and command-and-control type of regulation like emission standards. This comparison is made (a) in order to highlight the peculiarities of tradeable emission permits vis-a-vis other policy measures and (b) because carbon taxes have received much attention in the current debate on CO$_2$ emission reduction, both from policy makers and scientists. The different consequences for entry barriers between on the one hand TCP’s and on the other hand taxes and standards are studied in chapters 3 and 4. In chapter 6 the role of taxes and TCP’s are compared in international agreements on CO$_2$ emission reduction policies.
CHAPTER 2

DESIGNING A SYSTEM OF TRADEABLE CARBON PERMITS FOR THE EU.¹

2.1 INTRODUCTION

At the United Nations Conference on the Environment and Development in Rio de Janeiro in 1992 the Framework Convention on Climate Change (FCCC) has been signed by the representatives of over 150 countries of the world (UN 1992 and UN 1994). It was ratified by a threshold 50 countries late 1993 and it came into force on March 21 1994. The parties that have signed the climate convention agree that emissions of the so called greenhouse gases resulting from human activity are the cause of a rising global mean temperature and climate change and that steps have to be taken to curb emissions. Stabilization of emissions by the year 2000 on the level of 1990 is mentioned as a first target of a global climate policy. The convention leaves the countries free in the way they choose to fulfil their promises. For a time it has looked as if there was a political consensus that a tax on emissions of greenhouse gases, in particular a carbon tax to curb CO₂ emissions, would become the major instrument for implementing the climate convention. However, the initial postponement and eventual demise of such a tax by the Council of Environment Ministers of the then European Community (now the European Union, EU) in December 1994 and the pressure on US president Clinton to avoid increase of taxes have scattered the hope of an early introduction of a carbon tax². The political discussions about the now defunct carbon tax have made it quite clear that a large and probably decisive obstacle to the introduction of an economic instrument like carbon charges is that it evokes all the political resistance that any proposal to impose a new tax on a specific interest group

¹ This chapter is based on Koutstaal (1992) and Koutstaal and Nentjes (1995). See also Koutstaal, Vollebergh and de Vries (1994).

² Instead of introducing a EU-wide tax, it has been decided that "those Member States which want to do so may introduce, on a unilateral basis, a CO₂ energy tax" (Europe Environment, no. 445 - December 20, 1994, p.2).
will call forth. This has for example been shown by the activities of the Union of Industrial and Employers’ Confederation of Europe, a European business lobby based in Brussels, which has been a strong opponent of the carbon/energy tax (Skjærseth 1994, p.28). For that reason it makes sense to look for instruments that do not have the disadvantage of raising the tax burden or changing the existing tax structure and yet leave emitters more flexibility than direct regulation of emission or carbon use would do. In this chapter we will discuss such an instrument, that is tradeable carbon permits. Section 2 gives a short survey of the most important properties of tradeable emission permits (TDP’s) in general and of the experiences up to this date with tradeable permits. Section 3 considers the effect of TDP’s on business location choice and makes a comparison with taxes. Section 4 then sketches the outlines of a system of tradeable carbon permits (TCP’s). Special attention will be given to the design and feasibility of a system of TCP’s for the European Union.

2.2 TRADEABLE PERMITS

Tradeable permits in environmental policy are a relatively new instrument, in theory as well as in actual policy. The idea was developed by J.H. Dales in 1968. The basic concept, rationing of production and handing out of coupons to consumers, who are allowed to trade coupons among themselves has a much longer history. During the period of scarcity caused by the second World War and its aftermath the system has been applied in many European countries. As an instrument of pollution abatement policy tradeable permits were put to practice for the first time from 1975 on in the U.S.A. in the Environmental Protection Agency (EPA) Offset-program for air pollutants (a.o. sulphurdioxide, carbonmonoxide and nitrogenoxides). The main reason for introduction of the permit system was to create a means by which new firms could enter area’s in which no new sources of emissions were allowed because of high

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3 A short overview is given of systems of tradeable pollution permits which have been implemented up till know. For a comprehensive overview of past experience with full references see a.o. Tietenberg 1985, Peeters 1992, OECD 1992 and Klaassen 1995.
pollution levels. New sources could start operating under the condition that they acquired emission permits from established firms. This policy was called the offset policy. In addition, firms could use netting, bubbles and banking. Netting and bubbles are essentially methods in which firms are allowed to have sources which admit above the emission standards as long as they compensate this with sources which emissions fall below regulatory standards. Banking is used to save emission reduction credits (as the permits are called in this program) for later use or sale.

While the EPA-program has undoubtedly reduced abatement costs (bubbles and netting has resulted in an estimated cost reduction of $700 million, Dwyer 1992), it has fallen short of expectations (Hahn and Hester 1989). Especially the number of trades between different firms has been far less than was expected. Three main reasons can be mentioned (Klaassen 1995): regulations which restricted the number of potential trades, high transaction costs which reduced the attractiveness of trade and uncertainty on the future value of the permits which made it less attractive to buy them.

In 1973 a program started in the U.S. to reduce the lead content of gasoline (see Nussbaum 1992). Standards were brought down in a number of phases. The program allowed trade in lead rights and banking. The number of trades was large, up to 60 percent of the total number of lead rights available in 1987 (Hahn and Hester 1989). This can be explained by the modest administrative requirements and by the fact that the refineries already dealt with each other in a number of markets, which kept transaction costs low.

In 1995 an emission trading program started in the U.S. to reduce SO$_2$ emissions from fossil fuel fired power plants (see Klaassen and Nentjes 1995, Klaassen 1995 and Kete 1992). Emissions are reduced from a level of 19 million tons in 1980 to about 9 million ton in 2000. The permits are defined as a sulphur allowance which allows a source to emit 1 ton of SO$_2$. They are grandfathered to the established generator companies on the basis of average fossil fuel consumption in the period 1985-1987 and an emission rate. To assure sufficient supply of allowances for entrants in the power generating sector and to provide a price signal, permits are auctioned each year. The permits for the auction are provided by taking 2.8 percent of the permits grandfathered to the established power generators. In addition, firms can also offer their allowances for sale at the auction. The revenue of the sale of the special reserve of 2.8 percent is
returned to the established firms from which the reserve is taken (hence it is called a zero-revenue auction). Next to the auction, firms can trade directly with each other.

Trade in this program started in 1993. The first available overviews (Klaassen 1995) indicate that the volume of trade at the auction is lower than was expected while trade in the secondary market is above expectations. Transaction costs on the secondary market appear to be small, brokerage fees are around 5 percent.

The U.S. has also implemented a system for trade in chlorofluorcarbons and halons which deplete the stratospheric ozone layer, see Stavins and Hahn 1993 and Peeters 1992 for more details.

Outside the U.S. there has been no experience with full-blown tradeable permit systems for pollution control, although there has been some experience with schemes which allow firms to offset emissions from one source by another within the firm. In the Netherlands and in Denmark bubbles are introduced for the power sector for \( \text{SO}_2 \) and \( \text{NO}_x \) (Klaassen and Nentjes 1995 and SEP 1991). There is some experience with comparable systems in other policy fields. In New-Zealand (and in the European Union) tradeable quota systems are used to limit the amount of fish which can be caught and there exists a salmon quota system in the Atlantic in which trades have taken place. In the EU overproduction of milk is tackled with a tradeable quota system (Oskam c.s. 1987 and Schuurman 1992).

From the short overview of TDP’s sketched above the essentials of a system of tradeable pollution permits can be derived. A full blown system of TDP’s consists of the following elements:

- On national, or if necessary regional level the acceptable total release of a pollutant is determined and expressed in a homogenous unit of measurement, for example tons of carbon dioxide.
- Permits that entitle their owner to release pollutants are handed out, for free or in exchange for payments. The total of pollution quota distributed in this way equals the pollution ceiling mentioned under 1.
- The pollution permits can be traded.
It should be noted that the elements (1) and (2), with permission to pollute for free, are usually a part of existing environmental policies in developed countries. The innovative element is the possibility to transfer the entitlement to pollute.\textsuperscript{4} In principle tradeable pollution permits is an attractive instrument: it is effective, efficient and stimulates the development of cleaner technologies. Furthermore, by giving out permits for free to pollution sources the excess burden that is typical for (pollution) charges can be avoided.

Tradeable permits are effective because the number of units of released pollutants they represent is limited and determined by the targets of environmental policy. Consequently the total amount of pollutants emitted can not increase. Individual sources may increase their emissions and new sources may be established but this has to be compensated by reductions of released pollutants elsewhere. The total level of emissions permitted can be reduced in the course of time as environmental necessity dictates.

The efficiency of tradeable permits arises from the possibility to trade permits. Those who can reduce emissions at low costs will do so and sell permits to emitters which could reduce emissions only at very high costs. Consequently, the opportunity to trade permits opens the possibility to reallocate emissions and emission reduction in such a way that total costs of emission reduction are minimized. In a perfect market, trade will take place and reallocate pollution abatement in such a way that all sources reduce their emissions at equal marginal costs; total costs will be at a minimum and reduction of emissions will be allocated efficiently (see Tietenberg 1988, chapter 14).

Emitters are obliged to obtain permits for every ton of the regulated pollutant they emit. Since the permits have a price (even if they are handed out for free they have an opportunity cost) there is an incentive to search for opportunities to reduce emissions and to invest in the research for and development of new, cleaner technologies. In other words, tradeable permits are a dynamically efficient instrument (Downing and White, 1986; Nentjes and Wiersma, 1988).

\textsuperscript{4} A second importance difference is that no additional permits are made available for new sources as is practice under direct regulation.
The last, and certainly not the least, attractive feature (from the viewpoint of the existing emitters) of tradeable permits is the possibility of distributing permits for free to the emitters (Dijkstra and Nentjes 1994, p.203). This form of distributing is known as grandfathering. As a basis the environmental authority can take the ’historical rights’ of established polluters: existing sources receive an amount of permits which is a given fraction of their emissions in a reference year. Compared with a system of pollution charges polluters can save considerable expenditures, since the individual source has to pay only for additional permits, if needed, whereas under the charge system a price has to be paid for every unit of pollution that is released. Taken as a group permit holders which receive permits for free will only have to bear the abatement costs. Compare this with the cost impact of a charge. If within a given period the emissions of CO₂ are to be reduced with 10 or 20 percent only, the expenditure on charges on the residual emissions of CO₂ would be a multiple of the abatement costs. Even if the increase in tax revenue for the government is returned to tax payers in the form of a lower rate for other taxes it will not be possible to perform such an operation neutrally from a distributional point of view (see for example Pearson 1991). Those who benefit from tax reductions will not fully coincide with those who bear the charge. Consequently, resistance of industry, especially of the pollution-intensive sectors, can be overcome more easily with a system of tradeable permits with grandfathering than with a charge.

Tradeable pollution permits are a suitable instrument for reducing several forms of pollution on the condition that the market for pollution permits works well. The conditions are the usual ones for developed markets, like sufficient large numbers of buyers and sellers in order to induce ’workable competition’ (Hahn, 1984), certainty of entitlements and frequent transactions (which implies reasonably low transaction costs). Competition (anti-trust) policy would apply to permit markets in the same way it does to other markets.

Another important question with regard to the permit is whether grandfathering of permits can create barriers to entry for new firms. This issue, which has received scant attention in the literature, is addressed extensively in chapter 3.

A last point concerns the grandfathering of permits. Usually, the number of permits an emitter receives is based on his emissions in a reference-year. Therefore, the more
he has emitted in the past, the more permits he will receive. This will favour emitters which have done the least to diminish their pollution. One way to overcome this injustice is to limit the total number of permits an emitter can receive by choosing as a point of reference not the actual emissions in a reference year but the emissions that would have resulted if the firm had complied with a given (minimal) emission standard. This is the practice in the sulphur allowance trading system introduced in the U.S, as was mentioned on page 3.

2.3 GRANDFATHERING, RELOCATION AND COMPETITION FROM ABROAD

Given the differences in overall costs for polluters between a tax and TDP’s, the question arises whether the economic consequences will differ between the two instruments. The negative economic consequences of ill designed environmental policies can be considerable (see e.g. CPB 1992). In the now defunct European carbon/energy tax proposals energy intensive industries were exempted because these sectors are open to competition from outside the EU. It was feared that, if other regions would not impose comparable carbon reduction policies, these industries would shrink, emigrate or close down if they were subjected to the tax (Minne and Herzberg 1992). If instead of a tax TDP’s are grandfathered and overall costs reduced, would this change the competitive position of the industry vis-a-vis competition from abroad and will it affect firms decision whether or not to relocate to countries with less demanding environmental policies? On the one hand, it can be argued that grandfathering reduces expenditures for industry and therefore might reduce their incentive to move. On the other hand, moving has the added advantage of being able to sell the grandfathered permits.

A simple static model is used to clarify the issue. There are two regions in which firms can produce. In one region, denoted D (domestic), an emission reduction policy is implemented, either in the form of a tax or through TDP’s with grandfathering. In the other region, F (foreign), there is no policy for reducing emissions. Apart from the difference in environmental policy, it is assumed that there are no differences in
production costs between the two regions. Furthermore, it is assumed that relocation is costless. Consider first the situation in which emissions are reduced by way of a tax on emissions. Let $\pi^d_t$ be the profits earned when a firm produces domestic (the superscript $t$ denotes tax)

$$\pi^d_t = \max p q - [c(q) + t E(q)]$$  \hspace{1cm}  \text{subject to } c'_q, c''_q, E'_q > 0 \hspace{1cm} 2.1$$

$p$ = product price  
$c(q)$ = production costs  
$E(q)$ = emissions  
$t$ = emission tax

Without loss of generality, it can be assumed that abatement has higher costs than acquiring permits. Producing in the other region would yield profit $\pi^f_t$:

$$\pi^f_t = \max p q - c(q)$$  \hspace{1cm} 2.2$$

Domestic profit $\pi^d_t$ will be smaller than the profit earned when production is located abroad because of the expenditure on emission taxes. Therefore, there is an incentive for firms to move to regions which have no emission reduction policy$^5$.

Next, assume that TDP’s are used to reduce emissions. Assuming that the same emission reduction target is achieved, the permit price $P_p$ will be equal to the tax $t$. Let $G$ be the number of permits grandfathered to the firm (each permit covers 1 unit of emissions $E$). His profit is (the superscript $p$ stands for permits):

$$\pi^p_d = \max p q - [c(q) + P_p(E(q)-G) + P_p G]$$  \hspace{1cm} 2.3$$

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$^5$ In reality, there are many more factors, apart from differences in environmental policy, which influence business location decisions. Environmental costs are generally only a small part of total production costs, differences in environmental policy do not seem to be that important (see e.g. Komen and Folmer 1995). As our interest is in the effects of different forms of environmental policy, the focus is exclusively on the consequences of environmental policy for location decisions.
The firm does not have to buy the permits which it has been grandfathered, therefore its expenditure is lower than with the tax (second term within the brackets). However, using the grandfathered permits in its production process means that they can not be sold. In other words, the grandfathered permits have opportunity costs which must be taken into account in determining net profits (third term within brackets). Consequently, the net profit earned when production takes place at home under TDP’s equals the profits earned under a tax regime: $\pi^p_D = \pi^t_D$. Moving to the other region and selling of the permits that have been received would yield profit:

$$\pi^p_F = \max p \cdot q - c(q) + P_p \cdot G$$ \text{2.4}$$

Consequently, its profits will be higher by the value of its grandfathered permits compared with emigration under a domestic tax regime (equation 2). As far as net profits are considered, a TDP-scheme with grandfathering provides an additional incentive to relocate because in that case the grandfathered permits that have not to be used can be sold. This is not the case under a tax regime.

However, in addition to the differences in net profits, the differences in the change in net assets (net worth) should be considered as well. It is assumed that initially a firm has no net assets. First consider a tax. At the end of the period, net assets have increased by the retained earnings. When production took place abroad, net assets will equal net profit $\pi^t_F$. If the firm produced domestic, assets will be $\pi^t_D$. The increase in net assets therefore equals net profit when emissions are reduced by means of a tax, both domestic and foreign.

Next, assume that emissions are reduced by means of TDP’s. The retained earnings at the end of the period when production is domestic are $\pi^p_D + P_p \cdot G$. Although the opportunity costs have to be taken into account when the net profit is calculated, they are not actual costs which the firm has to make. Compared with a tax, a firm sells the same quantity of goods and earns the same gross revenue, but it does not have to bear the tax burden because it has received permits for free. Producing abroad yields
retained earnings of $\pi^p_F$. Compared with a tax, these are higher by $P_p \cdot G^6$. Table 2.1 summarises the results for the net worth of the firm.

<table>
<thead>
<tr>
<th></th>
<th>domestic</th>
<th>foreign</th>
<th>foreign - domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>tax</td>
<td>$\pi^t_D$</td>
<td>$\pi^t_F$</td>
<td>$\pi^t_F - \pi^t_D$</td>
</tr>
<tr>
<td>TDP’s</td>
<td>$\pi^p_D + P_p \cdot G = \pi^t_D + P_p \cdot G$</td>
<td>$\pi^p_F = \pi^t_F + P_p \cdot G$</td>
<td>$\pi^t_F - \pi^t_D$</td>
</tr>
<tr>
<td>TDP’s - tax</td>
<td>$P_p \cdot G$</td>
<td>$P_p \cdot G$</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.1: change in net assets

Grandfathering permits is equal to bestowing a capital gift on firms. Net worth is therefore higher by the value of the grandfathered permits when TDP’s are grandfathered compared with a tax regime (or sale of the permits). Obviously, this is more attractive for industry and therefore a TDP-scheme is politically more acceptable. The difference in net assets between producing domestic or in a region without an emission reduction policy is the same under both instruments. As regards the change in net worth of the firm, grandfathered TDP’s provide no additional incentive to relocate compared with a tax (but neither is the incentive less). This contrasts with net profit; producing abroad yields a higher profit with TDP’s. One could reconcile this difference as follows: The cash flow from ‘normal’ production is equal to those earned when a tax is in force (both domestic and foreign). In addition, under TDP’s there is the gain of the capital gift of the grandfathered permits. In this view, whether permits are grandfathered or not or whether there is a tax makes no difference regarding the incentive to relocate business.

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6 If the permits would not be sold, net assets would also increase with the profit $\pi^p_F$. The difference is that in the first instance the cash flow includes the revenue of selling the permits, in the second case net assets increase with the value of the grandfathered permits which have neither been used nor sold.
2.4 Outline and Feasibility of a System of Tradeable Carbon Permits

In this section, a system of tradeable carbon permits is described. More in particular the question is whether and how such a system would work in the context of international common markets like the European Community. Attention is given to (1) the definition of the permits, (2) the issue of permits over time, (3) the initial distribution of the permits, (4) the permit market, (5) compliance with the system and (6) the EU dimension of TDP’s.

Definition of the permits

For the time being fuel saving and fuel substitution are the major and nearly exclusive economically feasible options for reducing emissions of CO$_2$. For that reason and also for reasons of administrative efficiency and enforcement it makes sense to implement a policy of restricting CO$_2$ emissions by way of tradeable carbon permits. The use of carbon contained in fuel that is allowed in total can be calculated from the CO$_2$ emission targets of the government. On this base a limited number of tradeable carbon permits is issued. A carbon permit is equivalent to 1 ton of carbon, which means that one carbon permit allows the use of a quantity of fossil fuels which contains 1 ton of carbon. The permits are not limited in any way as regards the period or the place where they can be used. This property arises from the fact that the greenhouse effect is a consequence of the accumulation of gasses like CO$_2$ in the atmosphere and is independent of the place where CO$_2$ is emitted. Since the carbon permit can be used at any unspecified date, a permit will retain its validity until the moment it is ’used up’, that is to say until the time the carbon is released to the atmosphere. Consequently, permits are a homogenous good that can be traded easily, that is at low transaction cost, among a nation wide or even larger public of potential carbon users. The importance of these properties are illustrated by the experiences with the EPA-emission trading program: trading was restricted to the geographical area in which the permits originated and every single deal had to be approved by the authorities. Transactions costs were high and the future value of permits was uncertain.
These limitations have seriously restricted the number of trades and by the same token also the efficiency gains (see above, p.7).

When permits are grandfathered, firms receive a number of permits each year for free (a number which will decrease when the overall emission limit is reduced). The right to receive these gratis permits during an indefinite number of future years might be termed a quota. In addition to trading permits, firms can also trade quota. For example a firm which stops producing can sell its right to receive a number of permits for free to another firm which consequently is assured of a supply of free permits each year.

**Issue of the permits**

Fossil fuels are an essential resource to keep the economy going. Therefore a steady supply at a reasonable stable or steadily changing price is a necessary condition for economic stability. A system of tradeable carbon permits comes very close to a system of fuel rationing. Such a system must have enough flexibility to allow the economy to adjust smoothly to changing circumstances. A system which rigorously limits the number of permits which are available in each single year can lead to large price variations with negative consequences for the economy.

Therefore one should take special care to avoid unnecessary bottlenecks caused by a temporary lack of permits. One of the possibilities to increase the flexibility in supply is to maintain a permanent stock of permits from which can be drawn, for example in an extremely harsh winter which drives up fuel consumption. Such a permanent stock can be created when the system is launched. Instead of issuing permits for only one year, permits can be distributed which would cover expected use for four or five years. During the first years this stock of permits will be adequate to meet exceptional demand variations. The permits intended to cover the next period can be issued in advance in order to keep a reserve stock of permits. For example, permits for the second five-year period can be issued at the start of the last year of the first five-year period. Such mechanisms can assure that there will always be permits available to meet changes in demand due to exceptional circumstances. It should be noted that such a system does not mean that the number of available permits exceeds the emission limit.
The reserve of permits is created exclusively through the timepath used for issuing the permits.

In addition, it is important that the permit system allows the authorities some flexibility in setting its future emission targets because the problem of global warming is beset with uncertainties. Care must therefore be taken to avoid that the permits issued will commit policy for a long time to a specific emission limit. However, this requirement might conflict with the necessity that the supply of permits is determined and known in advance for a sufficient number of years. Given a known supply of permits, economic subjects can anticipate future demand and therefore form expectations about the development of the permit price. This is important not only for the development of a well functioning permit market, it is also important for firms which have to make long-term investments in which the permit price is a factor. For example, investments in the electricity generating sector will be influenced by the current and future permit price. As these investments are made for periods up to twenty years, it is important that there is some idea about the future price of permits. In order to reduce uncertainty for fuel users and at the same time to allow the government some flexibility with regard to future emission targets, a scheme can be used in which the government’s emission targets are set for a certain period. The emission targets should not be changed in the meantime. The emission limit for subsequent years need not be precisely specified. Instead, the government could announce an upper and lower bound for its planned distribution of permits, with a gradually increasing gap between the two for the years in the more distant future. Within these margins, the authorities have room to set the exact number of permits made available taking into account new insights in the enhanced greenhouse effect. The exact number of permits which are issued must be announced sufficiently in advance of the year in which they are distributed such as to assure a well functioning market.

In addition to these schemes, the development of a forward market in tradeable carbon permits will add further opportunities for risk-averse fuel users to shift uncertainties to those who are willing to bear them.
Distribution of the permits

In a system of tradeable carbon permits, both grandfathering and auctioning can be used side by side, according to political expediency. Since fuel intensive industries in particular would have to make large expenditures if they had to obtain carbon permits in auctions it can be politically expedient to hand out permits for free to firms in this category. A practical dividing line for the Netherlands would be between industry, horticulture and possibly freight transport as sectors which are fuel intensive and for that reason benefit from grandfathering and on the other hand consumer households, services and (personal) transport as sectors which fall under the auction regime.

![Diagram 2.1 Operation of the system of tradeable permits.](image)

The objective of grandfathering permits to energy intensive industries of course is to exempt them from the additional financial expenditure of buying permits for their full fuel use. For example, reducing CO₂-emissions in the Netherlands with 10 percent
from the 2015 level would require a charge which will raise 33 billion Dutch guilders (about 16 billion ECU’s, 1 ECU = f2.09). The abatement costs are only 2.3 billion Dutch guilders, or 7 percent of the revenue of the charge (Koutstaal, 1992). According to calculations of the Dutch Central Planning Bureau (CPB, 1992), reducing emissions in 2015 with about 10 percent by means of a unilateral tax on fossil fuels would have the result that the energy-intensive industry would be wiped out almost completely in the Netherlands. The proposed system of grandfathering tradeable permits would cost industry only a fraction compared to a charge. Firms will still bear opportunity costs for the permits grandfathered, see section 3, but their total expenditure is far less.

The carbon permits needed for the emissions of CO₂ emitted by the less energy intensive sectors and consumer households are auctioned by the government. It would not be efficient if consumer households and small enterprises in the service sector would have to buy the permits at the auction themselves because transaction costs would be huge. The alternative is that distributors of fossil fuels like gas distribution and oil companies buy permits at the auction. Subsequently, they can sell fossil fuels to customers from these sectors, putting a mark-up on the fuel price which is equal to the price of the permits. This will motivate small fuel users to reduce their fuel consumption (or to switch from fuels with a high carbon content, like coal, to fuels with a low carbon content like natural gas). It should be noted that in such a system it would not be consistent to hand out permits to the distributors for free. If that were the case, the distributors would be able to collect the scarcity rent without making any costs for reducing carbon use, because only their customers can reduce CO₂ emissions.

In diagram 2.1, the way the system functions is outlined schematically. Permits are distributed by the government, both through grandfathering (to industry, horticulture and transport) and by auction (to distributors of fossil fuels). The distributors deliver fossil fuels without a mark-up on the fuel price to those who have already acquired permits themselves through grandfathering (for example industry), the buyer pays the price and transfers permits equal to the carbon content of the fuel to the distributor. The other trade channel for distributors is to buy permits at the auction or from other firms. Those who have not acquired permits one way or another (for example consumer households) buy fossil fuels from distributors with a mark-up on the price.
<table>
<thead>
<tr>
<th>sector</th>
<th>CO2-emissions [mln. ton]</th>
<th>number of sources</th>
<th>average emissions [1000 ton / source]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and beverages</td>
<td>3.9</td>
<td>7258</td>
<td>5</td>
</tr>
<tr>
<td>Textiles</td>
<td>0.3</td>
<td>1515</td>
<td>2</td>
</tr>
<tr>
<td>Paper</td>
<td>1.5</td>
<td>362</td>
<td>41</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>6.6</td>
<td>12</td>
<td>5500</td>
</tr>
<tr>
<td>Other chemicals</td>
<td>3.8</td>
<td>838</td>
<td>44</td>
</tr>
<tr>
<td>Building materials</td>
<td>2.2</td>
<td>684</td>
<td>32</td>
</tr>
<tr>
<td>Base metal</td>
<td>8.8</td>
<td>119</td>
<td>740</td>
</tr>
<tr>
<td>Other metal</td>
<td>1.8</td>
<td>14563</td>
<td>1</td>
</tr>
<tr>
<td>Other industries</td>
<td>0.5</td>
<td>21358</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Refineries</td>
<td>12.1</td>
<td>7</td>
<td>17285</td>
</tr>
<tr>
<td>Power companies</td>
<td>36.8</td>
<td>88</td>
<td>4182</td>
</tr>
<tr>
<td>Transport</td>
<td>26.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>19.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horticulture</td>
<td>6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>141.7</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2 CO₂-emissions, Dutch economy, 1989.  

**The permit market**

In the system outlined above two markets can be discerned. First, there is the auction of part of the permits. This market can be called the primary market. In addition, firms can trade permits between themselves on the secondary market. In theory, the permit price will be equal between the two markets; otherwise arbitrage would occur which would equalise prices.
An important condition for a system of TDP’s is the development of a well functioning (secondary) market. A well functioning market implies that permits are traded in sufficiently large numbers to facilitate stable price-making. Whether this will be the case in the system of TCP’s will depend on the number of potential actors on the market and the supply and demand of permits. Table 2.2 provides data for the Dutch economy on emissions per sector, the number of firms per sector and average emissions per firm. Grandfathering permits to industry, refineries, transport and horticulture implies that about 50 percent of the permits are grandfathered. The other 50 percent would be sold at the auction which guarantees a large supply on the primary market.

The number of potential actors on the secondary markets is large. In industry alone there are more than 45000 sources and in addition energy suppliers like gas distribution companies and power generators can be expected to trade as well7. However, presumably not all industrial firms will trade actively on the market. Transaction costs might be relatively large for smaller firms and for firms for whom energy costs are only a small fraction of production costs. Instead, these firms can arrange with their suppliers of fossil fuels that they will supply them with the fuels they need and acquire the permits which these firms might need in addition to those they received through grandfathering (and presumably pass on the price). The suppliers might also get a mandate to sell permits which firms do not need. In essence, suppliers would take on a brokers role, bringing together supply and demand of permits.

The potential for trade not only depends on the number of actors but also on the supply of and demand for permits. This depends on differences in abatement costs. The larger differences are, the larger is the potential for trade because the gain of trade increases when cost differences increase. Studies indicate that the costs of reducing CO2-emissions differ considerably between different sectors (see Velthuijsen 1995 and Blok c.s. 1990). Consequently, there are sufficient incentives for trade.

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7 In a European-wide system of tradeable carbon permits the number of (potential) actors on the market would be much larger.
A last point concerning the permit market is the form which the secondary market will take. Ideally, permits are traded on an exchange like stock markets or exchanges for raw materials or agriculture products. However, this will only be possible if the volume of trade is large enough. Given the potential for trade and the number of actors such an exchange might develop in time in the TCP-system. Before that trade can take place through brokers, a role which might be fulfilled by suppliers of fossil fuels. In the CAAA sulphur trading scheme brokers facilitate trade on the secondary market (Klaassen and Nentjes 1995). In the EU tradeable milk quota program, a number of solicitor firms which were already active in agriculture have specialised in milk quota brokerage (personal interview, Scottish Agricultural College dairy test farm, 1993).

**Monitoring, enforcement and administrative costs**

As has been shown, distributors acquire the permits for the fossil fuels they sell to consumer households and other small CO₂-emitters. The permits industry receives through grandfathering can be handed over to the distributors in exchange for the carbon contained in the fossil fuels they buy from the distributors (see also diagram 2.1, double line). In this way, all permits will end up in the hands of the distributors, who to a large extent are the same as the producers and importers of fossil fuels (those distributors who do not produce or import fossil fuels themselves can in their turn hand the permits over to their suppliers. In the end, all permits will turn up at the producers and importers). This property of the system can be used to set up an efficient system of monitoring and enforcement. Producers and importers of fuel are placed under the obligation to turn over carbon permits for the carbon contained in the fossil fuels they have sold onto the market to the environmental authorities (see diagram 2.1) once a year. They have either received the permits from their clients or bought them at the auction.

The advantage of supervising compliance with the tradeable permit system in this way is that it fits in with existing institutions for levying excises on fossil fuels, which exist in most western countries. In the Netherlands, traders and suppliers of mineral oils have to have a licence. They are obliged to report each month how much they have supplied to the market and they have to turn over the excise tax to the authorities.
This administrative system of self-reporting is supplemented by occasional physical checks. The system operates satisfactorily (Parliamentary Accounts Dutch Parliament, nr. 21368, p.21). Instead of handing over the excise, suppliers and producers of fossil fuels hand over permits as has been described above. In addition, suppliers of other fossil fuels like natural gas and coal should be brought into the system.

Next to the administrative monitoring system, other sources of information might be used for double checking. Victor (1991) mentions four other sources of information:

- Direct monitoring of emissions. This might be an option for some large stationary sources. However, it is not practical for smaller and mobile sources.
- Data from other reports by either the source itself or from third parties. For example, data reported to the fiscal authorities from buyers of fossil fuels.
- Data from environmental annual reports. These kind of reports, which are sometimes verified by accountants, are published by an increasing number of companies.
- Data generated by modelling exercises. Starting from known input data, estimates can be made of emissions. These data are probably not very accurate, but they might serve to detect large scale frauds.

One way of direct monitoring are tamper-proof metering devices which are fixed to machinery and pipelines (Cnossen and Vollebergh 1992). Using the excise system will guarantee a high level of compliance and will make a system of TCP’s just as feasible as a carbon charge as far as compliance is concerned. Only the limited number of firms which produce or import fossil fuels has to be checked. In the Netherlands for example, there are about 40 to 50 of such firms.

Not only must there be an effective system of monitoring, enforcement must also be assured. For effective compliance two elements are of importance. First, sanctions should be such that the expected costs of fraud exceed the costs of sticking to the rules. Second, the environment should not suffer from fraud. Consequently, in

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8 The expected costs of fraud equal the chance that fraud is discovered times the level of the sanctions.
addition to a fine, firms which have failed to supply permits for the fossil fuels they have used should be forced to acquire permits to cover these emissions (this approach is taken in the tradeable sulphur allowance scheme, see Kete 1992).

The administrative costs of the system of TCP’s will consist of several elements. The two main cost factors are the costs of monitoring and enforcement and the costs of registration of the ownership of the permits. Furthermore, data will have to be collected for determining the quota which firms will receive when permits are grandfathered. This will also entail costs which however only have to be incurred once. Last, a yearly auction will have to be set up. The first cost factor, monitoring and enforcement, will be comparable with those of implementing a charge on carbon in fossil fuels. They will not differ very much from the costs of the current system for levying excises on fossil fuels. In Allers (1994, p. 71-75) the administrative costs of existing environmental taxes in the Netherlands are given. The environmental taxes which are levied under the WABM law (Wet algemene bepalingen milieuhygiëne) consists mainly of a tax on fossil fuels. In 1990, the administrative costs ran to 40.5 million guilders, about 20 million ECU. Compliance costs of this environmental tax are difficult to ascertain due to the fact that only data are available on compliance costs for all environmental taxes in the Netherlands (Allers 1994, p. 179).

Registration of the ownership and trade in permits is typical for TDP’s, no comparable arrangement is necessary when a charge is levied or standards are applied. The most efficient way to register ownership is probably to use a giro system comparable to the systems used to register ownership and trade in shares and certificates traded on stock exchanges. In the Netherlands, NECIGEF (the Dutch central institute for trade in shares by giro) registers the ownership of shares. Yearly operating costs of the institute were 9.5 million guilders in 1990 (4.6 million ECU’s) (NECIGEF 1990, p.29). The average number of trades registered in that year was 4532 per day. It is not to be expected that trade in CO₂-permits will exceed this number, therefore the costs of this institute might serve as an example of the costs of registering the carbon permits.

A rough estimate of the yearly operating costs of the system of TCP’s described here is about 50 to 70 million guilders if it is implemented in the Netherlands, around 29 million ECU’s. In addition costs will have to be made to grandfather permits (which
however will only have to be done at the start of the system) and an auction must be set up.

In the next section, compliance at the European level in a EU-wide system of TCP’s will be addressed.

EU dimension of tradeable carbon permits

An important question is whether a system of TCP’s would have to be confined by the boundaries of the national territory. The Member States (MS) of the EU have delegated part of their power to the European Union. Consequently, the freedom for independent policy is restricted by primary legislation (the treaty of the EU) and secondary legislation (e.g. directives and regulations). A national system of tradeable carbon permits restricts the use of carbon contained in fossil fuels. Consequently, TCP’s imply a restriction on the quantity of fuel that can be produced at home and imported from abroad. It might therefore be seen (by the European Commission) as a restriction of the free movement of goods between MS and consequently as a violation of article 30 EG. Art. 30 EG states that trade in goods between MS may not be restricted. In a system of TCP’s the import of fossil fuels is restricted by the total amount of carbon permits available and therefore it might be contrary to art. 30 EG.

However there are exemptions on art. 30 EG (Pisuisse and Teubner 1994, p.97). Restrictions of imports are allowed under art. 36 EG and under the ’rule of reason’. The rule of reason applies if the following conditions are met:
- There must be no Community measure regarding the policy area in which the MS wants to implement the policy measure which could restrict free movement of goods.
- The proposed policy measure must apply to domestic and imported products alike.
- The proposed policy measure must justify certain interests which are accepted by the Court of Justice. Examples of these interests are environmental protection and consumer protection.

The policy measure must be reasonable and it is subject to the proportionality test. This means that trade between MS must not be restricted any more than is necessary to achieve the policy purpose. Moreover there must not be another policy measure which would be as effective (and efficient) but which would not restrict trade to the same extent.

Concerning the first condition, there is currently no substantial greenhouse policy in the European Union. There has been considerable discussion on the use of a EU tax to limit carbon dioxide emissions in the last five years. However, on December 15, 1994, the Council agreed that no Community tax measures will be taken (Europe Documents no. 1918, 6 January 1995)\textsuperscript{10}. Instead, it was agreed that those MS which want to do so may introduce a CO\textsubscript{2}/energy tax themselves. Such unilateral carbon taxes should follow a Community framework which should be developed in further discussions by ECOFIN (the council of finance ministers). It is not clear at what time a framework will be developed and whether it would leave room for MS to use other policy measures to limit CO\textsubscript{2}-emissions like TCP’s. In the mean time, it seems plausible to assume that as there is no Community policy, nor a proposal for a regulation, MS can take their own policy measures.

The tradeable permit scheme described above does not discriminate between fossil fuels sold by national firms and firms from another MS. For all fossil fuels brought onto the market, regardless of their country of origin, carbon permits have to be acquired. The second condition is therefore fulfilled.

Environmental protection has been recognised as an interest which justifies a restriction of free movement of goods, therefore a system of TCP’s meets the third condition.

A system of tradeable emission permits is both an efficient and effective instrument to control CO\textsubscript{2} emissions. Other instrument types are either not as effective (e.g. a carbon tax) or not as efficient (e.g. emission standards). The last condition appears to be met as well.

\textsuperscript{10} At the Essen summit the heads of state already decided that there would not be a Community carbon tax.
Another question regarding the possibility to implement a system of TCP’s in one country in the EU is the issue of enforcement. As long as differences in excise taxes are allowed, the administrative system which is used to enforce the system (see above) remains in place.

Enforcement might also become more difficult when national inner frontiers are abolished within the EU. A start is made in the Schengen-agreement, which abolishes border controls between seven countries of the EU. Without such border controls, fraud is more difficult to discover. End-users could import fossil fuels directly from suppliers in other MS without procuring carbon permits and without running the risk of discovery at border controls. However, this problem should not be overstated. Large scale evasion of the obligation to acquire permits will remain difficult because of the properties of fossil fuels. Large scale transport of fossil fuels is bulk transport which moreover needs large installations for unloading. It is therefore difficult to evade the obligation to acquire permits for large quantities of fossil fuels because it will be difficult to escape detection.

It can be concluded that it is probably possible to implement the national system of TCP’s which is sketched in this chapter in one MS of the EU. A system of TCP’s might conflict with free movement in goods within the EU but it will probably fall under the rule of reason which allows exemptions to art. 30 EG. One problem might be that there will be no more room for other instruments once it is decided that MS can introduce a carbon/energy tax unilaterally. However it is not yet clear if and when such a decision will be taken and how it will be formulated. Enforcement might become more difficult when border controls are abolished. However, fraud on a large scale will still be difficult.

Although TCP’s might be realised within one country, it is preferable to introduce a system in the whole of the EU. A system will be more effective when emissions are limited in all MS of the EU instead of only one. Moreover, the problem is avoided that firms in MS which have implemented TCP’s have a disadvantage vis-a-vis firms from MS without CO₂ reduction policies.

As a first step for the introduction of the system the Council of the EU will have to decide on a time path for total carbon use within the EU, on the sectors that are selected for grandfathering and on the basis on which permits are grandfathered.
Another question to be decided on EU-level is whether and how the available permits should be distributed among the different member states. Permits can be grandfathered and sold at the EU-level or they can be allotted to the MS who in turn distribute them. With regard to this last option, it should be realised that MS would not be allowed to use their permits to support specific sectors or firms by grandfathering permits in excess of those allowed by the rules for grandfathering. Such a behaviour would be contrary to articles 92 - 94 EG. These articles prohibit governments to support sectors if this would reduce competition and obstruct trade between MS. Furthermore, a member state would not be allowed to sell the permits exclusively to firms registered within its own borders, thereby favouring its own industry, as this would be discrimination. Hence, the only rationale for allotting quota to MS would be that it is a method to distribute the revenue generated by the auction of (part of) the permits among the member states. The other option is to decide on an allocation rule for the revenue and to auction the permits at a central level.

When the system is introduced, a distinction must be made between the activities which should be undertaken at the central EU level and those which could be delegated to the member states. For the execution of the various tasks, a Brussels bureau should be set up (or alternatively the European Environmental Agency in Copenhagen might perform the task) as well as a network of national bureaus. The task of the national bureaus consists of (a.o.):
- Registration of the ownership of the permits.
- Grandfathering of permits to designated sectors.
- Monitoring and enforcement.

One of the tasks of the national bureaus is to set up giro system for registration of the permits (see page 13) and to operate them. Furthermore, the national bureaus should implement the rules made up for the grandfathering of permits to industry. For this purpose, the national bureaus must draw up a list of all firms eligible for grandfathering and issue them each year their allotted quota.

An important task of the bureaus is to enforce the tradeable carbon scheme. They should collect the permits which have to be handed in by importers and producers of fossil fuels (see page 20) registered in their MS. In addition the national bureaus should make periodical inspections to check whether firms accurately report the amount
of fossil fuels they have brought onto the market. The task of the Brussels bureau would be threefold:

- Supervision of (the performance) of the national bureaus.
- Acting as a clearinghouse for transactions between permit owners registered at different national bureaus.
- Evaluation of the programme.

The Brussels bureau should supervise the national bureaus on a number of points. The most important point is enforcement; the Brussels bureau should check with great care whether the national bureaus enforce the carbon permit scheme equally accurately and collect all the permits due. A EU wide system of tradeable carbon permits would show large "holes" to the detriment of its effectiveness (and efficiency) if some MS do not enforce the system. This would also be true of any other instrument (charges or regulation) if it would have to be applied under such awkward condition, but there is one difference. Under TCP’s, firms which operate in a MS without adequate enforcement can emit without handing over permits. Consequently, they can sell their permits to firms in other MS and as a result in these other MS pollution would increase. When taxes or regulation are used, firms which defraud cannot sell permits to sources in other countries. With these instruments pollution only increases above the allowed level in the country in which enforcement is not adequate. In a European system of TCP’s insufficient monitoring and enforcement in one or more MS will lead to higher overall pollution levels compared with instruments like charges or regulation.

As has been described above, MS are not allowed to favour specific firms or sectors by allocating them more permits than is allowed under the grandfather rules. The implementation of these rules should therefore be monitored at the European level. This task could be delegated to DG IV of the European Commission which deals with competition. Another field for supervision is competition between firms; firms would not be allowed to use carbon permits for limiting competition (see chapter 4 for an evaluation of using permits to limit entry). This task can also be undertaken by DG IV.

The evaluation of the programme can be made in the form of an annual report. Subjects to be dealt with are among others: the number of permits issued and of permits used, the volume of trade and the occurrence of fraud.
2.5 CONCLUSIONS

Tradeable permits are an instrument of pollution control that can be applied to tackle a large class of pollution problems. It is in particular suited if the problem is created by the emissions of a large number of sources and the pollutant is spread more or less evenly in the environment. This is the case with the emissions of CO₂; the greenhouse effect occurs worldwide and the different sources range from large stationary sources like power plants to small mobile ones like cars. With such a large number of diverging sources, it will be impossible to reduce emissions in a cost-effective way by means of direct regulation. The instrument of tradeable permits has the important advantage that emission reduction will be cost effective.

TDP’s have other attractive features. The instrument is effective in the sense that the emission targets are realized: the total amount of polluting emissions is limited by the number of permits issued. With regulation and taxes, the level of emissions can increase, although it has not been planned: for example in consequence of economic growth or sectoral shifts. Furthermore, permits can be grandfathered to polluters. This will considerably reduce their outlays compared with auction of the permits or with emission charges, they will only have to bear the abatement cost. Especially for the energy intensive sectors of industry, permit expenditure will be several times larger then the abatement costs. Therefore, tradeable carbon permits will be politically more acceptable than a tax.

Even though grandfathering reduces the overall cost burden for industries, this does not necessarily mean that the incentives for industries to relocate to regions with less exacting environmental policies is less than with a tax. Because of the opportunity costs of the grandfathered permits, net profit will equal the net profits firms make under a tax. However, from the point of view of the net worth of firms, they are better of under TDP’s. Presumably, the incentive to move for firms will not differ between either instrument.

It has been studied in detail in this chapter how a system of tradeable carbon permits should be designed. Elements on which the analysis has focused are: the definition and the issue of permits, the distribution of permits, the permit market,
monitoring and enforcement and the specific characteristics of a EU-wide system of TCP’s. As regards distribution of the permits, it seems most practical to grandfather permits to industrial sources and to sell the permits which cover the other emissions. As it is not practical to compel consumers to buy (and trade in) permits themselves, the government agency can sell these permits to their suppliers of fossil fuels, who can subsequently mark up their fossil fuel prices with the price of the permits.

Compliance in a national system of TCP’s does not pose greater problems than compliance with a carbon tax. Under both instruments producers and importers of fossil fuels can be obliged to hand over either the tax or the permits for the carbon contained in the fossil fuels they bring on the market. The existing mechanism for levying the excise on fossil fuels can be used for levying the carbon tax or carbon permits. In addition other information sources can be used to supplement monitoring like periodical checks and data on other taxes. The administrative costs do not have to be excessive as long as a giro system is used for registration of trades and ownership of permits.

So far there is no concerted EU policy on carbon dioxide reduction. There has been much discussion about introducing a European carbon/energy tax but in the end it was decided that it is left to countries themselves whether they introduce a tax or not. In the absence of a European policy, it seems to be possible for one MS to introduce a national system of TCP’s. Although a national system of TCP’s might be seen as a restriction on free movement of goods within the EU, it will probably fall under the ’rule of reason’ which allows exemptions to article 30 EG which deals with free movement of goods. The disappearance of border controls within the Eu might make enforcement more difficult but this does not seem to be a large problem due to the bulk character of fossil fuels.

Although a system of TCP’s can probably be introduced in one MS, it is preferable to implement it at the European level. The instrument will be much more effective and there will be no consequences for the competitiveness of firms in different MS. Within a European system of TCP’s all MS have to use the same grandfathering rules. They are not allowed to use the permits to support specific sectors or firms. Special care must be given to the enforcement within a EU-wide system. TCP’s would not be effective (or efficient) if firms can evade the system in one or more MS. Although a
system of TCP’s might be just as sensitive to fraud as other instruments like standards and taxes, the consequences for the overall pollution level are larger under TCP’s firms which can evade the obligation to hand over permits can sell them to firms in other countries. As a result, pollution will increase not only in the MS where enforcement is not adequate but also in the other MS.
CHAPTER 3
ENTRY BARRIERS AND TRADEABLE EMISSION PERMITS

3.1 INTRODUCTION

Permit markets might fail to coordinate pollution control decisions efficiently if there exist opportunities for abuse of market power in the permit market, or if a tradeable permit system creates barriers to entry on the product market. The first possibility has been researched by Hahn (1984). He studied the strategic behaviour of a firm which has market power in the permit market (it is a price maker rather than a price taker) and uses this power to minimise his abatement costs and expenditure on permits. The main conclusion of this study is that in the case of market power abatement costs for the industry as a whole can be higher than is necessary. The extent of the inefficiency is related to the number of permits allocated initially to the dominant firm. The more the number of allocated permits deviates from the number the firm will use in equilibrium, the less efficient is abatement. This holds both when the firm does not receive enough permits, in which case he will act as a monopsonist on the permit market, and when he receives more permits than he will use, in which case the firm behaves as a monopolist. In an empirical example which simulates trade in sulphates in the Los Angeles area (where an electric utility was a large emitter and therefore would have had market power on the permit market) Hahn studied the extent of the possible abatement cost inefficiency. The result was that total abatement costs would only rise significantly above the minimum level when the initial allocation to the dominant firm was sufficiently large. Otherwise, abatement costs efficiency would only be affected to a minor extent.

There are other studies of the effect of market power on abatement cost efficiency. A study by Hanley and Moffat (1993) analyses a potential tradeable emission permit scheme for controlling Biological Oxygen Demand discharges in the Forth estuary (near Edinburgh, Scotland). The data suggest that market power might be a problem in this scheme (which at this moment is considered for implementation (spring 1995)).
Pototschnig (1993) has studied the possibility of using tradeable permits for controlling acid rain in England and Wales. The permit market would be dominated by two firms (both electricity generators), who would account for about 85% of the demand for permits. Consequently, these sources would have market power and therefore might influence the permit price.

Overlooking the theoretical and empirical evidence, the problem of misuse of market power which might lead to higher abatement costs does not seem to be a large problem in the system of tradeable carbon permits described in chapter 2. It is essential that a firm does exert influence over the permit price. Given the size of the carbon market, it is not likely that one firm can exert much influence on the carbon permit price (see section 6).

The second possible source of market failure, entry barriers, is a relatively neglected problem in the literature on tradeable permits. Tietenberg mentions the possibility of entry barriers, stating that "In general, the new source bias inherent in forcing new, but not existing, sources to purchase offsets to cover any emissions is probably a more serious barrier to entry than the existence of market power." (Tietenberg 1985, p. 140). At first sight intuitively it makes sense that tradeable emission permits might lead to entry barriers. When permits are grandfathered for free to existing firms, this might disadvantage new entrants to the product market; they have to buy the permits and therefore their costs seem higher. Another possibility is that firms might try to exclude entrants from the market by limiting their access to the permits, as has been described by Misiolek and Elder (1989, see the next chapter).

In this chapter and the next we shall concentrate on this second form of market failure, entry barriers. The question is addressed whether, how and under what circumstances a system of tradeable permits might create barriers to entry in the product market or strengthen existing barriers. Both grandfathering and selling of the permits to incumbent firms are addressed. First, an overview is given of the general literature on entry barriers (section 2). Subsequently, the theories concerning entry barriers are applied to tradeable permits. Several potential entry barriers which might occur when a system of tradeable emission permits is introduced are identified and analyzed. Moreover, the relative importance of these barriers for the system of tradeable carbon permits proposed in chapter 2 is discussed.
We focus on the specific consequences of the instrument of tradeable emission permits for entry barriers as compared with other instruments like taxes and command-and-control regulation. Therefore, the possibility that entry barriers are created or raised due to the fact that firms have to bear abatement costs when an emission reduction policy is introduced is ignored; these would occur as well with other policy instruments.

3.2 THE THEORY ON ENTRY BARRIERS

In discussing entry barriers, the natural point to start with is Bain’s *Barriers to New Competition* (1956). In this treatise, Bain was the first to look systematically at potential competition as opposed to competition from existing rivals. Or, in other words, he studies entry of new firms into industries and the conditions that discourage entry. Bain viewed barriers to entry as being determined "by the advantages of established sellers in an industry over potential entrant sellers, these advantages being reflected in the extent to which established sellers can persistently raise their prices above a competitive level without attracting new firms to enter the industry" (Bain, 1965, p. 3). Subsequently, other authors have come up with their own definitions. Like Bain’s definition, most of them focused on the asymmetry in the costs of production between incumbent firms and entrants (see Stigler and Baumol & Willig in: Gilbert 1989 p. 476 - 478). In contrast, von Weizsäcker also includes the welfare effect in his definition: "a barrier to entry is a cost of producing which must be borne by a firm which seeks to enter an industry but is not borne by firms already in the industry and which implies a distortion in the allocation of resources from the social point of view" (1980, p. 400). A barrier to entry is defined here as *a cost which only firms entering an industry have to bear, making it possible for the existing firm(s) to enjoy a rent derived from incumbency* (see Gilbert 1989, p. 476 - 478). A cost advantage in itself is not necessarily a barrier to entry; it must also confer an advantage on the existing firms, like in Bain’s definition the possibility to reap higher than competitive profits. If such an entry barrier occurs, welfare will be adversely affected. The incumbent will charge a price higher than his minimal average costs. Resource allocation will be
inefficient and welfare is reduced. Therefore, the entry barriers identified in the remainder of this study will imply that long-term industry efficiency is impaired and therefore welfare is reduced.

What types of entry barriers do exist and which types might apply to tradeable permits? The basic identification and classification of categories of entry barriers was made by Bain. He distinguished three categories of entry barriers which will be briefly discussed (1965, p. 14 - 16):
1] Absolute cost advantages
2] Product differentiation
3] Large scale economies

**Absolute cost advantages**

Absolute cost advantages appear in several different guises. Existing firms may posses cheaper production processes than the potential entrants. Consequently, they can outprice them and therefore keep them off the market. There are several possible reasons for this cost advantage like learning by doing and research and development. The fruits of R & D might be protected by patents which deny use of the superior process to entrants.

Another form of absolute cost advantages exists when established firms can buy input factors at lower prices then entrants. This is also applicable to capital markets. When capital markets do not work perfectly, it might be more difficult or in other words more costly for new firms to acquire the necessary capital than for existing firms. Consequently, entrants have higher production costs than existing firms. This form of entry barrier has been referred to as the "deep pocket" or "long purse" theory and is associated with predatory pricing. Predatory pricing can be used by incumbents who posses larger (financial) resources than entrants to drive these new firms of the market whenever they try to enter. Predatory pricing will not be possible when capital markets work perfect, because entrants can indefinitely borrow on the capital market. But if capital markets work imperfect new firms have to incur higher costs when they borrow money (see Tirole 1992, p.377 and section 5 of this chapter). Consequently,
there will be a cost advantage for established firms which have larger resources and therefore do not have to bear the costs of borrowing

An extreme form of imperfect input markets occurs when existing firms control the supply of a strategic production factor and therefore have the ability to deny entrants access to this input. By excluding them from the use of this input factor, they force them to use inferior and more expensive alternatives, driving up their costs.

In all the cases discussed above, the entrant faces higher costs than the incumbent. Consequently, the incumbent will be able to charge a price which is higher than his average costs and make a profit, without having to be afraid of entry as long as the price he charges is lower than the average costs of the entrant. He thus reaps a benefit from the fact that entry is difficult, or, as the definition states, he enjoys a rent derived from his incumbency.

Product differentiation

The second type of entry barrier Bain identified was product differentiation. By differentiating their products, firms can set their product to a certain extent apart from the other products in their market. These products will not be viewed as perfect substitutes by the customers and therefore it is difficult for a new firm to induce them to switch. This makes entrance more difficult. There are several ways in which a firm can differentiate its product, e.g. design differences as compared with products of other firms, customer service, dealer systems and advertising. Especially in the consumer good industries, advertising is an important form of product differentiation (Bain 1965, table X, p. 123). Advertising can induce brand loyalty and make it seem less attractive for customers to switch to other brands. This raises the entry barrier for potential entrants because it is more difficult for them to acquire a viable market share.

Economies of scale.

When there is a systematic economy of scale in producing and selling such that firms of the efficient size provide a significant portion of demand, entrants will be at a disadvantage. In order to produce at minimum costs, an entrant would have to produce at a considerable scale. Selling this amount would mean that the market price for the product would drop and as a result the entrant would not be able to cover his
costs. Consequently, the incumbents would be able to set a price which is higher than their average costs without having to fear entry. There is a limit price, higher than the competitive price, which still deters entry while for any higher price entry will occur.

After Bain’s seminal work on entry barriers, the issue has been explored in more detail. A form of entry barrier which has received much attention (and which will be relevant for the discussion of tradeable emission permits and entry barriers, see section 4) is the limit pricing model, a form of economies of scale entry barriers. In the basic form of the limit pricing model (the Bain-Syllos-Labini-Modigliani model, see Gilbert 1989, p.480-493), the established firm chooses the quantity which he wants to produce before the entrant enters the market. Given the quantity produced by the incumbent, the entrant decides whether or not entering will be profitable. At a certain output of the incumbent, the limit output, profits of the entrant will be zero and therefore he will not enter. The associated price is the limit price. In this model, the incumbent acts as a Stackelberg leader while the entrant acts as a Cournot follower. The limit pricing model has been further developed later on by Spence (1977) and by Dixit (1981). These developments are described in section 4 of this chapter.

The next step is to go further into the different types of entry barriers and look in more detail at the developments in the theory and their relevance for tradeable permits. The short survey presented above gives the opportunity to indicate which of the three main types of entry barrier might be relevant for tradeable permits. As regards the second type of entry barrier, product differentiation, there is no obvious relation with the way tradeable permits might raise entry barriers. Product differentiation hinders entry because the product of an entrant will not be a perfect substitute for the product of the incumbent. Tradeable permits, however, do not create a difference between the product of the incumbent and the product of an entrant although they might create a difference in the conditions under which both products are made. Both products will remain the same to the consumers, regardless of how the necessary pollution permits are acquired.

The absolute cost and economies of scale (the limit pricing model) type entry barriers do appear to be relevant in the case of tradeable emission permits. In the next sections, these cases will be discussed extensively.
3.3 ENTRY BARRIERS AND TRADEABLE EMISSION PERMITS: OPPORTUNITY COSTS

At first sight, it might appear to be straightforward that grandfathering permits to existing firms and selling them to newcomers raises entry barriers, because entrants seem to have an extra cost (buying the permits) which incumbents do not have. However, this naive conception of cost is mistaken. The permits owned by the established firms are for them an opportunity cost which is as much a part of the cost of a firm as permits that have to be bought from others. Therefore the entrants’ cost for the input pollution is equal to the cost of the incumbent. If there are no other cost differences the cost functions are equal. The lowest price both can charge without making a loss is therefore the same as well. At every price above this minimum price, the entrant can enter and make a profit. Therefore, grandfathering in itself does not raise entry barriers.

Land property provides an illustrative comparison. New firms will have to buy land on which to establish themselves, while existing firms possess land. Even if established firms have completely written off their land, they still will take into account the opportunity costs of their land. These opportunity costs are equal to the price for which they can sell it. The fact that new firms have to buy land does therefore not create an entry barrier.

An example of the opportunity costs of permits are taxi medallions or permits which are needed in order to operate a cab in certain municipalities. When these medaillons are traded on a market, the opportunity costs of established firms of using their licences are equal to the price of the licenses on the market (Demsetz, 1982). Another example are the milk quota introduced in the European Community. Dairy farmers only get a guaranteed price for their milk as long as they do not produce more than their quota. These quota were grandfathered to established farmers when the scheme was introduced, new dairy farmers who started afterwards had to buy them

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1 If they produce more than their quota allows, they have to repay part of the guaranteed price (the so-called super levy). This means that the surplus quantity produced has to be sold at lower (market) prices.
from the established farmers. The milk quota have opportunity costs for the farmers. When they stop producing they can sell them. Actually, there has been a fair amount of trade in the quota and, additionally, quota have been leased. In the latter case, a quota is let for one year to another farm. The price for which quota are sold is roughly ten times their one-year lease price (Schuurman 1992).

For tradeable pollution permits, the case is the same. Even though established firms receive their permits for free while new firms have to buy their permits, they must take into account the opportunity costs of the permits. Therefore grandfathering permits does not necessarily raise entry barriers.\(^2\).

Taking opportunity costs into account does not mean that using the instrument of TDP’s will never raise entry barriers. The opportunity costs of assets are determined by the value they have in their next best use. Generally, this value is given by the price for which the assets are traded on the market. A prerequisite is that there is a well functioning market for the assets which conveys the value of the assets in their next best use to their current owners. With systems of tradeable pollution permits, this condition is not necessarily fulfilled. Most of the systems of tradeable pollution permits implemented up till now have suffered from the defect of a thin and poor functioning market (see Atkinson & Tietenberg, 1991). In section 4 the consequences of imperfect permit markets for the occurrence of entry barriers will be examined. Furthermore, even though markets for pollution permits function well and firms do take the opportunity costs of their grandfathered permits into account, there still is a difference between incumbents and entrants: the incumbents do not have to raise the money necessary for buying the permits as the entrants have to. When capital markets are not perfect this might lead to entry barriers as is argued by predatory pricing and the "deep purse" theory. The relevance of predatory pricing and imperfectness of capital markets in the context of TDP’s is explored in the next chapter. Also in the next chapter the possibility of manipulating the permit market in order to raise rivals costs, a subject discussed by Misiolek and Elder (1989), is considered.

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\(^2\) See also Gilbert 1989, page 494.
3.4 TRANSACTION COSTS AND THE LIMIT PRICING MODEL

3.4.1 INTRODUCTION

The first use of tradeable pollution permits as an instrument to curb harmful emissions, the emission trading program of the US Environmental Protection Agency, did not live up to expectations with respect to the costs savings predicted. The main explanation for this shortfall is generally considered to be the weak market performance of the market for pollution rights. About 80 percent of the 'trades' have been within firms instead of between different firms. Several reasons can be mentioned for the poor performance of these permit markets. New firms which enter an area do not only have to acquire the necessary permits, they also have to conform to stricter limits on their emissions which restricts the possibility of trade. Another cause of the limited trade was the behaviour of some local authorities. In order to reduce emissions they confiscated part of the permits which firms had banked for future use or for selling. Such a behaviour does not provide an incentive to firms to reduce their emissions in order to be able to sell permits (Dwyer 1991). The transaction costs associated with trading could be high. In the South Coast Air Management District, the costs of finding a seller inclusive of the necessary engineering studies and of securing approval for the trade from the authorities have been estimated at between $15,000 - $30,000 per trade. For average trades amounting to about $200,000 - $300,000, this comes down to 10 - 30% of the total costs (Dwyer 1991, page 17). In the Bay Area District, transaction costs seem to have been of less importance. For one reason, brokers emerged who significantly lowered the costs of finding sellers and securing approval by the authorities. However, even with brokers firms still have to bear transaction costs, albeit lower than without brokers. Hahn & Hester (1989) report that the costs of hiring a consultant who aids in identifying possible sellers can be as high as several thousand dollars.

However, in more recent examples of tradeable emission permit schemes transaction costs appear to be lower. In the late seventies and early eighties, a lead trading program was established in the U.S. for phasing down the lead content in
petrol. At the close of the scheme, refineries were not allowed to use lead any more. In this program, there has been a large number of trades (about 20 percent of the total amount of lead permits have been traded between refineries) (Nussbaum 1991). The good performance of the permit market in this example can be explained by the large size of the market, the lack of regulatory constraints on trading and the low transaction costs: the refineries did not have to incur large search costs to find trading partners because the potential sellers or buyers were well known to each firm and because they already dealt with each other in other markets.

The last example of tradeable emission permit schemes is the CAAA sulphur trading program for electricity generating companies. This scheme has officially started in 1995 but trading started before that. The first experiences with this program indicate that transaction costs are small. Brokerage fees are around 5 percent (Klaassen and Nentjes 1995), which is considerably lower than those in the EPA tradeable permit scheme described above.

Given the occurrence of transaction costs on permit markets, it will be analyzed how transaction costs might influence entry. Following Stavins (1994), transaction costs are defined as a margin between the buying and the selling price of a commodity in a given market. Transaction costs consist of the search cost necessary for finding a party with which to conclude the deal and the costs of reaching and implementation of an agreement. Regardless of who pays the direct transaction costs (the buyer or the seller of the permits), the effect will be that the price received by the sellers of the permits falls while the price paid by the buyers increase³. In the remainder of this chapter, transaction costs are presented as an additional cost which increase the price which buyers have to pay, thereby creating the positive margin between the buyer’s and the seller’s permit price.

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3 The effect on the change in price depends on the relative elasticities. The more inelastic the abatement cost function is, the larger will be the effect upon the price for this firm. If abatement costs are inelastic a firm will accept higher transaction costs because abating more will be expensive. The firm which buys permits will have higher abatement costs. In general the higher abatement costs are, the less elastic is the abatement costs function. Consequently, the upward effect on the buyer’s price will be larger than the downward effect on the seller’s price (see Stavins 1994).
How will transaction costs affect the costs of incumbents and entrants? When permits are auctioned by the authorities to both incumbents and entrants, their costs increase with the price which they pay for the permits (plus transaction costs\(^4\)). In that case, costs between incumbents and entrants do not differ.

When permits are grandfathered to the established firms, two cases can be discerned. First, the incumbent firms do not buy more permits than they have received for free\(^5\). In that case, their cost function includes the opportunity costs of the permits. These opportunity costs are equal to the permit price minus the part of the transaction costs which the incumbent would have to bear if he would sell permits. The entrant would have to pay both the permit price and the buyer part of the transaction costs. The difference between their costs is therefore equal to the total transaction costs. The second possibility is that the established firm buys more permits than he has been grandfathered (because this is less expensive than reducing emissions). It will have to pay for its additional permits and incur the buyer part of the transaction costs.

A last point which has to be mentioned is that transaction costs can take two forms: they can be once and for all costs which firms must bear whenever they make a transaction, regardless of the amount of permits traded. In that case, the transaction costs are fixed costs. The other option is that the transaction costs are in some way related to the amount of permits traded and therefore are variable costs. For example, a firm which needs many permits might not be able to acquire them from only one seller, so he would have to look for more potential sources of permits and therefore his transaction costs would be higher. When firms employ brokers, this might also result in variable transaction costs when the broker’s charge is a percentage of the value of the transaction.

**Firm behaviour**

Having established the characteristics of transaction costs and their consequences for the cost functions of incumbents and entrants, the next step is to analyze the effect of transaction costs on entry barriers. Whether transaction costs impose entry barriers

\(^4\) Transaction costs are presumably small at the auction (the primary market).
\(^5\) This is the case when the number of grandfathered permits covers the need of the established firm, or when abatement is less expensive than buying additional permits.)
or not will not only depend on the form the transaction costs take, but also on the form of behaviour of both incumbent and entrant and on the existing market structure. In a perfect competitive product market, the cost difference caused by transaction costs between the established firms and potential entrants (in the case of grandfathering when incumbents do not buy additional permits) does not mean that the established firms will be able to enjoy a higher rent derived from their incumbency (see the definition of entry barriers on page 3). Because they operate on a perfectly competitive market, established firms cannot charge a higher price, even though they have a cost advantage vis-a-vis the entrants: increasing their price would mean that they would lose their market because of competition from the other established firms.

In the next section, the consequences of transaction costs, both fixed and variable, for entry barriers will be analyzed in the context of the limit pricing model in which there is one established firm. Two cases are distinguished. In the first case, it is assumed that the incumbent has been grandfathered all the permits he need. In the second case, the incumbent buys additional permits and therefore has to pay transaction costs as well.

3.4.2 FIXED TRANSACTION COSTS

One form of entry barrier which has received much attention in the literature is the possibility that the entrant is kept out of the market by limit pricing. This form of entry barrier, known in its original form as the Bain - Sylos-Labini - Modigliani limit pricing model, states that by producing a certain output, the limit quantity, a dominant firm or cartel might be able to prevent entry. The ability to forestall entry depends on the fact that production exhibits increasing returns to scale over at least some range. In the limit pricing model, the incumbent chooses the quantity he will produce first and the entrant subsequently chooses his own quantity, assuming that the incumbent will not change the quantity initially chosen. The equilibrium in this sequential game is usually
called the Stackelberg equilibrium after the author of the original article dealing with this kind of behaviour\(^6\).

An important point to stress is that the incumbent must have some means to commit himself to the quantity he has chosen in the first period of the firm. If there is no commitment, the incumbent could change the quantity he produces in reaction to the quantity chosen by the entrant in the second period. In that case, his profit maximizing behaviour would be the same as in the one-stage Cournot game. In the absence of commitment, the optimal strategy in the second-period subgame for the incumbent is to accommodate entry and act as a Cournot competitor. The threat to stick to the quantity produced in the first period is not credible; in game theory terminology, it is not a subgame perfect Nash equilibrium (see Gilbert 1989, page 487).

One form of commitment has been described by Spence (1977) and Dixit (1980). By investing in the first period in capacity, a firm commits itself when its investment costs are sunk. In that case, it can not recoup its investments costs by selling part of its investments and therefore it prefers to use the capacity already installed. This model will be analyzed in more detail below in the section on variable transaction costs and limit pricing. First, it will be shown how fixed transaction costs can influence the outcomes of the limit pricing model.

The consequences of fixed transaction costs for entry barriers in the limit pricing model are explained with the aid of a simple model (borrowed from Tirole 1992, p.314-317). In the next section, which deals with variable transaction costs, the issues introduced here are considered in a more general model. It is assumed that both the incumbent and the entrant have the same profit function:

\[
\pi^i(q^i,q^e) = q^i(1-q^i-q^e) - f \\
\pi^e(q^e,q^i) = q^e(1-q^i-q^e) - f
\]

In equations 3.1 and 3.2, profit is equal to revenue minus costs. Revenue is the quantity sold times the price (the inverse demand function is \(1-q^i-q^e\)). The total costs

\[^6\text{Actually, the Stackelberg equilibrium does not differ in concept from the Nash equilibrium because both are non-cooperative equilibria. The only difference is that the Stackelberg game is a two period game while the Nash-equilibrium is the result from a one period game.}\]
f are assumed to be fixed and equal. In this way the role of sunk costs is incorporated in the model.

The model assumes that the entrant in maximising his profits will consider the quantity of the incumbent as given and that the incumbent is informed about the entrant’s behaviour and maximizes his profits taking into account the expected reaction of the entrant. In the first stage of the game, the incumbent can commit himself to a quantity he will produce in the second stage, when the entrant enters (or not). For a given level of $q^i$, the entrant will maximise $\pi^e$ in the second stage with respect to $q^e$. This yields the reaction function of the entrant:

$$q^e = R^e(q^i) = \frac{1}{2}(1-q^i) \tag{3.3}$$

Substituting equation 3.3 in 3.1 gives the profit function of the incumbent as a function of $q^i$. Maximising this yields the Stackelberg equilibrium in which $q^i = 1/2$, $q^e = 1/4$, $\pi^i = 1/8 - f$, $\pi^e = 1/16 - f$.

The Stackelberg equilibrium might not necessarily be the optimal choice of output $q^i$ for the incumbent. He might be able to increase his profits by preventing entry completely. The entry barring level for $q^i$ (denoted $q^i_b$) is at the point where the entrant’s best response yields him a profit of zero. Substituting 3.3 in 3.2 and setting $\pi^e = 0$ yields $q^i_b = 1-2\sqrt{f}$. Deterring entry is attractive for the incumbent if with deterred entry the profit of the incumbent exceeds the profit in the Stackelberg equilibrium. Therefore, deterring entry is attractive when:

$$2\sqrt{f}(1-2\sqrt{f}) > 1/8 \tag{3.4}$$

When the Stackelberg game yields a higher profit than the entry barring game, entry is *accommodated* (in Bain’s terminology) while in the other case entry is *deterred*. Another possibility is that at the monopoly level of $q^i$ (which in this model is $q^i = 1/2$) the entrant will not be able to make a positive profit and therefore will not enter at all (termed *blockaded* entry by Bain).
Diagram 3.1 illustrates the case of entry accommodation. In the northeast quadrant, the x-axis gives the quantity produced by the incumbent, the y-axis gives his gross profits, the revenue. The southwest quadrant shows gross profit of the entrant (x-axis) as a function of the quantity he produces (y-axis). The reaction curve of the entrant is shown in the southeast quadrant. First consider the incumbent. The curve titled 'π^1 monopoly' is the gross profit earned by the incumbent when there is no entrant, i.e. when he is a monopolist. His fixed costs are shown by the line titled f, net profit equals gross profit minus fixed costs f. Profit is maximised at q^1 (in the model used here at q^1 = ½). The curve titled 'π^1 accommodation' shows the profit when the entrant is also on the market. Profit is maximised when the entrant is accommodated at q^1, the Stackelberg equilibrium.

The gross profit earned by the entrant is given by pq_e in the southwest quadrant. Given fixed costs of f for the entrant, the incumbent will accommodate the entrant, produce q^1 and make a gross profit of D. Deterring entry is not attractive; he must
produce $q^i_3$ to keep the entrant out; at this point the entrant will produce $q^e_1$ as we can see from the reaction curve in the southeast quadrant. At $q^e_1$ profit of the entrant is zero: gross profit equals fixed costs. Deterring entry by producing $q^i_3$ is less attractive for the incumbent than accommodating entry because his gross profit $C$ on the monopoly curve is lower than $D$.

The occurrence of fixed transaction costs on the permit market will affect the profit of the entrant by increasing his fixed costs $f$ with $T$, the transaction costs:

$$\pi^e = q^e(1-q^e-q^i) - f - T$$  \hspace{1cm} 3.5

This will increase the probability that entry deterrence is more attractive than accommodation because the entry deterring level of $q^i$ decreases:

$$q^i_b = 1-2\sqrt{f+T}$$  \hspace{1cm} 3.6

This is illustrated in diagram 3.1. The transaction costs shift the fixed cost curve of the entrant leftward to line $f+T$. Consequently the entrant’s net profit is zero at level $q^e_2$. The corresponding (entry deterring) level of $q^i$, as determined by the reaction function, is $q^i_2$, which is lower than $q^i_3$. At this level of $q^i$ the gross profit which the incumbent will make is $B$ on the monopoly profit curve. This entry deterring profit is higher than the profit earned when entry is accommodated, $D$. Entry deterrence can become more attractive than accommodation for the incumbent when the introduction of tradeable permits raises the entrant’s costs with fixed transaction costs.\(^7\)

Above, it was assumed that the incumbent does not have transaction costs. However, the situation changes when the incumbent also buys permits and therefore also has to bear transaction costs. Consequently, his profit level will fall. The

\(^7\) It should be noted that if the transaction costs are high enough entry will be blockaded: this is the case if the entry deterring level of $q^i$ is equal to or lower than $\frac{1}{2}$, the monopoly output level of $q^i$. In that case, the incumbent produces the monopoly quantity $q^i=\frac{1}{2}$ and entry is blockaded because at that level the entrant’s profit is negative.
optimality conditions of the Stackelberg game are not affected when transaction costs are fixed, but his profits will fall at the level of \( q^i \) at which he will start to buy permits, that is at the level corresponding with the amount of permits he got through grandfathering. His profit function becomes:

\[
\pi^i = q^i(1-q^i-q^e) - f \quad q^i \leq G
\]

\[
\pi^i = q^i(1-q^i-q^e) - f - T \quad q^i > G
\]

in which \( G \) is the quantity \( q^i \) produced by the incumbent just covered by grandfathered permits. At higher levels, he has to buy permits and pay transaction costs\(^8\). The consequence is that entry deterrence might not be attractive any more. This can be the case when \( G \) is larger than \( q^i = 1/2 \) (the Stackelberg equilibrium) and when \( G \) is lower than the entry barring level \( q^b \). In this case, the profit the incumbent makes when he deters entry is lower by the transaction costs \( T \) while the profit level he makes when entry is accommodated remains \( 1/8 - f \). Consequently, the profit he makes when he accommodates entry \( (1/8-f) \) might be higher than the profit under entry deterrence with transaction costs for the entrant, even though the incumbent can deter entry at a lower level of \( q^i \).\(^9\) This is illustrated in diagram 3.2. Whith tradeable permits and fixed transaction costs on the permit market, the entrant’s fixed cost curve shifts leftwards to line \( f+T \) the entry deterrence quantity is as has been explained in the former section. If the number of permits grandfathered is equal to \( q_G \), the incumbent will also have to buy permits if he produces more than \( q_G \). Therefore, his fixed costs increase beyond this production level with \( T \) to line \( f+T \). Net entry deterrence profits decreases from \( BB' \) to \( BB'' \). Because \( q_G \) is higher than \( q_i \), the profit which the incumbent makes when he accommodates entry, \( CC' \), does not change

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\(^8\) For the moment, abatement is not included in the analysis. In the next section, it will be included.

\(^9\) In the specific model presented here, entry deterrence remains attractive. However, this is a specific model, in a more general model this is not necessarily the case.
because he does not have to buy additional permits. BB'' is less than CC', therefore accommodation is preferred over deterrence.

Diagram 3.2 Fixed transaction costs for both entrant and incumbent

When the incumbent also has to buy permits in the Stackelberg equilibrium, that is when $G$ is lower than $q_1 = \frac{1}{2}$ his profit in the Stackelberg equilibrium is $\frac{1}{8} - f - T$. The necessary condition for entry deterrence for the incumbent (equation 3.4) is:

$$\pi^i_b(q^i_b, 0) = 2\sqrt{(f + T)[1-2\sqrt{(f + T)}]} - f - T > \frac{1}{8} - f - T \quad 3.9$$

Because the transaction costs occur in both the deterrence profit (left side of the inequality) and in the accommodating profit (right side of the inequality), there is no difference with the case where only the entrant had to bear transaction costs. Deterrence becomes more attractive when there are fixed transaction costs in a system of tradeable permits, both in the situation where only the entrant faces transaction costs as in the case where both entrant and incumbent have to bear transaction costs.
If instead of grandfathering the incumbent would have to buy all his permits and therefore pay transaction costs, the same situation would apply. The existence of fixed transaction costs would make entry deterrence more attractive\textsuperscript{10}.

The conclusion from this section is that if only the entrant has to bear transaction costs, the probability that entry will be deterred or blockaded increases cet. par. This impact is moderated in so far as grandfathered permits do not fully cover production of the incumbent. In that case the incumbent might have to make fixed transaction costs as well when he deters entry.

3.4.3 VARIABLE TRANSACTION COSTS

In this section, a more general model will be used to analyze the consequences of variable transaction costs of tradeable permits for entry barriers in the limit pricing model. First, variable transaction costs will be introduced graphically with an adapted version of the simple model used in the former section on fixed transaction costs. Subsequently the more general model is used to analyse accommodation of the entrant by the incumbent.

Graphical illustration of variable transaction costs
In the model of the former section, variable transaction costs can be represented in the entrant’s profit function, where $t$ is the (constant) transaction costs per unit of output:

\[
\pi^e = q^e(1-q^e-q^i) - f - t q^e \tag{3.10}
\]

His reaction function is:

\[
q^e = R^e(q^i) = (1-q^i-t)/2 \tag{3.11}
\]

\textsuperscript{10} Transaction costs on the primary market (the auction) are presumably smaller (see note 4) than on the secondary market and therefore entry barriers will be affected to a lesser degree.
The incumbent’s profit function is (equation 3.1):

\[ \pi_i = q^i(1-q^i-q^e) - f \]  \hspace{1cm} 3.12

Substituting \( q^e \) from equation 3.11 yields:

\[ \pi_i = \frac{1}{2} q^i(t+1-q^i) - f \]  \hspace{1cm} 3.13

Diagram 3.3 shows the effect of variable transaction costs for the entrant. Curves \( \pi_i \) monopoly, \( \pi_i'a \), \( \pi_i'a' \), \( R^e \) and \( \pi_e \) present the situation without transaction costs (the \( \pi_i \) curves represent gross profit). Transaction costs shift the reaction curve of the entrant \( R^e \) to \( R^{e'} \). In the southwest quadrant transaction costs have been added to the (fixed) production costs, curve \( f+t \). As a result the level of \( q^e \) at which the entrant’s profit is zero increases from \( q^e_1 \) to \( q^e_2 \). The entry deterring level of \( q^i \), the level of \( q^i \) at which the entrant’s profit is zero, decreases from \( q^i_1 \) to \( q^i_2 \). The profit which the incumbent will make when he deters entry increases from \( A \) to \( B \). Therefore entry deterrence becomes more profitable for the incumbent. At the same time, the transaction costs increase the profit earned by the incumbent when he accommodates the entrant: his profit curve shifts upward from \( \pi_i'a \) to \( \pi_i'a' \) and profit under accommodation shifts from \( C \) to \( D \). Consequently, accommodation also becomes more profitable. Which effect dominates depends on the values of \( f \) and \( t \).

It should also be noted that in case accommodation is the most profitable strategy for the incumbent the impact of variable transaction cost is to raise the quantity produced by the incumbent (from \( q^i_3 \) to \( q^i_4 \)) and raise his profits compared to a situation without transaction costs, where as the equilibrium quantity and profits of the entrant will fall. This differs from the result which was derived for fixed transaction costs\(^{11} \).

\(^{11} \) It should be noted that in diagram 3.3 the profit curves for accommodation, \( \pi_i'a \) and \( \pi_i'a' \), are not defined beyond the point at which \( q^e<0 \). Beyond this point the incumbent enjoys a monopoly profit, curve \( \pi_i' \)monopoly.
The limit pricing model

The more general model used is based on the extension of the limit-pricing model of Bain-Sylos and Spence by Dixit in his seminal article "The Role of Investment in Entry Deterrence", 1980. The strategies of the incumbent and the entrant are comparable to those in the former section on fixed transaction costs. The main difference is that in the first period the incumbent chooses the optimal level of a strategic variable, taking into account the effect on the behaviour of the entrant in the second period. In the simple model discussed above, the incumbent chooses the quantity he will produce in the second period instead of the level of a strategic variable. In the second period, the incumbent and the entrant compete as Cournot quantity competitors (if the entrant enters at all). The profit function of the incumbent is:

\[ \pi^i = R^i(q^i, q^e) - C^i(q^i, K^i) \]  

3.14
R\(^i\) is the revenue raised by the incumbent. It is increasing and concave in q\(^i\). Total and marginal revenue will decrease when the entrant increases q\(^e\). C\(^i\) is increasing in q\(^i\) and convex. K\(^i\) is the strategic variable which the incumbent chooses in the first period. K\(^i\) can be interpreted as capacity. For a given output q\(^i\), there is an optimal level of K\(^i\) which minimises costs, C\(^i\) is convex in K\(^i\) as well. The marginal costs of output decrease when K\(^i\) rises:

\[
C_{qiKi} < 0
\]

This reflects the fact that investing in K\(^i\) in the first period lowers marginal costs in the second period because the costs of capacity K\(^i\) is sunk. The potential entrant has profit function:

\[
\pi^e = R^e(q^i,q^e) - C^e(q^e,M)
\]

His revenue function has the same properties as the revenue function of the incumbent. C\(^e\) is increasing in q\(^e\) and convex. C\(_{M}^e > 0\) and C\(_{qM}^e > 0\); an increase in M increases marginal costs. M reflects the introduction of the system of tradeable emission permits when transaction costs are variable. The entrant has to buy permits, therefore he has to pay transaction costs. This will increase his marginal costs because the transaction costs are variable. They will rise with the level of the transaction costs. \(^{12}\) M is an exogenously determined variable which will be used to analyze the effect of a change in the marginal costs of the entrant on the equilibrium and the conditions for entry deterring.

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12 Apart from the rise in marginal costs due to the occurrence of transaction costs in the permit market, the marginal costs of both firms will also rise with the price of the permits and with pollution control costs. In order to focus on the strategic effect of the difference between the incumbent and the entrant with regard to the transaction costs, the rise in the marginal costs due to the price of the permits will be ignored. When other instruments like taxes are used, this rise in marginal costs will occur as well and the consequences for entry which result from this rise in marginal costs are therefore not unique to the system of tradeable permits with transaction costs occurring in the permit market.
The Stackelberg equilibrium of the two-stage game is illustrated in diagram 3.4. The x-axis gives the quantity of $q^i$ produced by the incumbent, the y-axis the quantity of $q^e$ produced by the entrant. $R^e$ is the reaction curve of the entrant.

$I_1$ and $I_2$ are isoprofit curves for the incumbent. An isoprofit curve represents a given level of profit that can be obtained with different combinations of $q^i$ and $q^e$ (and setting $K^i$ simultaneously at such a level that profits are maximised). The closer the isoprofit curve is to the $q^i$-axis the higher is the incumbent’s profit. In the first period, the incumbent maximises his profits by choosing $K^i$ and $q^i$, taking into account the reaction curve of the entrant. The highest attainable profit is presented by point A. At this point, the isoprofit curve $I_2$ is tangent to the entrant’s reaction curve.

$R^i$ is the reaction curve of the incumbent in the second stage of the game when $K^i$ is fixed. Acting as a Cournot competitor the incumbent takes the quantity of the entrant $q^e$ as given and adjusts $q^i$. The equilibrium in the second stage (and assuming entry) is at the intersection of the reaction curves of entrant and incumbent.

We can proceed to analyze the consequences of introducing tradeable emission permits with variable transaction costs on the permit market. Variable transaction costs will increase the marginal costs of the entrant, represented by a positive change in $M$ in equation 3.16, shifting his reaction curve downward. The impact of a change in $M$ is illustrated in diagram 3.5. The initial equilibrium (before introduction of the tradeable permits) is point A. At this point, the incumbent’s initial profit is maximised: isoprofit curve $I_1$ is tangent to $R^e_1$. When $K^i$ is fixed, the downward shift from $R^e_1$ to $R^e_2$ results in a new equilibrium (point B) which lies on an isoprofit curve which
represents a higher profit. The incumbent produces more and the entrant produces less.

When a new level of $K^i$ can be chosen the Nash equilibrium will shift to point C where the lowest possible isoprotit curve is tangent to $R^e_2$, isoprotit curve $I_3$. The optimal level of $K^i$ is the level which yields reaction curve $R^i_2$ in the second period subgame. Consequently, the increase in the entrant's marginal costs caused by the variable transaction costs on the permit market will change the optimal level of the strategic investment chosen by the incumbent in the first-period.

The reaction function of the entrant (in the second-period subgame) can be determined by maximising $\pi^e$ assuming that $q^i$ (and $M$) is given. The first-order condition is:

$$R^e_{qe} - C^e_{qe} = 0$$

The second-order condition is:

$$R^e_{qee} - C^e_{qee} < 0$$

Total differentiation of 3.17 gives:
In equation 3.19 \( R_{qe}^{eq} < 0 \) and \( C_{eM}^{eq} > 0 \). The first term in equation 3.19 is negative, therefore the reaction curve of the entrant, with slope \( dq_e/dq_i \), is downward sloping. It is assumed that the Nash-equilibrium of the second-period subgame has an interior solution and that it is unique\(^{13}\). The second term on the right hand side of equation 3.19 is also negative. An increase in the marginal costs of the entrant will shift its reaction curve downward as was shown in diagram 3.5.

The reaction curve of the incumbent in the second period, *given the level of \( K^i \) chosen in the first period*, can be determined in the same way as the reaction function of the entrant. The first-order condition is:

\[
R_i^i - C_i^i = 0 \quad 3.20
\]

Totally differentiating (3.20) gives:

\[
[R_{qi}^{i} - C_{qi}^{i}] \ dq^i = -R_{qie}^{i} dq_e + C_{qiK}^{i} dK^i \quad 3.21
\]

dq^i/dq_e is negative, therefore the reaction curve of the incumbent is also downward sloping.

The incumbent can influence the second-period equilibrium determined by the intersection of the reaction curves by choosing the level of \( K^i \) in the first period (see diagram 3.4 and 3.5). The choice of \( K^i \) in the first period affects the reaction curve of

\[^{13}\text{Uniqueness requires that the absolute value of the slope of the reaction curve is smaller than 1. Let } r^j \text{ be the reaction function of firm } j:\]

\[
|r^j| = \left| \frac{\pi^j_{qj}}{\pi^j_{qi}} \right| < 1 \implies |\pi^j_{qi}| > |\pi^j_{qj}| \implies |R_{qiK}^{j}C_{qiK}^{j} | > |R_{qij}^{j}C_{qij}^{j} |.
\]

The absolute value of a change in marginal profit due to a change in its own quantity produced must exceed the change in its marginal profit when the quantity produced by the other firm changes, which is a plausible assumption.
the incumbent and thereby the equilibrium levels of q^i and q^e in the second period. The profit of the incumbent (equation 3.14) in this two-stage game is:

\[ \pi_i(q^i(K^i), q^e(K^i), K^i) = R_i(q^i(K^i), q^e(K^i)) - C_i(q^i(K^i), K^i) \]  

3.22

in which q^i and q^e are the equilibrium levels of q^i and q^e in the second-period game. q^i and q^e are a function of K^i which is chosen in the first period. The optimal level of K^i which maximises profit is found by differentiating 3.22 with respect to K^i and setting it equal to zero:

\[ \frac{d\pi_i}{dq_i} dq_i^* / dK_i + \frac{d\pi_i}{dq_e} dq_e^* / dK_i + \frac{d\pi_i}{dK_i} = 0 \]  

3.23

This can be written as:

\[ \frac{d\pi_i}{dK_i} = (R_i - C_i) \frac{dq_i^*}{dK_i} + R_i \frac{dq_e^*}{dK_i} = 0 \]  

3.24

The effect of a change in K^i on q^i* and q^e* (dq_i^*/dK_i and dq_e^*/dK_i) can be determined by differentiating the first-order conditions of the second-period equilibrium (equations 3.17 and 3.18) with respect to K^i. Totally differentiating these first-order conditions with respect to K^i (and M) yields equations 3.19 and 3.21, in which dq^i and dq^e are written as functions of dK^i (and dM). In matrix format this yields:

\[
\begin{bmatrix}
R_{q,q}^i - C_{q,q}^i & R_{q,q}^e \\
R_{q,q}^e & R_{q,q}^e - C_{q,q}^e
\end{bmatrix}
\begin{bmatrix}
dq_i^* \\
dq_e^*
\end{bmatrix}
= 
\begin{bmatrix}
C_{q,k}^i dK_i \\
C_{q,M}^e d\bar{M}
\end{bmatrix}
\]  

3.25

Let \( \Delta \) be the determinant of the coefficient matrix\(^{14} \). \( \Delta \) must be positive for the equilibrium to be stable. Solving dq^e from 3.25 and substituting it in 3.24 yields (in the Nash-equilibrium of the second-period subgame, \( \delta\pi/\delta q^i = 0 \), therefore dq^i does not enter into the equation (the envelope-theorem)):

\[ 3.26 \]

\(^{14} \) \( \Delta = (R_{q,q}^i - C_{q,q}^i)(R_{q,q}^e - C_{q,q}^e) - R_{q,q}^e R_{q,q}^i \)
$$d\pi^i = -( \frac{R^i_{q'q} C^i_{q'E}}{\Delta} + C^i_{K'} ) \cdot dK^i + ( \frac{R^i_{q'q} (R^i_{q'q} - C^i_{q'q}) C^e_{q'EM}}{\Delta} ) \cdot dM$$

The optimal level of $K^i$ is at the point where the incumbent’s profit in the Stackelberg game is maximised, point A in diagram 1. Profit is maximised when $d\pi^i/dK^i = 0$ in equation 3.26 (in equation 3.24 profit is maximised when $d\pi^i/dK^i = 0$; 3.24 has been rewritten as 3.26 therefore in 3.26 $d\pi^i/dK^i$ must be zero).

Subsequently we will analyse the consequences of an increase in the entrant’s marginal costs caused by the transaction costs of tradeable permits. In our model this is represented by an increase in $M$ which shifts the reaction curve of the entrant downward, see diagram 3.5. First consider the consequences for the second-period Nash-equilibrium. The consequences of a change in $M$ on the levels of $q^*$ and $q^e*$ in this second-period equilibrium are determined in the same manner as the effect of a change in $K$ on the second-period equilibrium levels of $q^*$ and $q^e*$. Differentiating the the first-order conditions of the second-period equilibrium with respect to $M$ has been done in equation 3.25. Writing out the effect of a change in $M$ on $q^*$ and $q^e*$ yields:

$$dq^* = R^i_{q'q} C^e_{qeM} / \Delta \cdot dM > 0 \quad 3.27$$

$$dq^e* = (R^i_{q'q} - C^i_{q'i}) C^e_{qeM} / \Delta \cdot dM < 0 \quad 3.28$$

The increase in the entrant’s costs caused by the transaction costs ($dM$) increases the quantity produced by the incumbent and decreases the quantity produced by the entrant. This is represented by the shift from A to B in diagram 3.5. As a result of these changes in $dq^*$ and $dq^e*$ the profit of the incumbent increases because in equation 3.26 $d\pi^i/dM$ is positive: in the numerator $R^i_{q'q}$ is negative, $(R^i_{q'q} - C^i_{q'i})$ is negative and $C^e_{qeM}$ is positive therefore the numerator is positive. The denominator $\Delta$ is positive as well.

The change in $M$ will not only affect the second-period equilibrium but also the optimal choice of $K^i$ in the first period. In diagram 3.5 this is shown by a shift in the incumbent’s reaction curve which shifts the equilibrium from B to C. The optimal level
of $K^i$ is determined by maximising the incumbent’s profit, equation 3.24. Rewriting 3.24 yielded 3.26, therefore $K^i$ is chosen such that $d\pi/dK^i$ in equation 3.26 is zero:

$$\frac{d\pi^i}{dK^i} = G = -\left( \frac{R^i_q R^e_{q^e} C_{q^e q^i}^i}{\Delta} + C_{K^i q^i}^i \right) = 0 \quad 3.29$$

The increase in $M$ will affect condition 3.29: the second-period equilibrium has changed because of the change in $M$ and the level of $K$ which was chosen before $M$ changed might not be optimal anymore. The increase in $M$ affects the optimality condition through the effect which it has on $q^i^*$ and $q^e^*$: $q^i^*$ increases and $q^e^*$ decreases. The new second-period equilibrium levels of $q^i$ and $q^e$ influence the values of the terms in equation 3.29 and therefore $d\pi/dK^i$ might not be optimal anymore, given the value of $K^i$ chosen before the entrant’s costs increased. We can determine the effect of the change in $M$ on this optimality condition by differentiating 3.29 with respect to $dM$, holding $K^i$ fixed:

$$dG/dM = dG/dq^i^* dq^i^*/dM + dG/dq^e^* dq^e^*/dM \quad 3.30$$

This yields (assuming that third-order derivatives are zero):

$$(R^i_{q^i q^e} R^e_{qq} C_{q^i q^i K^i} / \Delta + C_{K^i q^i}^i ) dq^i \quad 3.31$$

All terms are negative except $\Delta$ which is positive. Therefore the increase in $q^i$ caused by the increase in $M$ decreases the coefficient of $d\pi/dK^i$. Consequently $d\pi/dK^i$ becomes negative, given the level of $K^i$ chosen when the entrant did not have transaction costs. In other words the level of $K^i$ is not optimal any more: the incumbent must change $K^i$ to maximise profits. Increasing $K^i$ increases $C_{K^i q^i}$ in (3.29), which counters the negative effect of the change in $M$. The incumbent will therefore increase the level of his strategic investment in $K^i$ in the first period when tradeable emission permits are introduced and the entrant has to bear transaction costs. The higher level of $K^i$ increases the second-period level of $q^i$ and decreases the second-level of $q^e$ as can be seen from equation 3.25:
\[ dq^i = (R^e_{q eqe} - C^e_{q eqe}) C^i_{q Ki} / \Delta \quad dK^i > 0 \quad 3.32 \]

\[ dq^e = - R^e_{q eqi} C^i_{q Ki} / \Delta \quad dK^i < 0 \quad 3.33 \]

This is shown in diagram 3.5 by the shift from B to C which results from the shift in the reaction curve caused by the higher level of \( K_i \): \( q_i \) increases and \( q_e \) decreases. Profit is further increased because at the initial level of \( K_i \) profit was not maximised.

The conclusion is that a rise in (marginal) costs, which the entrant has to face because he has to bear the transaction costs arising from the imperfect permit market, has a direct and an indirect effect on the accommodating equilibrium. The direct effect is a downward shift in the entrant’s reaction curve. The entrant enters at a smaller size and the incumbent increases his production and his profits. This is the same result as was derived in the more specific model with variable transaction costs on page 48). The indirect effect is that the incumbent will increase his first-period strategic investment \( K_i \), which further increases production and profit of the incumbent. The change in production of the incumbent and the entrant differs from the result which was derived for fixed transaction costs under accommodation (see the former section). In that case, the quantities produced by the incumbent and the entrant did not change as long as the incumbent continued to accommodate the entrant after introduction of the permit scheme.

**Transaction costs for the incumbent**

A striking feature of tradeable permits and entry barriers in the limit pricing model is that it does not make a difference in the entry accommodation case whether the incumbent has received all the permits he needs through grandfathering in the first period or through auction. When the incumbent has to buy permits in the first period he has to pay the permit price plus the transaction costs. Selling them in the second period will only yield the permit price, the transaction costs can not be recouped, they are sunk. Consequently, the opportunity costs of using the permits in the second period are equal to their price only, not to the full price plus transaction costs paid for them.
in the first period. Let $G$ represent the permits grandfathered in the first period, $E$ the permits acquired in the first period and $E(q^i)$ the permits used (and therefore acquired) for emissions in the second period. $P_p$ is the permit price and $t$ are the variable transaction costs per unit of emissions bought. Writing out the cost function of the incumbent in the second period yields\footnote{It is assumed here for the moment that abatement is less attractive than buying permits.}:

\begin{align*}
C^i(q^i,K^i) + P_p (E(q^i) - G) + P_p G & \quad E(q^i) < E, \quad E \leq G & 3.34 \\
C^i(q^i,K^i) + P_p (E(q^i) - G) + P_p G + t(E - G) & \quad E(q^i) < E, \quad E > G & 3.35 \\
C^i(q^i,K^i) + P_p (E(q^i) - G) + P_p G + t(E(q^i) - E) + t(E - G) & \quad E(q^i) \geq E & 3.36
\end{align*}

If the incumbent has received all the permits he uses in the second period through grandfathering in the first period, he has no transaction costs because he does not buy any permits: equation 3.34. If he buys more permits in the first period than he receives for free, he pays transaction costs for the number of permits he buys, $t(E - G)$, equation 3.35. He cannot recoup these costs, therefore they are sunk. He can sell the permits he has acquired in the first period for their price $P_p$, therefore he has to take into account their opportunity costs. When the incumbent has to buy additional permits in the second period, transaction costs increase with the number of additional permits he has to buy: equation 3.36.

Marginal costs in these three situations are:

\begin{align*}
C^i_{q_i} + P_p E_{q_i} & \quad E(q^i) < E, \quad E \leq G & 3.37 \\
C^i_{q_i} + P_p E_{q_i} & \quad E(q^i) < E, \quad E > G & 3.38 \\
C^i_{q_i} + P_p E_{q_i} + t E_{q_i} & \quad E(q^i) \geq E & 3.39
\end{align*}
As long as the incumbent has acquired the permits he needs in the first period, the variable transaction costs do not enter his marginal cost function in the second period, regardless whether he has acquired them through grandfathering or buying. Consequently, the Stackelberg equilibrium of the game presented above does not change whether or not the incumbent buys permits and incurs transaction costs in the first period. The conclusion that variable transaction costs on the permit market can raise the entry barrier in the Stackelberg game is therefore independent of the choice between grandfathering permits to the incumbent or auctioning to all firms, both entrants and incumbents.

However, it should be noted that the transaction costs made by the incumbent, \( t(E(q^i) - G) \), do influence the profit made by the incumbent in the second period: both the accommodation profit and the profit made when entry is deterred will change. This will influence the choice between entry deterrence and entry accommodation. The reader is referred to the former section on fixed transaction costs for a more detailed discussion.

**Strategic investment in permits**

It has been discussed how variable transaction costs in the permit market can change the conditions under which incumbents can deter entry and how they change the conditions of entry accommodation when incumbents can commit themselves to output levels in the second period by investing in the first period. The strategic investment in the model discussed above was capacity which can not be sold without considerable losses and therefore creates sunk costs. An interesting feature of tradeable emission permits with variable transaction costs is that investing in the permits themselves can act as a strategic investment because, as has been explained above, the transaction costs cannot be recouped in the second period and therefore are sunk.

The consequences for entry can be shown using a version of the Dixit model presented above. Let \( R^i \) again be the revenue of the incumbent. \( R \) is a function of \( q^i \) and \( q^e \) (\( R^i \) is increasing and concave in \( q^i \) and decreasing and concave in \( q^e \)). Production costs excluding permit costs are increasing in \( q^i \) and convex. For the moment it is assumed that acquiring permits is less expensive than abatement. Therefore in addition to the production costs the incumbent has to buy permits if the
number of permits grandfathered is not sufficient. Permit costs equal emissions (which are a function of the quantity produced) times their price \( P_e \). The profit function of the incumbent in the second period is:

\[
\pi^i = R^i(q^i, q^c) - C^i(q^i) - P_e \cdot E(q^i) - t(E-G) \quad E(q^i) \leq E \\
\pi^i = R^i(q^i, q^c) - C^i(q^i) - P_e \cdot E(q^i) - t(E(q^i)-G) \quad E(q^i) > E
\]

As long as the emissions resulting from the quantity produced in the second period are less than the number of permits acquired in the first period, \( E \), (either by grandfathering or buying), profit is determined by 3.40. When the incumbent produces and emits more, he has to buy permits and his profits equal 3.41. Marginal costs are:

\[
C_{qi}^i + P_e \cdot E_{qi} \quad E(q^i) \leq E \\
C_{qi}^i + (P_e + t) \cdot E_{qi} \quad E(q^i) > E
\]

The entrant’s profit function is:

\[
\pi^e = R^e(q^e, q^i) - C^e(q^e) - (P_e + t) \cdot E(q^e)
\]

The second-period Nash-Cournot equilibrium will depend on the number of permits the incumbent has acquired in the first period. As long as the emissions resulting from the output produced by the incumbent are lower than the number of permits acquired, his marginal costs are given by 3.42. If he has to buy additional permits, his marginal costs will be higher as shown by 3.43. This also has
consequences for his reaction curves. This is shown in diagram 3.6 (adopted from Dixit 1980). The reaction curve MM’ is the reaction curve of the incumbent when he buys the permits he needs in the second period. Curve NN’ is the reaction curve for the case where no additional permits have to be bought and therefore marginal costs are lower. The reaction curve of the entrant is curve RR’. T is the Nash-equilibrium when transaction costs matter for the incumbent, V when they do not. These two equilibria can be considered the extremes of the range of equilibria which the incumbent can achieve by choosing the number of permits he buys in the first period. For example, let the number of permits acquired by the incumbent in the first period be sufficient for the production of Q in diagram 3.6. For \( q^i \leq Q \), the incumbent’s reaction curve is curve NN’. When the incumbent produces more than Q, he has to buy permits and incur the transaction costs. His reaction curve shifts to MM’ for \( q^i \geq Q \). The Nash-equilibrium in this case is W, the point where the entrant’s reaction curve intersects the reaction curve of the incumbent (the dotted line). The incumbent can act as a Stackelberg leader and choose the optimal output level, provided that it falls within the range set by the Nash-equilibria for the two extremes T and V.

Following the analysis presented above (see the former section on fixed transaction costs) and Dixit 1980, page 100-101, several cases can be discerned.

1] At T the profit of the entrant is negative. For \( Q \geq Q_T \), the entrant can never make a positive profit and the incumbent is a monopolist.

2] At V the entrant’s profit is positive. In this case the incumbent will accommodate the entrant and act as a Stackelberg leader, choosing the number of permits with correspond to the quantity and equilibrium which maximise his profits, e.g. Q and W in diagram 3.6.

---

16 The reaction curve shifts leftward when marginal costs increase (e.g. because of the transaction costs), see page 2. A simple model illustrates the leftward shift. Let the incumbent’s profit be:

\[ \pi = q^i(1-q^i-q^e) - t q^i \]

Differentiating this profit function with respect to \( q^i \) yields the reaction function for the incumbent:

\[ q^i = \frac{1}{2}(1-q^e-t) \]

Let t be initially zero (no transaction costs). For a given level of \( q^e \), transaction costs will reduce the optimal quantity of \( q^i \): a leftward shift of the reaction curve.
3] At T the entrant makes a positive profit while at V his profit is zero. This means that there is a point between T and V at which the entrants’ profit is zero. Consequently the incumbent can deter entry by choosing the number of permits such that this equilibrium occurs. He will choose entry deterrence when this yields a higher profit than accommododation.

\textit{Abatement efficiency}

A point of interest is whether strategic investment in tradeable emission permits would affect abatement cost efficiency. In order to explore this, the model of the former section is extended to include abatement. The abatement cost function is \( A(E(q^i)) \), with \( A_E > 0 \). The total cost function of the incumbent in the second period is\(^{17}\):

\[
\begin{align*}
C_i(q_i) + P_p E(q_i) + A_E E(q_i) + tE & \quad \text{for } E(q_i) \leq E \\
C_i(q_i) + P_p E(q_i) + A(E(q_i)) + t(E(q_i) - E) + tE & \quad \text{for } E(q_i) > E
\end{align*}
\]

For emissions below the number of permits bought in the first period (\( E \)), transaction costs are sunk. When emissions rise above \( E \) the incumbent has to take the transaction costs \textit{if} he buys more permits. Marginal costs are:

\[
\begin{align*}
C_i(q_i) + P_p E(q_i) + A_E E(q_i) & = 0 & \quad \text{for } E(q_i) \leq E \\
C_i(q_i) + (P_p + t)E(q_i) + A_E E(q_i) & = 0 & \quad \text{for } E(q_i) > E
\end{align*}
\]

Abatement costs are minimised when the permit price equals marginal abatement costs, \( P_p + A_E = 0 \), for \( E(q_i) \leq E \). For emissions above \( E \), the optimal level of abatement is at the point where marginal abatement costs equal price plus transaction costs, \( P_p + A_E + t = 0 \).

The higher the quantity produced in the second period, the higher are emissions. At a certain point, it will be optimal for the incumbent to use all the permits acquired

\[\begin{align*}
\textit{17} & \quad \text{For the sake of clarity of the exposition, grandfathering is left out. Including grandfathering would not change the fundamental analysis and conclusions.}
\end{align*}\]
in the first period (E). This point is denoted \( q_i^* \). If production increases further, the incumbent has the choice of either buying more permits and incurring transaction costs or abating more. Buying new permits is only attractive if marginal abatement costs equal the price of the permits plus the transaction costs, equation 3.48. Marginal abatement costs will therefore rise when production increases beyond \( q_i^* \), the point where all previously acquired permits are used efficiently. This is illustrated in diagram 3.7. The x-axis shows the quantity of \( q \) produced, the y-axis shows marginal abatement costs. At \( q_i^* \), abatement costs start rising, up till they are equal to \( P_p + t \). It should be noted that marginal abatement costs do not rise directly to \( P_p + t \) at \( q_i^* \).

At \( q_i^* \), marginal abatement costs equal \( P_p \), the permit price. Increasing production beyond \( q_i^* \) increases emissions. The incumbent can either buy more permits, at costs \( P_p + t \), or abate more. Increasing abatement will be cheaper (assuming that abatement costs are a continuous function of emissions \( E(q_i^*) \)) because the incumbent can abate at marginal costs lower than \( P_p + t \). At some point marginal abatement costs will have risen to \( P_p + t \): at that point it is more efficient for the incumbent to acquire more permits and paying the transaction costs instead of abating more himself.

Given a certain number of permits bought in the first period, the reaction function of the incumbent will change given the increase in marginal abatement costs for \( q_i > q_i^* \). This is shown in diagram 3.8. Instead of jumping from reaction curve NN' to reaction curve MM' when \( q \) rises above \( q_i^* \), marginal production costs increase with \( q \). The new reaction curve is shown by the striped line which slopes towards the MM' line. Equilibrium is at W.

For the entrant, abatement does not really change the case. He will abate up to the point where marginal abatement costs equal the permit price plus transaction costs.
Including abatement does not affect the conclusions concerning entry barriers and tradeable permits in the limit pricing model. The incumbent can still choose the optimal point in the Stackelberg game by investing in permits in the first period.

Abatement costs efficiency is not affected either. Total abatement costs will be minimised, even though marginal abatement costs of the incumbent can range between the permit price and the permit price cum transaction costs. For emissions up to the point where all permits acquired in the first period are used, the incumbent will equate marginal abatement costs with the permit price. Subsequently, he will increase abatement up to the point where buying more permits and paying in addition the variable transaction costs is less expensive.

Conclusions

In this section on variable transaction costs it has been analyzed how variable transaction costs of buying pollution permits will influence the consequences for entry barriers in the limit pricing model. In this model, an incumbent firm can influence the size of potential entrants (in terms of the quantity they will produce for the market) or even deter them completely. The incumbent achieves this by committing itself in the first period of the Stackelberg game, for example by installing capacity which cannot be fully recouped in the second period.

Variable transaction costs increase the marginal costs of the entrant. Consequently under accommodation the incumbent will increase his strategic investment and the quantity which he produces and he will make a larger profit. The entrant will enter at a lower quantity. This conclusion is independent of the choice between
of pollution permits to the incumbent or auctioning to all firms, both entrants and incumbents.

The entry barrier is raised for two reasons. The first reason is that buying permits involves transaction costs which cannot be recouped later. The second factor is that the incumbent has a first mover advantage. He uses this to invest strategically and create sunk costs in the first period in order to commit himself to certain output levels in the second period. He can invest both in already available strategic investments like capacity and in the permits themselves. The abatement cost efficiency of the permit scheme is not impaired when transaction costs increase entry barriers in the limit pricing model.

3.5 CONCLUSIONS AND PRACTICAL CONSEQUENCES

In most programs of tradeable emission permits which have been implemented up till now, established firms have received their permits for free while new firms had to buy them. This difference in treatment between established firms and entrants has raised concern about the consequences for entry into industries. At the outset it should be noted that the naive notion that grandfathering creates a cost advantage for established firms compared with potential entrants is not necessary true. Grandfathered permits have an opportunity cost when they are used. These opportunity costs are equal to the price for which they can be sold and therefore established firms do not have a cost advantage over entrants just because they received permits for free.

This does not mean that the instrument of TDP’s cannot raise entry barriers. Three types of entry barriers have been identified which in theory are affected by TDP’s. First, transaction costs on the permit market can have consequences for entry in the limit pricing model. Second, capital markets might not work perfect, in which case grandfathering puts incumbent firms at an advantage. Third, firms can try to exclude entrants from the permit market by raising their costs and prevent entry. Imperfect capital markets and exclusion are studied in the next chapter.
In this chapter it has been discussed how transaction costs on the permit market (born by either the buyer or the seller of permits or both), affect entry barriers in the limit pricing model. The limit pricing model is a two-period Stackelberg game in which the incumbent firm invests in the first period, taking into account how the potential entrant will react in the second period. In this way he influences the output of the entrant in the second period. It might also be profitable for the incumbent to deter entry completely.

In the first case considered it was assumed that transaction costs are fixed. Assuming that the incumbent receives all the permits he will use through grandfathering, entry can be deterred at lower output levels for the incumbent than would be possible in the absence of (fixed) transaction costs. Moreover, the transaction costs might make entry deterrence attractive when entry was initially accommodated: entry deterrence takes place at a lower output level and therefore a higher profit for the incumbent. In these cases total output will fall and welfare declines. If the most profitable option for the incumbent is to accommodate the entrant, transaction costs do not affect the output level of incumbent and entrant because the fixed transaction costs do not affect the equilibria conditions for accommodation.

The analysis changes when the incumbent has to buy permits in addition to the number he received for free. Consequently, he will have to incur transaction costs as well. This does not influence the equilibrium under accommodation, but it might make accommodation more attractive than deterrence. This is the case when the number of permits grandfathered exceeds the permits he needs when he accommodates but are less than his requirement when entry is deterred. Choosing to deter the incumbent means that the incumbent has to pay transaction costs while with accommodation no permits have to be bought and therefore no transaction costs are made. Accommodation might therefore be more attractive in this special case.

In the section on variable transaction costs, the focus has been on accommodation of the entrant. In contrast to the case with fixed transaction costs, the accommodation equilibrium will change with variable transaction costs. The incumbent produces more and makes a higher profit while the entrant produces less. The incumbent invests more in the strategic investment which commits him in the first period. Total output is reduced and welfare diminishes.
A perhaps surprising conclusion is that with variable transaction costs it does not make a difference for the accommodation equilibrium whether the incumbent receives all the permits he needs for free or whether he has to buy additional permits and incur transaction costs as well. The reason for this is that he can buy permits in the first period. The transaction cannot be recouped in the second period: they are sunk. Therefore they do not enter the second period equilibrium.

Instead of investing in already available strategic investments like capacity, the incumbent can also invest in the permits themselves. Because the transaction costs are sunk, the incumbent to some extent commits himself when he buys permits in the first period. In the limit pricing model analyzed here abatement cost efficiency of the permit scheme is not impaired when transaction costs increase entry barriers.

It should be stressed that the analysis of the consequences of transaction costs in the permit market for entry barriers in the product market presented here is only partial in nature. The strategic interactions between firms studied here have been restricted to at most two periods. In reality, firms will make decisions which affect competitors and potential entrants regularly. These long term interactions should in principle be taken into account. Moreover, only one form of firm behaviour has been addressed, the limit pricing model, although there is a "richness" of competing theories and assumptions about firm behaviour.

Given the conclusions from the theoretical analysis of entry barriers and transaction costs on permit markets outlined above, it remains to assess the practical implications for the system of tradeable carbon permits described in chapter 2. Although theoretically entry barriers can occur when the permit market does not function perfectly, the practical consequences appear to be small. The carbon permit market is a large market with many potential actors, which will increase the chance that a well-functioning market develops with low transaction costs. For example in the market for sulphur allowances in the U.S. the broker’s costs are 5 percent of the value of the permits traded (Klaassen and Nentjes 1995). Furthermore, the auction of part of the permits means that there is a primary market on which transaction costs will be low as there are no search costs associated with buying permits at the auction.

Another point is that the situations analyzed in the former section are theoretical cases. In general, game theory has found relatively little empirical support (see e.g.
Tirole 1992, p.3). Even though transaction costs might appear on the carbon permit market, it will be difficult to identify possible situations in the product markets concerned which bear similarity to the theoretical cases analyzed. Therefore, the overall conclusion concerning transaction costs and entry barriers in the tradeable carbon permit scheme is that in practice it is not a relevant issue.
CHAPTER 4
ENTRY BARRIERS AND TRADEABLE EMISSION PERMITS II

In the former chapter three types of entry barriers have been identified which might occur when a system of tradeable permits is introduced. The consequences of transaction costs on the permit market for entry have been discussed in the context of the limit pricing model. In this chapter the two other types of entry barrier are investigated. In section 1 the consequences of imperfect capital markets and grandfathering for entry barriers are discussed. In section 2 exclusionary manipulation with tradeable permits is examined. The practical consequences for the system of tradeable carbon permits discussed in chapter 2 are determined for both types of entry barriers.

4.1 TRADEABLE PERMITS AND THE LONG PURSE THEORY.

It has been argued in the former chapter that potential entrants are not necessarily put at a disadvantage when they have to buy permits while established firms get them for free. The incumbents have to take into account the opportunity costs of using their grandfathered permits and therefore they do not have a cost advantage over the entrants. However, in reality markets do not always work perfectly. In this section the focus is on the capital market. It will be considered whether the difference between incumbents and potential entrants with regard to grandfathering has consequences for the entry barriers when capital markets do not function perfectly. First the long purse theory, which is based on imperfect capital markets, is discussed (section 1.1). Subsequently the theory is applied to tradeable emission permits (section 1.2). In the last section some empirical evidence on imperfect capital markets is discussed (section 1.3).
4.1.1 History of the Long Purse Theory.

The analysis of the relation between imperfect capital markets and entry barriers is part of the literature on predatory pricing. Predatory pricing is a pricing strategy used by a firm (the predator) to force its rival (the prey) out of the market and/or to deter potential entrants. The general definition of predatory pricing is: predatory pricing behaviour involves a reduction of price in the short run so as to drive competing firms out of the market or to discourage entry of new firms in an effort to gain larger profits via higher prices in the long run than would have been earned if the price reduction had not occurred. (Tirole 1992, p.373).

There are three types of predatory pricing: signalling predation, predation for reputation and long purse predation (Ordover and Saloner 1989, p. 546). Signalling predation is used by predators when they possess information the potential entrant does not have (asymmetric information), for example on the predators costs or market demand. The price the predator sets provides the prey with information on the market conditions. Presumably, the predator wants to convey bad news to the potential entrant in order to discourage him from entering the industry. Setting a low price might indicate that demand is slack or that the predator has low costs and therefore entering would not be profitable.

Firms predate for reputation when they do not only want to drive out a firm which has just entered but when they also want to show by preying on the first entrant that they will fight all subsequent potential entrants. Fighting the first firm which enters has the added benefit (apart from driving it out) that potential other entrants will be deterred as well. This form of predation is also based on asymmetric information: the potential entrants do no know a priori whether the incumbent will want to fight or whether he prefers to accommodate.

For our analysis in section 1.2 the relevant variant of predatory pricing is the long purse theory. Therefore we shall discuss its development more extensively. According to the long purse theory, predators who have larger financial resources than their prey will start a price war which in the end will financially exhaust their prey. Although the price war will initially diminish profits for the predator as well, it will be attractive for the predator to predate if the monopoly profits he expects to earn after the prey has left
outweigh his price war losses. Because of his larger financial means he can outlast the prey: when the prey goes bankrupt the incumbent is still solvent.

The long purse theory has initially been quite popular. One of the earlier references is from Edwards (1955) who wrote: "An enterprise that is big in this sense obtains from its bigness a special kind of power, based upon the fact that it can spend money in large amounts. If such a concern finds itself matching expenditures or losses, dollar for dollar, with a substantial larger firm, the length of its purse assures it of a victory". Given that the (monopoly) profits the incumbent will enjoy after the prey has left the market outweigh the losses he has to sustain during his fight, predation will be an attractive strategy for the incumbent. It should be noted however that even if predation is profitable, it is not necessarily the most attractive strategy available to the predator (McGee 1958). For example, advertising or exclusionary manipulation are strategies that might have the same effect on the prey but which come at a lesser cost.

Apart from McGee’s observation, two other reservations have been voiced. One criticism that has been made first by Telser (1966) and subsequently by Benoit (1984) is that if long purse predation would be successful the entrant would not enter at all. Assuming complete information, the entrant can foresee that the incumbent will start a price war and that somewhere in the future he will have to leave the market because he has run out of resources. Consequently he would prefer not to suffer the losses of the price war during the time he is in the market because he will not be able to compensate them. He can avoid these losses quite easily by staying out and using his initial resources for a more profitable enterprise. Given that long purse predation is an attractive strategy for the incumbent the entrant will stay out and therefore long purse predation will not occur. The theory of the long purse is in this sense too successful because it predicts that long purse predation will never take place in practice. However, it demonstrates that "having a long purse may provide a credible threat of post-entry predation and thus could deter entry" (Ordover and Saloner 1989, p. 548).

Benoit (1984) has shown that the criticism that long purse predation will never occur follows from the assumption that both firms have perfect information. This however is a strong assumption. Benoit assumed that instead of possessing perfect information, the incumbent does not know whether the entrant is financially constrained or not. He showed that in that case it is possible that a firm will enter and
that subsequently he will be driven out through long purse predation.

Another criticism of the long purse theory is that it is not clear why the potential entrant should be financially constrained. Apparently, if he had enough credit available he would stay in the market because he would in the end be able to make a profit (otherwise he would not enter at all). Therefore it should be in the interest of his creditors to extend more credit facilities so as to make it possible for him to outlive the price war. Presumably, there is no reason why firms should be financially constrained and because the "long purse story lacked theoretical foundations, it slowly fell from grace." (Tirole 1992, p. 377).

However, nowadays there is some justification for the theory. First of all there is evidence that in reality there might exist something like a financial constraint. This evidence stems from the study of the capital structure of enterprises. In order to explain how firms decide on the optimal levels of debt and equity, several theories have been formulated. One of these theories is the pecking order theory. Basically, this theory states that when firms need funds in order to finance new investments, they have a strong hierarchy of preferences for types of finance. They prefer to use internal finance as far as possible. If there are not enough internal funds available and they have to turn to external financing, they will first borrow, subsequently use convertible bonds or likewise hybrid securities and if none of these is possible they will issue equity (Myers 1984, p. 581). The aggregate figures seem to support this theory. Myers notes that in the decade of 1973-1982, capital expenditures of non-financial corporations in the U.S. where covered on average for 62 percent by internally generated cash. Of the external financing the largest part was debt; only 6 percent of the external financing was raised by issuing new stock. While this does not provide an explanation of the financial constraint in the long purse theory, it does indicate that financial constraints might exist.  

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1 Whether the pecking order supports the financial constraint of the long purse theory or not depends on its rationale. One of the reasons why firms might prefer internal financing is that external financing is more expensive because of administration and underwriting costs. However, these costs seem not to be so large as to warrant the preference for internal funding (Myers 1984, p. 582). Another explanation relies on asymmetric information. Myers and Majluf assume (1) that managers have more information about the benefits of an investment project than potential investors and (2) that it is their objective to increase the intrinsic value of the shares of the "old" shareholders. They conclude that given these assumptions profitable projects which would be undertaken when firms can use internal funding might not be
Other support for the existence of financial constraints is found in recent work on capital markets and asymmetric information. Gale and Hellwig (1985) have studied the question "what is the firm’s budget constraint?" (p. 647). More specifically, they want to find out what the optimal debt contract is and whether credit rationing does appear. The model they study assumes that a firm has a project which yields a revenue which depends on the level of investment and the unknown state of the world. The firm does not have the necessary funds himself so it has to borrow money from an investor. At the time of investment, neither of them knows what the state of the world will be. When the investments matures, the firm will observe his returns but the investor does not know them (this is the asymmetric information). As long as the firm fulfils its contract and pays the debt, the investor has no reason to find out how large the returns are. But if the firm does not pay its debt, the investor will have him declared bankrupt. In that case the worth of the firm is investigated and the scrap value of the firm is distributed among its creditors. The investor will have to bear the costs of bankruptcy. Gale and Hellwig conclude that the optimal contract for the investor for lending money is the standard debt contract. The firm pays a fixed interest on his debt; when it can not pay the interest, the investor will investigate the state of the world, that is he will have the firm declared bankrupt. Another conclusion which Gale and Hellwig draw is that under asymmetric information credit is constrained compared with the first-best level of investment, that is the amount of money which would be supplied if there was no asymmetric information.

The last, and for our analysis important point is that "the lack of liquidity [...] lies at the root of the credit-rationing problem because, if the firm’s net wealth were large enough to finance the first-best investment, the firm would obviously choose that level of investment" (Gale and Hellwig 1985, p.648). If a firm’s own capital suffices to finance an investment, it does not have to borrow and credit-rationing would not occur.

Tirole and Fudenberg (1985) have used the approach of Gale and Hellwig and they have shown how credit rationing might make it profitable for a predator to embark

undertaken when they have to be financed by external funds because of the asymmetric information between the managers and the investors. Also, debt is preferred over new issue of equity. According to this explanation of the pecking order theory, there is not necessarily a financial constraint for the firm. Firms prefer internal funds but they would use external if they had to.
upon a price war against his prey and drive him out of the market. In their two-period model, they assume that at the start of the second period the entrant has to invest a certain amount of capital if he wants to stay in the market. The sum which the entrant can borrow is limited by his own capital, as will be shown below. The own capital resources of the entrant are his retained earnings from the first period. The incumbent can reduce this retained earnings by embarking on a price war which decreases the profits of both firms. The lower the retained earnings of the entrant are, the larger is the additional capital to be borrowed (at higher cost). Consequently, the chance that borrowing additional capital to invest is unattractive increases. Therefore it is more likely that the entrant will find it unprofitable to stay in the market.

This long purse theory is based on two assumptions. First, there exists an asymmetry between the incumbent and the entrant because the latter does have to invest if he wants to continue in the market while the former can stay without investing. Second, external financing is limited (the financial constraint). We will look at this assumption and its consequences in more detail (the approach and notation is adopted from Tirole 1992, page 378). In section 1.2 the theory will be applied to investments in tradeable permits.

Suppose a firm wants to invest in a project which it needs to finance partly by borrowing. The gross profit (the total value of the firm after the project has finished) which the project will yield, \( \pi \), falls within an interval \( [\pi_L, \pi_H] \). The total investment is \( K \), the amount of capital to be borrowed is \( D \). As long as the profit made is larger than the debt and interest, the firm will not default on the loan and repay the bank who has lend the money. The firm earns a profit of \( \pi - (1+r)D \). However, when the firm earns less than \( (1+r)D \), it can not repay the loan and it will go bankrupt. The bankruptcy involves costs like the cost of appointing retainers and the probable losses which occur when the firms assets have to be sold. The firms retain nothing, the creditor gets \( \pi - B \); \( B \) are the bankruptcy costs.

Let the random profit \( \pi \) be distributed with a density \( f(\pi) \) on the interval \( [\pi_L, \pi_H] \).

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2 It should be realised that this assumption makes the model less general: if the incumbent would have to reinvest as well, the price war would not be attractive. Presumably, this asymmetric investment requirement is part of the first mover advantage of the incumbent.
The expected value of the profit in case $\pi$ is less than $(1+r)D$ is denoted $\pi^d$ (defaulted). The probability that $\pi$ is smaller than $(1+r)D$ is denoted $(1-F)$. The expected value of $\pi$ in case $\pi$ is above $(1+r)D$ is denoted $\pi^r$ (repayed), the probability that $\pi$ is above $(1+r)D$ is $F$. The expected profit of the bank (the creditor), $\pi_B$, consists of the repayment of the loan and interest times the probability that the firms profit is above $(1+r)D$ and $\pi - B$ times the probability that its profit is below $(1+r)D$:

$$E(\pi_B) = (1+r)D \cdot F + (\pi^d - B)(1-F) \quad 4.1$$

If we assume that the capital market is competitive, the net profits of the banks (after deduction of its capital costs which are $r_0$) will be zero:

$$E(\pi_B) = (1+r_0)D \quad 4.2$$

Equation 4.1 and 4.2 define an interest rate $r$ which is larger than $r_0$ because the bank faces the risk that the firm defaults on the debt. We will assume that there exists a rate $r$ at which the bank wants to extend the loan. It is not necessarily the case that it is profitable for the bank to extend a loan. The debt $D$ might be too high with respect to the expected profits and the level of the bankruptcy costs. While a higher $r$ might seem to compensate the bank for a higher default risk, it should be realised that a higher $r$ also increases the probability of bankruptcy. The derivative of the expected profit of the bank would in that case decrease in $r$.

The expected profit of the firm is equal to the profit he earns minus the repayment of the loan and interest times the probability that the profit is above $(1+r)D$ and the profit he gets when he has to default, which is zero. His net expected profits $E(\pi_i)$ are equal to his gross profits minus the opportunity costs of the capital he has invested

---

3 $r_0$ is the capital cost for the bank. Or in other words, it is the interest rate charged in the absence of risk.

4 Combining equations 5.1 and 5.2 yields: $(1+r)D + (\pi^d - B)(1-F) = (1+r_0)D$. Rewriting yields: $r = r_0 + (\pi^d - B)(1-F)/D$. An increase in the chance that the firm will default (represented by decrease in $F$) increases the margin between $r$ and $r_0$, between the interest which the firm has to pay and the no-risk market interest.
himself, \((1+r_0)(K-D)\):

\[
E(\pi_i) = (\pi' - (1+r)D)F - (1+r_0)(K-D) \quad 4.3
\]

The firm’s expected net profit, equation 4.3, can also be written as the total expected retained earnings from the project, denoted \(\pi'\), minus the opportunity costs of the firm’s own capital, minus the expected bankruptcy costs (the bankruptcy costs times the probability that the firm goes bankrupt):\(^5\)

\[
E(\pi_i) = \pi' - [B\cdot(1-F)] - (1+r_0)(K) \quad 4.4
\]

When the firm has less own capital and therefore has to borrow more, its expected profits will decrease:

\[
dE(\pi_i)/dD = - d[B\cdot(1-F)]/dD < 0 \quad 4.5
\]

Equation 4.5 is negative because \((1-F)\), the chance that the firm will go bankrupt, increases when the amount borrowed increases: the creditor will charge a higher interest and the debt increases, therefore \((1+r)D\) increases and therefore the chance that the expected profits at least equals \((1+r)D\) declines. An increase in the amount of capital the firm borrows increases the interest \(r\) the bank will charge and the probability that the firm goes bankrupt. Therefore, the chance that the project yields a positive net profit to the firm decreases. In other words, the smaller the amount of own capital of the firm, the smaller is the probability that the project is worthwhile for the firm. Or, as has been noted above, the smaller the amount of own capital the larger the probability that banks do not want to extend a loan. Lack of (internal) funds can therefore restrict firms in the projects they undertake.

The foregoing analysis has consequences for entry barriers when there is a difference between incumbent firms and entrants in that entrants are more depended

\(^5\) This is achieved by including into equation 5.3 the zero-profit condition for the bank: 
\[(1+r)D - (\pi'\cdot-B)(1-F) - (1+r_0)D = 0\]. The total expected retained earnings from the project are: 
\[\pi' = \pi' F + \pi'd (1-F)\].
on borrowed money than incumbents. Consequently the incumbent can engage the entrant in a price war and drive him out of the market; the entrant has smaller financial resources and therefore he cannot endure a price war as long as the incumbent. Borrowing money does not help because the costs of lending money are higher for the entrant with his smaller resources than they would be for the incumbent.

In the next section this financial constraint theory will be adapted and applied to the problem of tradeable emission permits. It will be shown how the introduction of a system of tradeable emission permits can create differences in access to internal and external (debt) finance, increases the likelihood of predation and thereby raises entry barriers.

4.1.2 Predation and Grandfathering

In the former section, it has been shown that in case firms are constrained in the amount of capital they can borrow their propensity to invest will be smaller. In this section, this theory will be used in a simple game-theoretic model in order to illustrate how introducing tradeable permits with grandfathering might make it more attractive to use predatory pricing in order to drive entrants out (or to deter entry). The model used is an application to tradeable permits of work done by Benoit (1984) and of the financial constraint theory of Fudenberg and Tirole (1985) described in the former section.

Two different situations are discerned. As has been described in chapter 2, a tradeable permit can be defined as a permit which gives a polluter the right to emit 1 ton of a certain pollutant. Each year, authorities can grandfather a number of permits to established firms. The entitlement to such a number of future grandfathered permits can be termed a quota. Firms can sell (and buy) both quota and permits. Buying a permit means that a firm acquires the right to emit one ton, once. Buying a quota means that a firm buys the right to receive a number of free permits each year. Buying permits might therefore be looked at as leasing a quota instead of buying it. In the first variant of the game considered below, the entrant leases quota in each period (he only buys the permits he needs for each period). In the second variant, the entrant buys a
quota which provides him with all the permits he will need in the subsequent periods. In addition to considering tradeable permits, the potential for impeding entry under a system of TDP’s with grandfathering will be compared with the effect standards and emission charges will have on entry barriers.

Leasing a quota

The game considered here is a repeated game. The game consists of two firms, an incumbent (firm i) who initially has a monopoly and a potential entrant (firm e). At the beginning of the first game, the entrant decides whether he enters or not. Subsequently, in each stage game the incumbent first decides whether he will fight the entrant or whether he will accommodate him. After this decision of the incumbent, the entrant decides whether he will stay or whether he will leave the industry. The game is a dynamic game with perfect and complete information.

A central assumption of the model is that at the beginning of each stage game, including the first one, both firms have to invest (for example, in capital goods) in order to be able to produce and stay in the market. It is assumed that the investment can be undertaken after the firm has decided to stay (or leave). In order to be able to make these investments, the firm can either use retained earnings from the former period of the game, or he can lend funds on the capital market. However, the capital market does not work perfectly; a firm is constrained in the amount it can borrow by his own wealth as has been described in the former section. Therefore, the lower the retained earnings of a firm in an earlier period, the higher is the fraction of capital for investment he has to borrow in this period and the larger will be the probability that the investment (entry) will not be undertaken since expected net profits are negative, or because creditors do not want to extend a loan. Consequently, it is forced out of the market. At the end of each stage game, firms who have borrowed money must repay their debt and the interest over that period out of their retained earnings (or go bankrupt).

Apart from investing in capital, firms also need a given amount of emission
permits in each period in order to be able to produce\(^6\). We will assume that the amount of permits grandfathered has value \(G\) and that it covers exactly the amount of permits needed for one period (this assumption can be made without loss of generality). Let \(K\) be the investment which both firms have to make at the beginning of each period excluding the purchase costs of pollution permits. In addition they have to invest in the permits, therefore the total investment for both firms is \(K + G\). It is assumed here that both firms, the incumbent and the entrant, are equal in all respects except with regard to the emission permits. It is assumed that in case no permits were required both firms start with the same amount of own capital, which by assumption is equal to \(K\), the amount of investment needed to start in the market. The incumbent receives permits for free (in all periods) and the entrant has to buy them. The free gift of the permits to the incumbent constitutes an increase in its own capital of \(G\).\(^7\)

As a result of these assumptions the entrant will have to borrow \(G\) at the start of the first period because it has to acquire permits worth \(G\). The incumbent does not need to borrow any capital because it has been grandfathered the permits it needs. This means that the entrant will face higher costs than the incumbent because of the costs of borrowing money on the imperfectly working capital market. His expenditure on permits plus interest costs exceeds the opportunity costs which the permits have for the incumbent.

The actions both players take determine the level of profits they will earn. Furthermore, it is assumed that the profits are also influenced by some random variable. One might for example think of this random variable as representing the level of economic growth, inflation or other macro-economic variables which have an effect on demand in individual product markets. Consequently, the profits which firms can

\(^6\) In reality, firms will normally have the choice between either buying permits or reducing their emissions. It is assumed that the amount of permits needed represents the least cost solution for both firms, given the (exogenously determined) price of the permits. The entrant does not need to buy permits but as this is the least cost solution, this is the most attractive option.

\(^7\) It should be noted that it does not necessarily matter how large the initial amount of money is. The crucial element is that both firms start equally, the only difference between the firms is the difference in treatment under the tradeable permit scheme. Assuming that both firms start with \(K\) own capital is attractive from the point of view of comparing it with a situation in which no permits are needed.
make, given the actions they take, are assumed to be random in an interval \( [\pi_l, \pi_H] \) with density \( f \). The different profits given in table 4.1 below should therefore be thought of as being the expected profits of the specific actions chosen, given the probability distribution \( f \). For example, let the actions be fight and stay. The expected profit in the case of fight is \( \pi^F \) which is the expected profit based on a random profit in interval \( [\pi^F_L, \pi^F_H] \) which has density \( f \). The same reasoning applies to the other expected profits, \( \pi^A \), \( \pi^F' \) and \( \pi^M \). It is assumed that all the different profits have the same density function \( f \) in their different intervals. In other words, the random variable which influences profits apart from the actions the players take is independent of the strategies chosen by the players.

Table 4.1 shows the pay-offs (in gross retained earnings) of the different actions both firms can take each period (the so-called extensive form of the game). The first profit between brackets is the profit which the incumbent will make, given the actions chosen by both firms, the second is the profit of the entrant.

Table 4.1: pay-off matrix

<table>
<thead>
<tr>
<th></th>
<th>incumbent</th>
<th>Fight</th>
<th>Accommodate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stay</strong></td>
<td>(( \pi^F, \pi^F ))</td>
<td>(( \pi^A, \pi^A ))</td>
<td></td>
</tr>
<tr>
<td><strong>Leave</strong></td>
<td>(( \pi^F', 0 ))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the incumbent chooses to fight and the entrant stays in the market, there will be a price war and both firms will earn \( \pi^F \). We will assume that these (expected) earnings cover the investment in production capital (exclusive of the permits) both firms have to make in order to stay in the market in the next period: \( \pi^F = K \). While these gross expected retained earnings are positive, the net expected profit in this price war is negative, both for the incumbent and for the entrant.\(^8\)

---

8 This is not necessarily the only way in which the effects of a price war can be modelled. For example, one could imagine that a price war reduces profits even further such that both firms would have to borrow. This does not basically alter the game; the crucial point is that the entrant has less resources because he has not received permits for free. Consequently his
When the entrant leaves, the expected profit of the incumbent is \( \pi^F \). In the subsequent periods, when the entrant stays out of the market, the incumbent makes monopoly profits \( \pi^M \). It is assumed that (for both firms):

\[
\pi^M > \pi^A > \pi^F' > \pi^F
\]  

We will assume that when the incumbent has the choice between fighting and driving out the entrant in the first period and accommodating the entrant for ever, he will choose to fight. That is, the incumbent can make larger profits by fighting one period and subsequently enjoying monopoly profits than by cooperating in this period and all following periods. Formally:

\[
\pi^F' + \sum_{t=1}^{\infty} \frac{\pi^M}{(1+r_0)^t} > \sum_{t=0}^{\infty} \frac{\pi^A}{(1+r_0)^t}
\]  

The last assumption made is that initially, at the start of the first period, the entrant prefers to enter if he would be accommodated by the incumbent. The expected gross profits \( \pi^A \) are such that, given the amount of capital \( K \) and the amount of money he has to borrow in order to buy permits with value \( G \), his expected net profits are positive:

\[
\pi^A - (1+r)G - (1+r_0)K > 0
\]  

If this would not be the case, the entrant would not find it attractive to enter and he would stay out. Condition 4.8 states that the expected net benefits of entering are positive when the incumbent chooses to accommodate the entrant. The entrant’s gross profits minus the repayment of his debt, which is equal to the value of the permits he has to buy, \( G \), plus interest, are equal to or larger than the opportunity costs of his capital \( K \).

Having described the game, we can proceed with the analysis of the equilibrium.
Suppose the incumbent chooses to fight. The expected gross earnings are $\pi^F$ for both firms. The expected net profit of the incumbent is:

$$\pi^F_i = \pi^F - (1+r_0)(K+G)$$

It was assumed that $\pi^F = K$, therefore the net expected profits of the incumbent are negative when both firms fight each other in the first period. They are negative because the firm does not earn enough to cover the opportunity costs of his investment $K+G$ (his total own capital: initial wealth plus the permits he received for free). The expected net profit of the entrant after the first period is (the reader is referred to the former section for the derivation of the net profit of a firm which has to borrow on imperfect capital markets (equation 4.4)):

$$\pi^F_e = \pi^F - (1+r_0)(K+G) - B(1-F)$$

$(1-F)$ is the chance that the gross expected profit $\pi^F$ is smaller than $(1+r)G$, in which case the firm cannot repay his debt and goes bankrupt. $B$ are the bankruptcy costs. The net expected profit of the entrant is lower than the net profit of the incumbent by $B(1-F)$. The entrant has to lend money on the (imperfect) capital market to buy permits and therefore he incurs extra costs compared with the incumbent.

More important than the net profits are the cash flows of the firms because these have consequences for the next stage game. As has been described above, in order to be able to produce each firm has to invest before the start of each period (to be able to produce in that period). This investment consists of the capital investment $K$ and the permits needed for production $G$. The incumbent receives his permits by grandfathering. His retained earnings, which (in the case of fight) are equal to his gross profit $\pi^F$, are $K$. Therefore he can invest in production capital $K$ without having to borrow money. He receives the permits which he needs in the next period for free.

The entrant, however, is in a different situation. From his retained earnings, $\pi^F$, he has at first to pay off his debt to the bank. This debt is $(1+r)G$, therefore he has only left $K - (1+r)G$. The capital he needs for his investment in order to have production capacity for the next period consists of the investment capital $K$ and the permits he
needs in the next period which have value G. Consequently, he has to borrow again. The amount he has to borrow is:

\[ K + G - [K-(1+r)G] = (1+1+r)G \]

4.11

The amount the entrant has to borrow rises with \((1+r)G\) as compared with the amount he borrowed at the start of the first period.

As the game continues, the entrant will have to borrow more and more as long as the incumbent plays 'Fight'\(^9\). Eventually, a point is reached at which either the project is not attractive any more to the entrant, because his net expected profits when accommodated fall below zero, or because the bank does not want to provide a loan any more (see page 37). At this point (which we will call period N), the entrant will therefore play 'Leave' and exit the market. The strategy of fighting is therefore an attractive strategy for the incumbent in period N because he will drive out the entrant and he can subsequently enjoy monopoly profits.

In period N-1, fighting will also be attractive for the incumbent. If the entrant would choose to stay in the market, the next period game would be a stage game in which he would have to leave. However, choosing strategy 'Leave' in period N-1 would save him the costs of fighting the price war in this period and therefore it would be optimal to leave already in N-1. Proceeding by backward induction, as Benoit (1984) has shown, in each foregoing period it would be optimal for the entrant to leave, and therefore it would not be optimal to enter in the first period at all. In the sub-game perfect Nash equilibrium of this entry-exit game with tradeable emission permits the incumbent would choose 'Fight' in the first period and the entrant does not enter at all. The incumbent subsequently enjoys monopoly profits (which he preferred over accommodating the entrant, see the assumption in equation 4.7).

In order to be able to draw conclusions about the consequences of introducing a system of grandfathered tradeable emission permits for entry into industries, the situation described above must be compared with the situation in which no

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\(^9\) The amount to be borrowed in period t is \(\Sigma (1+r)^t G\). As t rises, the amount to be borrowed rises as well.
grandfathered tradeable emission permits are introduced. In that case, neither of the firms needs to have emission permits, or both would have to buy all their permits (with auction), therefore the necessary investment is confined to the capital investment \( K \), respectively \( K+G \) (with auctioning). In the first case (when neither firm has to buy permits) if the incumbent would choose to play 'Fight', both firms would have just enough retained earnings, \( \pi^F = K \), to invest again. The entrant would never be restricted by the amount of capital he has to borrow and therefore he would be able to endure the price fight indefinitely in this situation. Because the incumbent can not drive out the entrant, he will prefer to accommodate him: the pay-off of accommodating is higher than the pay-off of fighting indefinitely. The entrant will not be deterred when the incumbent chooses to fight: the threat to fight indefinitely is non-credible because accommodating is more attractive. The perfect equilibrium in this case is to accommodate entry for the incumbent and to enter for the entrant.

In the second case (when both firms have to buy permits), playing 'Fight' is not attractive for the incumbent either. Both firms would retain earnings \( \pi^c = K \) minus their debt \( (1+r)G \). Consequently, both firms would have to borrow more in order to invest for the next period. The incumbent does not have an advantage over the entrant, therefore he cannot outlive a price war with the entrant. Playing 'Accommodate' is therefore more attractive.

Consequently, it follows that the implementation of the TDP-scheme with grandfathering and more in particular the different treatment of existing firms and newcomers raises entry barriers. Because of the imperfect capital market, the incumbent can force the entrant out through conducting a price war. This price war makes it progressively less easy for the entrant to raise the money he needs to make the necessary investments for staying in the market. Finally, it is not attractive any more for him to stay and therefore he will leave. Looking forward, both firms can predict this outcome and therefore the entrant will decide not to enter at all.

**Buying a quota**

In the game discussed above, the entrant buys permits every period ("leases a
quota”). Another possibility is that outright at the start of the first period he buys a quota. Subsequently, he does not have to buy permits any more in the following periods. How would this affect the entry exit game discussed above? First, the price of a quota must be determined. The price of a quota can be deduced from the price for which the rights are sold (or for which quota are leased). Because a quota is a right to receive a permit for free every period, its current value is the sum of the discounted value it will have in the future:

\[
\text{value quota} = \sum_{t=0}^{\infty} \frac{1}{(1+r_0)^t} G = \frac{1}{r_0} G
\]

where \(r_0\) is the discount rate (the minimum lending rate) and \(G\) remains the value of the permits needed each period. If the entrant wants to buy a quota and enter the market at the beginning of the first period, he will have to invest the total sum of \(K + 1/r_0 G\). Assuming that the initial capital of the entrant is \(K\) (as was done in the first variant of the game), this means that the firm will have to borrow more than in the variant presented above: \(1/r_0 G\) instead of \(G\). This will have consequences for his expected profits. As is stated in equation 4.8, it is a necessary condition that the expected profits of the entrant when he is accommodated (profits are \(\pi^A\)) are positive because otherwise he would not enter at all. This condition also holds when the entrant has bought a quota instead of the amount of permits he needs for one period. He will make the necessary investments as long as his net profit in the first and each subsequent period is positive. In this variant he has to repay a larger loan at the end of the first period: not \(G\) but \(1/r_0 G\).\(^{10,11}\)

\(^{10}\) The requirement that the whole loan is repaid at the end of the first period is a strict condition. Another possibility is that the incumbent and the bank sign a debt contract which allows the incumbent firm to spread out his repayment. This would be more in line with the fact that the expected profits he makes on his investment in the quota of emission permits are also spread out over a long time. Other forms of debt contracts will be discussed below.

\(^{11}\) The entrant could sell his quota in order to pay of his debt (assuming there is a well functioning market for emission permits and quota). However, this would mean that in the next period he would have to buy another quota if he wants to stay in the market. Selling and buying a quota at the same time however does not make much sense.
In addition, the interest on the loan will also be higher compared with the interest paid when a quota was leased. The amount borrowed is higher, therefore the risk of default is higher. Consequently, the bank will ask a higher interest rate (see former section, page 8 for proof of this proposition).

Because of the higher debt and next to that the higher interest rate, the expected profit of the entrant will be lower. The chance that entering is not profitable at all is therefore larger when the entrant buys a quota with borrowed money than when he leases a quota every period.

Assume for the moment that the net expected profit of the entrant is positive, therefore he prefers to enter the market if he is accommodated by the incumbent. What are the pay-offs if the incumbent would choose to fight? Again, both firms would make a gross expected profit of $\pi^F$ if the incumbent would choose to stay in the industry. As has been described above, this leaves the incumbent with exactly enough capital to reinvest $K$ and to continue in the industry.

The situation which the entrant faces is different from the variant in which he only leased a quota. Because he has acquired a quota, he does not need to buy permits any more: just like the incumbent, he ‘receives’ them for free each period. Consequently, he only needs to invest $K$ instead of $K + G$ in all periods starting at period 2. His gross profits from the first period are $\pi^F = K$, his net retained earnings are $K - (1+r'/r_0)G$: the gross profits minus the amount borrowed plus interest on his debt (the interest is denoted $r'$ to distinguish it from the interest which the entrant has to pay when he leases a quota). Therefore, he has to borrow $(1+r'/r_0)G$ in order to be able to stay in the market. If the incumbent continues to play fight in all subsequent periods, the amount which the entrant needs to borrow will rise: in the beginning of period $t$, he has to borrow $(1+r')^t G/r_0$. Eventually he will be unable to borrow the capital he needs or reinvesting is not attractive anymore because his net expected profit becomes negative.

Following the same argument as in the lease-variant discussed before, the perfect equilibrium of the game is for the incumbent to play fight if the entrant enters and for the entrant not to enter at all. In both variants, the fact that the entrant needs to borrow on an imperfect capital market makes it possible for the incumbent to drive him out if he would enter the market at all. It should be noted that under buying the entry
barrier is not higher than under leasing, even though the expected profit of the entrant is lower. In both cases, the entrant decides not to enter at all and the incumbent enjoys monopoly profits.

Three remarks can be made with regard to this analysis. First, the debt contract which has been specified above might not be the optimal debt contract. Second, the assumption about the amount of capital both firms own at the start of the first period might be changed. Third, according to this game, entry does not occur and therefore long purse predation does not arise either.

1] The debt contract specified above assumed that the entrant had to repay his debt at the end of the first period. However this is a strict condition. It might be more plausible to assume that the entrant will repay his loan over a longer period. An extreme form of such a debt contract is a credit facility, which allows a borrower to have an overdraft up to a certain limit. With such a debt contract, there is no need to repay the debt as long as the interest is paid in each period. If such a debt contract would be available for the entrant, what would the consequences be for the outcome of the entry exit game? At the start of the first period, he would borrow the amount needed to buy a quota: $1/r_0 - G$. Assuming that the incumbent plays "Fight" and that the entrant stays in the market, both firms will earn $\pi^E = K$. The entrant does not need to pay back his loan, nor does he have to buy permits in the second and subsequent periods. However, he does have to pay the interest, $r'/r_0 - G$. Therefore, he has to borrow $r'/r_0 - G$ if he wants to continue in the market. Assume that the extra borrowing falls within the entrants credit facility limit and that he only has to pay the interest on this lending. After the second period, the interest which has to be paid is: $r(1+r)/r_0 - G$. If the incumbent continues to pay fight, the interest which has to be paid by the entrant will continue to rise and in the end he will have to exit the market. A lenient debt contract which takes the form of a credit facility where the sum borrowed need not to be paid back does not change the outcome of the game. Fighting remains attractive for the incumbent and therefore the entrant will stay out.
Another point which concerns the form of the debt contract has been raised by Fudenberg and Tirole (1985,1986). Suppose that the bank and the entrant sign a long-term contract under which the bank guarantees the entrant that it will always be able to borrow money. In that case, there would be no incentive for the incumbent to prey upon the entrant because he can not drive him out. However, the problem with such a debt-contract is that the promise of guaranteed finance is a non-credible promise. If the incumbent would choose to play "Fight" in the first and all subsequent periods, the entrant would need to borrow more and more as has been described above. When the point is reached where the expected net profit of the entrant is negative, it would be more profitable for the entrant and the bank to change the debt contract and to leave the market. As there is nothing to stop them from renegotiating the contract, the "threat" of the long-term debt contract to stay in the market indefinitely is non-credible and therefore it still pays for the incumbent to play "Fight".

2] One of the assumptions made in the game described here is that both firms start with an initial capital of K, which exactly covers their capital investment. If there was no emission reduction policy and therefore no grandfathered tradeable emission permit scheme was introduced, both firms would start equal and entry deterrence would not be possible (see page 11). When a TDP scheme with grandfathering is implemented, the entrant has to borrow in order to buy emission permits and therefore the incumbent can drive him out of the market.

However, the case would be different if the entrant would have enough capital himself to make the necessary investment in both capital and a quota of emission permits: \( K + \frac{1}{r_0} G \) instead of \( K \). In that case, he would not have to pay interest and therefore he could endure a price war in which gross profits are \( K \) indefinitely. Essentially, his position in all subsequent games would be the same as the position of the incumbent. Playing 'Fight' would then be ineffective for the incumbent because the entrant would not have to take recourse to borrowing money.

While this argument might seem to weaken the case of entry deterrence as a result of the TDP-scheme, it should be realised that in this situation an asymmetry is introduced between the incumbent and the entrant with regard to their initial
capital resources. The entrant starts with $K + 1/r_0 \cdot G$ own capital while the incumbent starts only with $K$ (in addition to which he receives TDP’s worth $1/r_0 \cdot G$). Instead, it should be assumed that, if the entrant owns $K + 1/r_0 \cdot G$, the incumbent owns the same amount of money. With these assumptions, the entry exit game studied here would still yield the conclusion that the incumbent would not be able to prevent entry. However, the game could be easily modified to allow the incumbent to impede entry effectively. If we assume that the price war results in a profit of $\pi^f$ instead of $\pi^F$, with $\pi^f < \pi^F$, then both firms will have to borrow if they want to stay in the market. However, the entrant has smaller reserves than the incumbent and therefore he will be forced out while the incumbent can still borrow\textsuperscript{12}.

3] In the introduction to this paragraph, the point was raised that the deep pocket theory was too successful because under complete information the entrant would never enter (see page 2). The same criticism applies to the game of perfect and complete information described above. Analogous to Benoit 1984, the game could be changed to allow for incomplete information. More specifically, it might be assumed that the incumbent is not sure whether the entrant is a firm which already owns a quota (for example, because it had formerly been operating in an industry which also emitted the same type of pollution) or which does not have it yet. It could be shown that in that case a situation might arise in which an entrant without permits would still enter and might or might not be driven out by the incumbent\textsuperscript{13}.

**Welfare consequences**

The analysis of the welfare consequences of the conclusions of the game presented here is relatively simple. The incumbent will enjoy monopoly profits because the potential newcomer will stay out of the market. If the incumbent would not have been

\textsuperscript{12} See also Benoit 1984.

\textsuperscript{13} It would go too far in the context of this study to elaborate on this game with incomplete information. Moreover, the basic analyses of such a game can be found in Benoit 1984.
able to keep the entrant out, profits would have been lower. Their level depends on the form accommodation takes: the two firms might collude, in which case they would together produce the monopoly level\textsuperscript{14}, or they might compete (either in quantities or in prices). As compared with the latter case, welfare will be lower under the TCP-scheme because the incumbent, being a monopolist, will produce the monopoly output. Consequently, there will be a deadweight loss as compared with the fully competitive case. When the two firms compete, they will produce at least the Cournot oligopoly quantity or even the full competitive quantity (Bertrand competition) with a corresponding smaller welfare loss.

Comparison with standards and taxes

The analysis presented so far has focused on the difference between on the one hand implementing a TDP reduction policy with grandfathering and on the other hand not having any emission reduction policy at all. The conclusion was that such a type of policy would, under certain conditions, raise entry barriers. An important question is how entry barriers would be affected if other types of policy were implemented. Three other instruments will be analyzed: standards, emission charges and auctioned tradeable emission permits.

When standards are used, both the entrant and the incumbent have to meet this standard (assuming that the same standards apply to both established firms and newcomers, which is not necessarily the case). Therefore there is no difference between the two firms. Fighting a price war does not limit the entrant in its ability to endure the price war and therefore it is not successful. The incumbent will therefore accommodate the entrant.

With emission charges, both firms will have to pay the charge on their remaining emissions. Because both firms are assumed to be equal in all respects, including their abatement cost functions, they have to pay the same amount of tax. If the tax level is equal to the price of the permits (which would be the case if the same emission

\textsuperscript{14} Note that in the game described here, collusion is less attractive for the incumbent than fighting a price war because he can drive the entrant out. When he can not forestall the entrant, collusion might be preferable above competing, especially if the discount rate is not too low (Folk-theorem, see Tirole 1992, p.246).
reduction would be achieved as with the permit scheme), the revenue they have to pay is equal to G, the value of the permits. If the incumbent would choose to play "Fight", both firms would earn a gross profit of $\pi^F = K$. However, they would have to pay the tax, so their net retained earnings are $K - G$. Consequently, both firms have to borrow G if they want to continue in the market in the next period. If the incumbent again plays "Fight" and the entrant stays, their net retained earnings are $K - (1+r)G$ and they will need to borrow $(1+r)G$. Eventually playing "Fight" will mean that neither of the firms can profitably reinvest at the start of the next period. In that case, the incumbent will prefer to play "Accommodate". Proceeding by backward induction, it follows that the optimal strategy for the incumbent is to accommodate the entrant right at the start of the first period. The entrant’s optimal strategy is to enter. When emission reductions are pursued by means of emission charges, entry barriers are not raised.

This analysis and its conclusion also applies to the case in which all firms, both established and entrants, have to buy permits under a TDP-scheme. The financial consequences for all firms of such a TDP-scheme with auctioning of all permits are similar to a tax, therefore entry barriers will not be raised either.

Conclusions

In this section, it has been shown by means of a repeated game with complete and perfect information that the introduction of a system of TDP’s can make entry unprofitable for new firms when, ceteris paribus, the incumbent firm receives permits for free (through grandfathering) while the entrant has to buy them. The fundamental reason for this is that because of its larger financial resources the incumbent firm can start a price war which will eventually drive out the entrant (the deep purse theory). Because of the free gift of the permits, the incumbent can finance its losses internally at lower costs than the entrant who has to borrow money on the capital market, which is assumed to work imperfectly. A sufficient condition for the incumbent is that he can make higher profits by fighting just one period and enjoying monopoly profits in the other periods than by accommodating the entrant.

Because the incumbent does not have to compete with others, the total output produced will be the monopoly output. As compared with a situation in which the incumbent competes with another firm, the quantity produced will be less (as long as
the incumbent and the entrant would not collude when they are both active on the market) and welfare will be lower.

The conclusion that entry can be impeded when emission are reduced by means of TDP’s is specific for the instrument of grandfathered TDP’s. The incumbent does not have a first mover advantage when standards or taxes are used and therefore these instruments do not raise entry barriers.

What does this conclusion tell us about the practical consequences of introducing tradeable emission permits in an economy? Obviously, the model presented here is quite theoretical in nature. It assumes that initially the incumbent has a monopoly and that both firms are equal in all respects except with regard to the way they are treated under the TCP-scheme. Furthermore, a central assumption is that firms are limited in external financing by their initial capital endowment. These restrictions make it difficult to apply the conclusion straightforward to a more mundane setting. However, if there is a grain of "empirical truth" in the conclusions yielded by this game, grandfathered TDP’s might reduce the competition of newcomers and therefore the dynamics in certain sectors of industry.

The logical next step is to take a closer look at the empirical evidence. Unfortunately, there is no empirical evidence on this model. In general, empirical evidence on game-theoretic models in Industrial Organization is scarce and difficult to get. However, there is a growing body of research which, although it is not based on the game-theoretic models directly, does investigate the empirical data on entry and exit. In the next section, this research is studied and applied to TDP’s.

4.1.3 EMPIRICAL EVIDENCE ON CAPITAL REQUIREMENTS AS AN ENTRY BARRIER

In the former sections, the long-purse theory has been analyzed and applied to tradeable emission permits. In this section the empirical evidence for the theory that capital requirements can be an entry barrier will be discussed. Given the findings of
this analysis, it will be evaluated to what extent a system of tradeable carbon permits with grandfathering might raise entry barriers.

Most recent empirical studies of the determinants of entry have used the model developed by Orr in his study of entry in the Canadian manufacturing industries (1974). In this study, Orr has investigated various entry barriers in a cross section of 71 Canadian three-digit industries$^{15}$ for 5 consecutive years (1963-1967). In his model, he assumed that there is a certain price-cost margin below which no entry is induced. When the price-cost margin rises above this level, entrants will enter an industry. In the absence of entry barriers, this limiting price-cost margin is assumed to be equal across industries. However, entry barriers will differ between industries and therefore the limiting price-cost margin will differ as well. The model used to estimate the relative importance of the various entry barriers postulates that entry is a positive function of the difference between the actual profit rate which an industry enjoys and the long run profit rate which can be predicted for an industry given the level of entry barriers. Moreover, entry will also be a positive function of the growth rate of the industry because a growing industry will induce additional entry. The model is (Orr 1974, p.59):

\[
E = f_1(\pi_p - \pi^*, \dot{z})
\]

\[
\pi^* = f_2(\mathbf{X})
\]

\[E\] entry: number of entrants per year
\[\pi_p\] past industry profit rate
\[\pi^*\] long run profit given the level of entry barriers in the industry
\[\mathbf{X}\] vector of entry barriers
\[\dot{z}\] past industry rate of growth output

The vector of entry barriers Orr used consisted of:

---

$^{15}$ Industries are classified according to systems like the International Standard Industry Code. In these classification systems the number of digits stands for the level of disaggregation: the larger the number of digits, the higher the level of disaggregation.
the market share of the minimally effective size (MES) plant
- capital requirements (CR)
- advertising intensity
- research and development intensity
- risk
- concentration within the industry

Here, our interest is in the second barrier, capital requirements. As is stated by von der Fehr (1991, p.95), "The hypothesis is that, with imperfect financial markets, average financial costs will increase with the amount needed to enter an industry. [...] If capital costs differ between entrants and incumbents, capital requirements act as a barrier to entry." If the variable used for capital requirements is significant it indicates that CR acts as an entry barrier and that capital markets might work imperfectly and capital costs differ between entrants and incumbents. It might be seen as an empirical validation of the long purse theory. It should be noted that CR differs from the entry barrier which might be created by economies of scale. In the Orr model, the MES plant is used as a proxy for economies of scale type entry barriers.

The measure of CR used by Orr is the costs of fixed capital necessary for establishing a plant of minimally effective size. He calculated this by multiplying total industry fixed assets by the percentage of sales of a MES plant. The size of the smallest plant which still makes a profit was assumed to be an approximation of MES. In the final form of equation 4.15 which Orr has used for his estimations, he used the log value of both E and CR. Consequently, it was estimated whether there was a correlation between the variables in percentage terms, not in absolute values. In the wake of Orr, more empirical studies have been done to determine the significance of various forms of entry barriers. In Geroski and Schwalbach (1991) a number of recent empirical studies are collected, several of which use Orr-type models. Those studies which include CR in their entry barriers cover Portugal, Norway, Belgium and Korea. A study of the V.S. which also includes CR uses a closely related model. Although the studies use the same type of model, their precise formulation, the definitions and measurements of the variables used and the time period covered differ. Table 4.2 presents the different approximations used for CR, the time period covered and the
significance level of CR as a determinant of entry barriers. With the exception of Belgium, in all studies presented above CR, either as capital-to-output ratio or as the capital necessary for a MES plant, came out as a significant determinant of entry. The empirical evidence available therefore appears to confirm that capital requirements can act as an entry barrier.

Table 4.2: The significance of CR as an entry barrier

<table>
<thead>
<tr>
<th>study</th>
<th>time period</th>
<th>CR</th>
<th>significance (percentage level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada (Orr 1974)</td>
<td>1963 - 1967</td>
<td>fixed capital for MES plant</td>
<td>1 percent</td>
</tr>
<tr>
<td>Portugal (Mata 1991)</td>
<td>1979 - 1982</td>
<td>total capital for MES plant</td>
<td>1 percent(^a)</td>
</tr>
<tr>
<td>Norway (v/d Fehr 1991)</td>
<td>not indicated</td>
<td>fire insurance value MES plant</td>
<td>1 percent</td>
</tr>
<tr>
<td>Belgium (Sleuwaegen 1991)</td>
<td>1980 - 1984</td>
<td>capital-to-output ratio</td>
<td>not significant(^b)</td>
</tr>
<tr>
<td>Korea (Jeong 1991)</td>
<td>1977 - 1981</td>
<td>capital for MES plant</td>
<td>5 percent(^c)</td>
</tr>
<tr>
<td>V.S. (Dunne 1991)</td>
<td>1963 - 1982</td>
<td>capital-to-output ratio</td>
<td>1 percent</td>
</tr>
</tbody>
</table>

\(^a\) In this study, a division was made between small and large entrants. For large-scale entrants, CR was not significant.

\(^b\) The model included also capital outlays on equipment and machinery as a percentage of total sales times MES. This variable was significant at the 1 percent level.

\(^c\) Significant at the 5 percent level when tested for two different periods: 77-78 and 79-81. The first period was a period of economic expansion, the second one of contraction. When tested over the full period, CR was not significant.

What are the consequences for tradeable emission permits? It should be noted that in the studies mentioned above, the capital requirements were determined on the basis of a measure of fixed capital. Variable costs are not included in the capital requirements necessary for entering a market. The idea behind this is that the costs
which an entrant has to make when he wants to enter a market, the entry costs, are his fixed costs for the first period. The division between fixed and variable costs depends on the time period considered; in the long run, there are no fixed costs because in the long run no costs have to be born regardless of whether a firm produces or not. In contrast, in the short run some costs are unavoidable. How should the costs of tradeable emission permits be considered in this respect? When tradeable emission permits (as defined in chapter 2) can be bought at any time at any quantity, their costs are variable costs; firms need only buy their permits when they need them. However, when there is no day-market in permits, they will have to buy them in advance and consequently they need to invest in permits when they enter the market. To what extent firms will want to invest in permits before they enter a market will depend on the organisation of the permit market. The more regularly markets take place, the more regularly firms can acquire permits. Consequently the number of permits firms need when they start production will be less when markets take place more regularly. Presumably, trade in permits will take place both at regularly organised markets and through brokers. In the U.S. acid rain tradeable permit scheme, there is a yearly auction of permits and there is a secondary market which functions to a large extent through brokers (Klaassen and Nentjes 1995).

Another factor which might influence the number of permits which a firm wants to start with is the life span of its investments. For example, a power generating company which builds a new plant might want to assure itself of a supply of permits needed to cover its CO₂ emissions in the period during which its plant is economically viable. Power generating equipment can last for up to twenty or thirty years, such a firm might therefore want to acquire permits to cover emissions for thirty years.

We will take a permit supply which covers emissions for one year as a lower limit to the number of permits which firms will buy when they enter the market.

The extent to which entry barriers might be raised will depend on the increase in capital requirements when entrants have to buy permits. Presumably, there will be

---

16 Instead of buying permits (leasing a quota), a new firm can also choose to buy a quota, assuring himself of a supply of permits. In that case, it buys permits for an indefinite period. His initial capital requirements will then increase with the quota price. However, when capital markets are not perfect and the costs of a quota would therefore increase the entry barrier, entrants have the option of buying permits for a more limited period instead.
differences between different sectors of industry.

<table>
<thead>
<tr>
<th>Sector</th>
<th>CO2 emissions 1990 [1000 ton]</th>
<th>number of firms 1990</th>
<th>Capital goods stock (CGS) 1-1-91 [mln. f]</th>
<th>average CGS (ECU)</th>
<th>1-year expenditure with permit price of 20 ECU per ton CO2 [mln f]</th>
<th>% CGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral extraction</td>
<td>1406</td>
<td>-</td>
<td>45631</td>
<td>58</td>
<td>0,13%</td>
<td></td>
</tr>
<tr>
<td>Petroleum industry</td>
<td>9219</td>
<td>24</td>
<td>22641</td>
<td>943</td>
<td>1,69%</td>
<td></td>
</tr>
<tr>
<td>Food and beverages</td>
<td>4010</td>
<td>875</td>
<td>58006</td>
<td>66</td>
<td>0,29%</td>
<td></td>
</tr>
<tr>
<td>Textiles</td>
<td>273</td>
<td>217</td>
<td>6710</td>
<td>31</td>
<td>0,17%</td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td>1551</td>
<td>146</td>
<td>12382</td>
<td>85</td>
<td>0,52%</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>13385</td>
<td>263</td>
<td>70066</td>
<td>266</td>
<td>0,79%</td>
<td></td>
</tr>
<tr>
<td>Building materials</td>
<td>2066</td>
<td>299</td>
<td>15149</td>
<td>51</td>
<td>0,55%</td>
<td></td>
</tr>
<tr>
<td>Base metal</td>
<td>4001</td>
<td>52</td>
<td>24395</td>
<td>469</td>
<td>0,68%</td>
<td></td>
</tr>
<tr>
<td>Other metal</td>
<td>1219</td>
<td>2500</td>
<td>76534</td>
<td>31</td>
<td>0,07%</td>
<td></td>
</tr>
<tr>
<td>Other industry</td>
<td>513</td>
<td>1778</td>
<td>44661</td>
<td>25</td>
<td>0,05%</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>6154</td>
<td>376175</td>
<td>1556</td>
<td>0,41%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) 20 ECU/ton CO2 is the tax which according to Barrett (1991, p.14) would be needed to stabilize CO2 emissions in the EU in 2010 on the level of 1989 (1 ECU = f 2,07).

Table 4.3  Increase in CR with TCP’s, Dutch economy.

Table 4.3 provides an overview of different sectors in the Dutch economy. Unfortunately, the data required were only available at the two digit level. Consequently, the data can only very roughly indicate in which sector a tradeable emission permit scheme might increase capital requirements for new firms. A considerable disadvantage of these aggregated data is that they do not allow to focus on specific markets. Moreover, the average capital requirements are only a very rough indication because within a sector plant sizes will differ considerable, depending on the specific market concerned.

Column 2 of table 4.3 gives the CO2 emissions of each sector in 1990, the next column gives the number of firms per sector. The fourth column gives the value of the capital stock per 1-1-91, in prices of 1991. Dividing column 4 by column 3 yields the average capital stock per firm (column 5). The petroleum industry has the highest average CR, followed by base metal and chemicals. In order to assess the impact of a TCP-scheme on the CR one needs a permit price. It is assumed here that the permit price is 20 ECU. This is the price calculated by Barrett (1991) which is needed to stabilise CO2 emissions in the EU in 2010 on the level of 1988. This price is used to calculate the expenditure each sector would have to make on permits for one years’
CO₂ emissions (column 6)\textsuperscript{17}. Dividing this expenditure by the total CR gives percentage increase in capital requirements for each sector. This is the average increase in capital which new firms have to meet when they enter the market. On average, the CR increase is small, only 0.41 percent. The sectors with the highest percentage increase are, in descending order, the petroleum industry (1.69%), chemicals (0.79%) and base metal (0.68%), all three sectors with a high energy use. These are also the sectors with high average capital requirements. The sectors where the CR increase is largest and therefore a system with grandfathered tradeable permits might erect an entry barrier are the sectors where presumably the entry barrier caused by CR are already high.

The overview presented here of the empirical consequences of CR for entry indicate that in practice CR does limit entry, which can be viewed as a confirmation of the long purse theory. Introducing a system of TCP will increase the CR for new firms (as long as the permits are grandfathered to established firms) and therefore it can reduce entry. However, the extent to which entry will be reduced appears to be small. In our calculations it was assumed that firms acquire permits to cover the emissions of one year. Entry will be further impeded if firms start with more permits. The most affected sectors are the energy intensive industries because in these sectors CO₂ emissions are relatively large and therefore the CR of acquiring sufficient permits are large as well. The average CR in these sectors is high to start with, therefore it might be expected that the entry barrier due to the CR already is high before introduction of the permit scheme.

\textsuperscript{17} Instead of emitting CO₂ and consequently needing permits to cover their emissions, another option for firms is to abate more. This would however also require expenditure, the abatement costs. These costs will consist partly of investment in more energy-efficient equipment, an investment which firms will have to make when they enter the market. Consequently, these costs will also increase their CR. The extent to which firms will prefer to abate more over buying permits will depend on their abatement costs function. For simplicity, it is assumed here that firms will buy permits.
4.2 **TDP’S AND EXCLUSION**

Absolute cost advantages are one type of entry barriers described by Bain. There are numerous ways in which established firms can raise the costs of (potential) rivals. Indeed, firms have been rather inventive in finding ways to increase their rivals costs. Cost-raising strategies include "exclusive dealing arrangements, inducing input suppliers to discriminate against rivals, lobbying legislatures or regulatory agencies to create regulations that disadvantage rivals, commencing R&D and advertising wars, and adopting incompatible technologies." (Salop and Scheffman 1987). A famous example of the first type is the Alcoa case. Alcoa, the major aluminium producer in the U.S. after WW-II, is reported to have concluded agreements with power companies not to provide electricity to potential rivals of Alcoa (Krattenmaker and Salop 1986, p.227). As electricity is an important input for aluminium production, rivals where put at a considerable disadvantage and therefore competition was reduced. Another example, from the European Community, is the case of the Commission of the European Community against Instituto Chemioterapico Italiano (ICI). ICI is a firm which is owned by the U.S. firm Commercial Solvents Corporation (CSC). CSC is a major world producer of aminobutanol, a semimanufacture for some types of medicines. ICI is both a producer of these medicines itself as a resaler of the semimanufacture to other firms in the Common Market. In 1970, CSC and ICI decided to stop the resale of aminobutanol to other firms. One of those firms was Zoja, also a producer of medicines on the basis of aminobutanol. It discovered that, now that the sale of aminobutanol by ICI was stopped, acquiring the semimanufacture on the world market was impossible as the only producer appeared to be CSC, which refused to sell. In this way, CSC and ICI excluded other producers of the medicines from a necessary input. Consequently, when Zoja brought the case to the court, ICI and CSC were obliged to resume supplying Zoja with aminobutanol (Decision of the Court, March 6, 1974).

In both cases, the established firm in one way or another controlled an important input and used its power on this input market to foreclose the product market. In these cases, competition was completely excluded, which is an extreme case. Instead of effectively deterring entry, incumbents can also use their market power on an input
market to reduce competition from (potential) rivals.

Tradeable emission permits are also an input. Therefore, firms which have market power on the market for emission permits can in theory use this power to reduce competition. If an established firm could reduce supply of the permits sufficiently to drive up its price, rival firm’s costs would be increased. They would either have to abate more or buy the permits at their higher price. This would reduce competition from rival firms or potential entrants. However, driving up the permit price will also increase costs for the incumbent firm.

Cost-raising strategies have been studied extensively by Salop in conjunction with Scheffman and Krattenmaker (Salop and Scheffman 1983 and 1987, Krattenmaker and Salop 1986a and 1986b). Subsequently, Misiolek and Elder (1989) have used the Salop-Scheffman model and applied it to tradeable emission permits. Here, the Salop-Scheffman-Misiolek-Elder (SSME) model is reproduced and it is determined under what conditions TDP lend itself for exclusion. Subsequently, it is analyzed whether the TCP-system described in chapter 2 is susceptible to exclusionary manipulation.

The model

In the standard SSME-model, there is an established firm, which can either be a price-taker or a dominant firm which has control over the price of it’s products\(^{18}\). Furthermore, there is a competitive fringe. Here, it will be assumed that there is an incumbent firm which faces potential competition from a rival entrant. Initially, when there is no potential rival, the incumbent maximises:

\[
\pi^i = p q^i - C^i(q^i, L) \quad \text{s.t.} \quad q^i = D(p) \tag{4.15}
\]

\[q^i_p < 0, \ C^i_{q^i} > 0, \ C^i_L \text{ is convex}\]

\[p \quad = \text{product price}\]

\(^{18}\) It should be noted that it is not necessarily the case that the established firm has market power in the product market. The essential fact is that he uses his market power on the input market to influence the product market. See Salop and Scheffman (1984) for an analysis of the model in which the established firm is a price-taker.
\[ q^i = \text{quantity produced by the incumbent} \]
\[ C^i = \text{incumbent’s costs (including abatement and permit costs)} \]
\[ D(p) = \text{market demand for the product} \]
\[ L = \text{tradeable emission permits acquired by the incumbent} \]

From the market equilibrium condition the inverse demand function \( p(q^i) \) can be derived. The first-order conditions are:

\[ \pi_p^i = q^i + p q^i_p - C^i_{q_i} q^i_p = 0 \quad 4.16 \]
\[ \pi_L^i = C^i_L = 0 \quad 4.17 \]

Equation 4.16 the usual monopoly profit maximisation condition: marginal revenue equals marginal costs. Equation 4.17 determines the optimal amount of permits: given the amount of \( q^i \) produced, the number of permits \( L \) is chosen such that the sum of the abatement costs plus permit costs are minimised. The monopoly quantity produced in this non-strategic equilibrium is denoted \( q^{i*} \), the number of permits used is denoted \( L^* \).

When there is a potential entrant, the market conditions for the incumbent change. Instead of total market demand, he now faces a residual demand curve. The maximisation problem becomes:

\[
\max_{(p,q^i,L)} \pi^i = p q^i - C^i(q^i,L) \quad \text{s.t.} \quad q^i = D(p) - q^e(p,P_p) \quad P_p > 0 \\
P_p = P_p(L)
\]

\[ q^e = \text{quantity produced by the entrant} \]
\[ P_p = \text{permit price} \]

The permit price \( P_p \) depends on the quantity of the permits acquired by the incumbent, reflecting the market power he is assumed to have on the permit market. The entrant is a price taker on both the market for outputs and the inputs, including permits. The quantity which the entrant produces is determined by maximising his profit function:
max $\pi^e = p q^e - C^e(q^e,P_p)$ s.t. $\pi^e > 0$ $C^e_{q^e}, C^e_{p^e} > 0$ \hspace{1cm} 4.19

An increase in the product price will increase the quantity produced by the entrant, an increase in the price of the permits $P_p$ will increase his marginal costs and therefore he will reduce his production: $q^e_p > 0$, $q^e_{p^e} < 0$.

Optimizing 4.19 yields the following first-order conditions (for an interior solution):

$$\pi_p^i = q^i + p q^i_p - C^i_{q^i} q^i_p = 0 \Rightarrow p - C^i_{q^i} = -q^i/q^i_p$$ \hspace{1cm} 4.20

$$\pi_L^i = p q^i_{P_p} P_{p^e} - C^i_{q^i} q^i_{P_p} P_{p^e} = 0 \Rightarrow p - C^i_{q^i} = -C^i_{i^e}/(P_{p^i} q^i_{P_p})$$ \hspace{1cm} 4.21

Using $q^i_p = D_p - q^e_p$ and $q^i_L = -q^e_p$, $P_{p^i}$, equations 4.20 and 4.21 can be rewritten as:

$$\frac{q^e_L}{D_p - q^e_p} = \frac{C^i_L}{q^i_L}$$ \hspace{1cm} 4.22

The evaluation of equation 4.22 is straightforward (see Salop and Scheffman 1987, p.22 and Misiolek and Elder p.161). The left-hand side of the equation is equal to $\partial p/\partial L |_{q^i}$, that is the rise in the product price which results from the reduction in output of the entrant as a result of price-rise of the permits following an increase in $L$, holding $q^i$ constant. Or, as Salop and Scheffman stated (1987 p.22), this derivative represents "the vertical shift in the residual demand curve" of the incumbent. The right-hand side of equation 4.22 equals the change in his average costs, with output $q^i$ remaining fixed, resulting from an increase in $L$.

Instead of an interior solution, there is the possibility of a corner solution. A necessary condition for the entrant is that his profit is positive (equation 4.19). At a certain level of $L$, below the strategic equilibrium level of $L$ determined by equations 4.20 and 4.21, the costs of the entrant might increase to such a level that profit falls

---

19 $\partial p/\partial L |_{q^i}$ is determined by totally differentiating $D(p) - q^e(p,P_p(L)) = q^i$ with $\partial q^i = 0$. 
108
below zero. Consequently, the entrant will not enter. The incumbent will buy permits up to the point where the entrant’s profits are nil. Using Bain’s terminology, this could be termed effectively deterred entry. Another possibility is that at the non-strategic equilibrium \((q^*,\bar{L})\), the price of the permits \(P_p\) is such that the entrant can not make a positive profit and therefore will not enter at all. In that case, entry is blockaded.

From an analytical point of view, the most interesting case is when entry is accommodated. It can now be determined whether it will be profitable for the incumbent to raise the entrant’s costs through raising the price of the permits. This is the case when:

\[
\frac{\partial p}{\partial L} > \frac{\partial (C^*/q^*)}{\partial L}
\]

4.23 evaluated at \((q^*,\bar{L})\), with \(q^*\) and \(\bar{L}\) defined as the quantity produced and the number of permits used in the non-strategic equilibrium (where the incumbent is a monopolist and the entrant does not produce). The increase in permit purchases by the incumbent will raise the price of the permits. The change in the product price resulting from the reduction of the entrant’s supply which follows this increase of the permit price must at least equal the increase in the incumbent’s average costs in the non-strategic equilibrium \((q^*,\bar{L})\). If this condition is not fulfilled, increasing the entrant’s costs through manipulation of the permit market is not attractive for the incumbent. The probability that increasing the entrant’s cost is profitable is larger when (see Salop and Scheffman 1987, p.23 and Misiolek and Elder 1989, p.161):

i. the effect on the permit price of increased purchases of permits by the incumbent is larger.

ii. the effect on the entrant’s supply of a rise in the permit price is larger.

iii. market demand for the incumbent’s product is less elastic.

iv. the supply of the entrant is less elastic with respect to changes in the product price.
Given these conditions, systems of tradeable emission permits can be evaluated with respect to their susceptibility to exclusionary manipulation. First of all, it is important that the incumbent firm has sufficient market power and therefore considerable effect on the permit price. If the costs (of extra permits) he will have to make to raise the price are too large, his average costs will rise too much and exclusion will not be profitable.

Moreover, the increase in the permit price must sufficiently raise the entrant’s costs. If permit outlays per unit of product are relatively small, the increase of the entrant’s marginal costs is relatively small as well and therefore his supply to the product market will only be marginally affected. This implies that EM is more profitable for the incumbent if production of the entrant is pollution intensive.

Last, the demand for the product should be inelastic. The rise in price of the product due to the reduction in the entrant’s supply will then be large, which means that the incumbent will be able to make a large profit.

Given these considerations, how susceptible is the system of TCP’s described in chapter 2 to EM? The foremost requirement is that a firm which wants to reduce competition from potential rivals is able to influence the price of the permits without having to incur costs which are too large. In the case of TCP’s however this requirement is a rather strong one because carbon permits are used in almost any branch of industry and the carbon permit market is not divided up in regional markets. As Misiolek and Elder rightly note (1989, p.160), EM is more likely to occur when permit markets are relatively small and particular to one branch of industry. When the permit market is not divided up into regional markets and all branches of industry require the permits, it will be much more costly for a specific firm to raise the permit price sufficiently to influence its rivals. This is illustrated by table 4.4, which shows emissions per sector, the number of firms and the average market share on the permit market if the TCP system described in chapter 2 were introduced in the Netherlands. The highest average market shares are to be found in the refinery industry and the fertilizer industry. However, the highest average share is only 1.2 %. Given these shares, influencing the permit price will indeed be a costly enterprise, even for firms
from these industries. As regards the other industries, market shares on the permit market are negligible.

The total value of the permits on this market, calculated on basis of a price per ton CO$_2$ of 20 ECU, is about 6 billion guilders (this is the price which is calculated by Barret (1991, p.14) as being the CO$_2$ price necessary for stabilising CO$_2$-emissions in the EU in 2010). Table 6.1 only covers the Netherlands. In effect, it is more realistic to assume that a TCP-system operates EU-wide (see chapter 2). Consequently, the permit market will be still larger and therefore market power on this market is even less likely to occur. With 2676 mln. ton CO$_2$-emissions in the EU in 1988, the market value of the permits in a EU-wide system would be 111 billion guilders in 2010 if emissions were stabilised at the 1988 level.

Given the size of the market, it will be difficult for any one firm to influence the permit price. However, it might be different when the permit market functions imperfectly. If, like in the early examples of implemented tradeable emission permit schemes (see Hahn 1989), there is little supply of permits, influencing the price of permits is less difficult because the actual market is small. In the TCP system, this problem is less likely to occur because part of the permits are auctioned by the authorities. This means that there is a large primary market. EM would in that case require that firms could control the price on the primary market, the auction. With about half of the permits yearly available put on auction, any effort to influence the price of the permits would still be costly, even though the secondary market might be small.

The foremost requirement for influencing prices, possessing some degree of market power, appears not to be fulfilled in the TCP-scheme. However, if a firm would be able to control prices, its chance that EM would be profitable would also depend on the product market. Sectors in which demand for the product is inelastic are more vulnerable, as has been argued above. Another point is the emission intensity of a sector. If emissions are large per unit of product, permit prices have a large effect on the average and marginal production costs. This however is a two-edged sword, because while it increases the effect on the entrant’s supply and therefore the profitability of EM for the established firm, it also increases average costs of the incumbent.
<table>
<thead>
<tr>
<th>sector</th>
<th>CO₂-emissions (mln. ton)</th>
<th>number of firms</th>
<th>TCP market share per firm (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and beverages</td>
<td>3.9</td>
<td>7258</td>
<td>0.0004</td>
</tr>
<tr>
<td>Textiles</td>
<td>0.3</td>
<td>1515</td>
<td>0.0001</td>
</tr>
<tr>
<td>Paper</td>
<td>1.5</td>
<td>362</td>
<td>0.0029</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>6.6</td>
<td>12</td>
<td>0.3881</td>
</tr>
<tr>
<td>Other chemicals</td>
<td>3.8</td>
<td>838</td>
<td>0.0032</td>
</tr>
<tr>
<td>Building materials</td>
<td>2.2</td>
<td>684</td>
<td>0.0023</td>
</tr>
<tr>
<td>Base metal</td>
<td>8.8</td>
<td>119</td>
<td>0.0522</td>
</tr>
<tr>
<td>Other metal</td>
<td>1.8</td>
<td>14563</td>
<td>0.0001</td>
</tr>
<tr>
<td>Other industries</td>
<td>0.5</td>
<td>21358</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Refineries</td>
<td>12.1</td>
<td>7</td>
<td>1.2199</td>
</tr>
<tr>
<td>Power companies</td>
<td>36.8</td>
<td>88</td>
<td>0.2951</td>
</tr>
<tr>
<td>Transport</td>
<td>26.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>19.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horticulture</td>
<td>6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>141.7</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4 CO₂-emissions, Dutch economy, 1989.  

**Conclusions**

Exclusionary manipulation is a strategy in which firms try to deny (potential) rivals the use of important inputs to their production processes. This can take the form either of excluding rivals completely or of driving up the price of the strategic inputs. Consequently, these firms either have to use more expensive or less suitable substitutes or use the more expensive input. EM can be an effective way to limit competition,
especially when a firm can exert control over a strategic input at not too high costs. EM does not only exist as a theory, it also occurs in practice. In this section, it has been studied whether it might be possible to use tradeable permits to exclude rivals. Following the analysis of Misiolek and Elder (1989), several conditions have been derived which can be used to establish the susceptibility of systems of tradeable emission permits to EM. Important points are that the increase in the rival’s costs due to EM is large and that the costs of controlling the supply of the permits (the costs of driving up the permit price) is small.

Overlooking the evidence, it can be concluded that the system of TCP’s sketched in this study is not very susceptible to EM. The market for TCP’s, especially for a EU-wide system, appears to be too large for one firm to exercise any market power on this market. Moreover, the auctioning of part of the permits alleviates the danger that the market is too thin, which would make it more easy for a firm to influence the price.

4.3 CONCLUSIONS

In this chapter the analysis of tradeable permits and entry barriers is continued from the former chapter. Two types of entry barrier which might be affected by tradeable permits have been studied in addition to transaction costs which have been studied in the former chapter. First, imperfect capital markets in which case grandfathering puts incumbent firms at an advantage. Second, firms can try to exclude entrants from the permit market, which will raise their costs and reduce entry.

The first type of entry barrier occurs when capital markets do not work perfectly. Given imperfect capital markets, firms with more financial resources can outcompete firms which have less capital. The incumbent firm initiates a price war which the entrant will lose because of his smaller financial resources and consequently higher costs of capital. This form of predatory pricing is known as the long-purse theory. We have applied this theory to the instrument of TDP’s, assuming that the incumbent and the entrant are equal in all respects except as regards the allocation of permits; the incumbent receives them for free while the entrant has to buy permits. Grandfathering
permits is in effect equal to making a capital gift. Therefore, the incumbent will have larger financial resources than the entrant. Consequently, the incumbent can drive potential entrants out of the market in a price war and therefore entrants will not enter the market. Grandfathering effectively reduces entry.

Subsequently, it has been investigated how serious this threat is in practice. There is some evidence from empirical studies that capital requirements do create entry barriers: there is a negative correlation between capital requirements and entry rates across industries.

Introducing the system of tradeable carbon permits described in chapter 2 means that new firms will have to buy carbon permits, which increases their capital requirements. Given the negative correlation between capital requirements and entry rates, this might increase entry barriers. However, the increase in capital requirements appear to be small in the system of tradeable carbon permits. Assuming a permit price of 20 ECU (necessary for stabilisation of the EU emissions in 2010 on the level of 1988), capital requirements increase is small in the Dutch economy. The energy intensive industries are the most affected sectors (the largest increase is in the petroleum industries, 1.7 percent). In these sectors, the entry barrier is already high as far as the capital requirement for the average firm is concerned.

The last, extreme form of entry barriers studied here can occur when a firm or group of firms controls a vital input and exclude other firms from the use of this input. This will force these firms to use less optimal and more expensive substitutes and reduce their competition, or even exclude them from the market. An essential condition for exclusion is that a firm has market power on the input market. Without the power to influence the input’s price, a firm cannot drive up the costs of its rivals.

In the tradeable carbon system described in chapter 2, the market for tradeable carbon permits will be large, especially if the system is introduced in the whole of the European Union. It will be very costly or even practically impossible to influence the permit price on this market. Exclusionary manipulation will not be a problem on this market.

To sum up our results, grandfathering permits to established firms and auctioning them to entrants does not necessarily raise entry barriers because of the opportunity costs of the permits. However, in the case of imperfect capital markets, grandfathering
will raise entry barriers. As far as the system of tradeable carbon permits studied here is concerned, grandfathering and imperfect capital markets will raise entry barriers only to a small extent. The most affected sectors are the energy intensive sectors.
CHAPTER 5
COORDINATION OF ENVIRONMENTAL POLICY
IN A SECOND-BEST WORLD

5.1 INTRODUCTION

In the former chapters, attention has focused on a system of tradeable carbon permits which operates within one country. However, the enhanced greenhouse effect is an environmental problem which occurs worldwide. Tradeable permits and other economic instruments like taxes can also play a role at an international level. The main advantage of these instruments is that, for a given emission reduction, total abatement costs will be minimised because all sources of carbon dioxide will limit their emissions up to the point where their marginal abatement costs are equal. In the case of a tax, emitters will reduce their emissions up to the point where their marginal abatement costs are equal to the tax. With a system of tradeable permits such as has been described in chapter 2, marginal abatement costs will be equal to the price of the permits. To minimize worldwide costs of CO₂ abatement, marginal costs would have to be minimized not only among sources within countries but also among countries. When the marginal abatement costs are higher in one country than in another, it would be efficient to reduce emissions in the country with the low marginal costs further and to increase the emissions in the country with the high marginal costs. Introducing a tax on carbon dioxide which is equal in all countries would in theory equalize marginal costs in all countries and result in the lowest aggregate reduction costs, as has been shown by Hoel (1991).

This straightforward result and its clear implication for policy which follows from the standard analysis does not necessarily hold if a more realistic world is taken as a starting point. One of the complications which has to be faced is that the use of fossil fuels, the main source of anthropogenic CO₂ emissions, is already taxed for various reasons in most countries of the OECD at different tax rates. The question arises how a carbon tax should be combined with these existing taxes on fossil fuels. This
question is not only of academic interest, but it has also practical policy implications. Countries with high current implicit taxes on fossil fuels will argue that they have already limited their emissions and should therefore be exempted from a tax which is equal to the carbon tax introduced in countries with current low taxes. Hoeller en Coppel have investigated the differences in taxes (and subsidies) on fossil fuels in the OECD countries (1992). They show that introducing a uniform carbon tax in the OECD countries on top of the existing implicit taxes on fossil fuels leads to higher total abatement costs than equalising the existing taxes and introducing a uniform tax. Their analysis however is only partial: they only look at abatement costs of different countries and do not take into account the welfare consequences of the revenue raised by the existing taxes and the carbon tax. As has been shown by Hoel (1993), in a general equilibrium model in which there is no deadweight loss from taxation, carbon taxes should be uniform as well across countries in order to maximise collective welfare.

In this chapter, the issue of how to combine carbon taxes with existing taxes on fossil fuels is addressed in the setting of a second-best world, using a simple general equilibrium model (described in section 2). A second-best problem can best be described as an allocation problem with a constraint on the policies feasible which makes it impossible to reach the first-best optimum (Bohm 1988, p. 282). In the context of the optimal taxation problem explored here, the constraint on government policies is that lump-sum taxes are not possible and neither can proportional excise taxes be used because not all goods and endowments can be taxed. Therefore, revenue has to be raised by means of distorting taxation, like taxation on fossil fuels.

The problem is set in an international context since we are interested in solutions which are optimal in the sense that they maximise welfare (net benefits) for participating countries, collectively and individually. Account should be taken of the way countries behave with respect to each others policies. There is a wide range of strategies available to countries: from free-rider behaviour and non-cooperation to optimal cooperation with sidepayments. To simplify the analysis we restrict our model to a world existing of two countries which are involved in global pollution; i.e. the damage caused by the pollutant in a country is independent of the country in which it was emitted.
This contribution differs from the earlier literature on the subject by extending the second-best equilibrium analysis of pollution to an international context. Second-best general equilibrium models including pollution for national economies have been developed by Sandmo (1975), Auerbach (1987), Pezzey (1992) and Bovenberg and v/d Ploeg (1992).

The object of this chapter is to determine the welfare maximising tax structure when two countries cooperate in abating pollution and use a tax on a polluting good (the carbon tax) as the instrument or, alternatively, a system of national or international tradeable permits. Moreover, it is examined whether and how sidepayments are necessary to induce countries to cooperate. The two countries are assumed to be equal except with respect to the damage suffered from pollution and the government budget. Our interest is in how these two variables affect the changes in tax structure and the sidepayment when countries cooperate.

The structure of this chapter is as follows. In the next section, the model used is introduced for one country. In section 3, the model is extended to two countries and the non-cooperative and cooperative equilibria (with and without sidepayments) are determined. Moreover, the optimal tax structures in both countries are established. Unfortunately, the analysis does not provide clear answers to the question of how different government budgets and damage functions affect the tax structures and the sidepayment. Therefore in section 4 a more specific functional form is used to simulate the equilibria and to get answers to the questions asked above.

This chapter serves as a basis for the analysis in the next chapter in which the role of tradeable permits in cooperation in a second-best world is examined.

5.2 General Equilibrium Model of a Tax on an Externality in a Second-Best World

In this section, the model used in the remainder of this paper is presented. The model used is comparable to the one used by Sandmo [1975], Auerbach [1987], Pezzey [1992] and Bovenberg and v/d Ploeg [1992]. The economy consists of one
representative consumer, with the following utility function:

\[ U = u(x, y, l) \text{ subject to } (1+t_x)x + (1+t_y)y \leq M - l \]  \hspace{1cm} 5.1

- \( u_x, u_y, u_l > 0 \)
- \( u_{xx}, u_{yy}, u_{ll} < 0 \)

- \( x = \) dirty good
- \( y = \) clean good
- \( t_y = \) tax on good \( y \)
- \( t_x = \) tax on good \( x \)
- \( l = \) leisure
- \( M = \) given time endowment

The consumer can consume two products, \( x \) and \( y \) which are produced by sacrificing leisure. His budget constraint is determined by the production function \( (1+t_x)x + (1+t_y)y = M - l \) which has constant returns to scale. Prices of the two products \( x \) and \( y \) and of labour (the wage rate) are normalised at unity without loss of generality (Bovenberg & v/d Ploeg 1992). The consumer maximises his utility under the constraint of the production function without taking account of the externalities, i.e. the pollution generated by the consumption of the dirty good \( x \). Maximising this utility function under the constraint of the production function gives demand functions for good \( x \), good \( y \) and leisure \( l \) which are functions of \( t_x \) and \( t_y \). Although labour (\( M-l \)) is not taxed, the amount of leisure 'consumed' by the consumer will react to changes in the tax rates on good \( x \) and good \( y \). When the taxes on \( x \) and \( y \) increase, real income of the consumer will fall and consequently he will work less and take more leisure. From the demand functions, the indirect utility function for the consumer can be derived, \( V = V(t_x, t_y) \).

The government has to raise a given revenue requirement \( R \) by means of the taxes on good \( x \) and good \( y \). A lump sum tax is not available, Leisure \( l \) (or labour \( M-l \)) is the untaxed good. This defines a so called second-best world; second-best because distorting consumption taxes have to be used instead of non-distorting taxes like lump-
sum taxes or proportional excise taxes on all goods and leisure/labour.

Furthermore, the government must limit environmental damage which results from the consumption of the dirty good x. Direct abatement is not possible in this model, so all abatement has to come from a reduction in the consumption of x. This is the prevailing situation as regards the emission of CO$_2$, which can only be reduced by limiting the consumption of fossil fuels. The problem for the government is to choose the tax structure which will maximize consumer welfare, taking into account both the distortions of taxation and environmental damage. First the (standard) optimal tax rules for the second-best world will be established ignoring pollution caused by the consumption of x. Subsequently, the optimal tax rates are determined when the environmental damage caused by the consumption of x is taken into account.

The optimal tax rates (ignoring pollution) are determined by maximizing the following function:

$$V(t_x,t_y) \text{ subject to } t_x x + t_y y \geq R$$  \hspace{1cm} 5.2

Consumer utility is maximized (by maximizing the indirect utility function $V$) subject to the revenue constraint of the government, which states that the amount of revenue raised by the taxes on x and y is at least R (which is exogenously determined).

The first order conditions are:

$$L_{tx} = V_{tx} + \mu [x + t_x x_{tx} + t_y y_{tx}] = 0$$  \hspace{1cm} 5.3

$$L_{ty} = V_{ty} + \mu [y + t_y y_{ty} + t_x x_{ty}] = 0$$  \hspace{1cm} 5.4

$$L_{\mu} = t_x x + t_y y - R = 0$$  \hspace{1cm} 5.5

Equations 5.3 and 5.4 present the standard formulas for optimal tax rates in situations
where no lump sum taxation is possible. \( \mu \), the Lagrange multiplier, can be interpreted as the shadow costs in terms of utility of raising an additional dollar of revenue \( R \) by the government.

Next, the optimal tax rates in the presence of pollution emanating from the consumption of \( x \) are determined by maximizing the following function:

\[
V(t_x, t_y) + D(x) \text{ subject to } t_x x + t_y y \geq R
\]

in which \( D(x) \) is the damage from pollution which is a result of the consumption of good \( x \). Damage is negative benefit, so \( D(x) \) is negative. Furthermore, damage increases when \( x \) increases, therefore \( D_x < 0 \). It is assumed that \( D_{xx} < 0 \), so marginal damage rises when \( x \) increases.

The first order conditions are:

\[
L_t = V_t + D_x x + \mu [x + t_x x + t_y y] = 0
\]

\[
L_{xy} = V_y + \mu [y + t_y y + t_x x] + D_x x = 0
\]

Equations 5.7 and 5.8 can be rewritten as:

\[
V_{tx} + \mu [x + (t_x + 1/\mu D_x) x + t_y y] = 0
\]

\[
V_{ty} + \mu [y + t_y y + (t_x + 1/\mu D_x) x] = 0
\]

Marginal environmental damage \( D_x \) can be internalised in the decisions of the representative consumer by adding an appropriate pollution tax to the existing revenue raising tax on good \( x \). Let \( t_x^R \) be the optimal tax when pollution was ignored (the

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1 The optimal tax problem has originally been discussed by Ramsey. See Auerbach 1987 for a recent overview of the optimal tax problem.
Ramsey tax) and $t^R_x$ the tax when pollution is taken into account (the Ramsey-Pigou tax): tax $t_x$ in equations 5.7 and 5.8 and 5.7a and 5.8a. Comparing equations 5.3 and 5.4 with 5.7a and 5.8a, it follows that $t^{RP}_x$ can be written as [Auerbach, 1987, p. 113]:

$$t^{RP}_x = t^R_x - \frac{1}{\mu} \frac{D_x}{5.9}$$

Equation 5.9 states that the optimal tax on good x in the presence of pollution is composed of two elements:

1] A tax on x which is calculated by the standard optimal tax formulas as given in equations 5.3 and 5.4 (tax $t^R_x$, the Ramsey part of the tax on x).

2] A tax which corrects for the damage resulting from the pollution caused by the consumption of x (the Pigouvian part of the tax on x, termed subsequently $t^P_x$) which is equal to the marginal damage $\delta D/\delta x$ divided by the marginal disutility of government revenue $\mu$. When $\mu$, the shadow costs in terms of utility of raising an additional dollar of government revenue rises (for example, because government raises its revenue requirement), this Pigouvian part of the tax declines. As Bovenberg and v/d Ploeg state (1992, p.9): The government can afford less tax differentiation aimed at environmental protection as the revenue raising objective of the tax system becomes relatively more important. This also implies that in this second-best world, where tax revenue is exogenously given and independent of environmental damage, relative environmental protection will be weaker the higher the revenue requirement of the government is. The consequences for the absolute level of pollution are not clear. With a rise in R, $t^R_x$ will increase while $t^P_x$ will fall. Under certain conditions (see appendix) total tax $t_x$ will increase when R is raised. Assuming that x is a normal good, consumption will fall and environmental quality will improve.

From equation 5.7a and 5.8a, it follows that the optimal tax rules for the tax on good y, the non-polluting good, are not affected by the internalisation of environmental damage in the tax system. Note however that the level of $t_y$ will change: the environmental tax will bring in revenue, which reduces the absolute level of the Ramsey taxes on both x and y.
In the following sections, this model will be extended and used to analyze the consequences for the optimal taxes for two countries.

5.3 Non-cooperation and cooperation in a second-best world

When pollution is transboundary, as is the case with carbon dioxide, environmental policy is confronted with the problem of coordinating environmental policy between independent states. In contrast with environmental problems which are confined within the boundaries of one country, the difficulty is that there is no single authority which can make a cost-benefit analysis and implement an international abatement scheme. It is realistic to assume that countries will base their own policies upon the behaviour in other countries with respect to the transboundary pollution. For example, the European Community has formulated a CO\(_2\) policy which includes a tax on energy and carbon, but it is only to be implemented if Japan and the U.S. will reduce their emissions as well. Therefore one should determine how countries would react to reduction strategies in other countries. In section 3.1, the non-cooperative Nash equilibrium will be examined and in 3.2 the cooperative equilibrium. In 3.3, the cooperative equilibrium is extended by allowing the countries to use sidepayments.

5.3.1 Non-cooperative Nash-equilibrium

At the outset, the model presented in the former section must be amended to account for the transboundary character of pollution. It is assumed that there are two countries, in both of them both x and y are consumed and both governments have to fulfil their (given) revenue requirement by taxing the two consumption goods x and y. It is assumed that the environmental damage which results from the consumption of x occurs everywhere, regardless of the location where x is consumed. Therefore, the damage function for both countries, D\(_1\) and D\(_2\), are not only a function of the consumption of x in the own country, but also of the consumption of x in the other
country:

\[ D_1 = D_1((x_1 + x_2)) \]  
\[ D_2 = D_2(x_1 + x_2) \]

The social welfare function, equation 5.6, then becomes (for country 1):

\[ V_1(t_{x1}, t_{x2} + D(x_1 + x_2) \text{ s.t. } t_{x1} x_1 + t_{y1} y_1 \geq R_1 \]

In order to determine the optimal taxes and pollution both countries end up with when they do not coordinate their policies (the non-cooperative Nash-equilibrium) it is assumed that both countries take the pollution in the other country as given. Taking \( x_2 \) as given, country 1 will maximize its social welfare function (5.12) (and vice-versa for country 2), yielding the following first order conditions:

\[ L_{tx1} = V_{tx1} + D_{1x1} x_{tx1} + \mu_1[x_1 + t_{x1} x_{tx1} + t_{y1} y_{tx1}] = 0 \]  
\[ L_{ty1} = V_{ty1} + D_{1x1} y_{ty1} + \mu_1[y_1 + t_{y1} y_{ty1} + t_{x1} x_{ty1}] = 0 \]

Comparing these first-order conditions with those in the single country case, the only difference is the occurrence of \( x_2 \) in the derivative of the damage function. Damage is not only caused by the pollution resulting from consumption of \( x \) in the own country but also by the given level of pollution imported from the other country.

In order to determine the way country 1 will react to a change in emissions in country 2, we take the total differential of the first-order conditions (including \( t_{x1} x_1 + t_{y1} y_1 = R_1 \)) with \( t_{x2} \) as a parameter change. Solving the system gives:

\[ \frac{dt_{x1}}{dt_{x2}} = \frac{(y_1 + y_{ty1} t_{y1}) D_{1x12} x_{2x2} [(y_1 + y_{ty1} t_{y1}) x_{1tx1} - (x_1 + x_{ty1} t_{y1}) x_{1ty1}]}{\lvert H \rvert} \]

\( H \) is the Hessian matrix.
The right hand side of equation 5.15 is negative (see appendix). Therefore, when tax \( t_2 \) rises, tax \( t_1 \) decreases. When country 2 raises its tax on good \( x \) and therefore reduces consumption of \( x \) and emissions, the marginal damage resulting from the consumption of \( x \) will diminish (in absolute terms), not only in country 2 but also in country 1. Consequently, country one can increase pollution and therefore consumption of \( x \) and it will be able to lower the Pigouvian part of its tax on \( x \). In diagram 5.1 curve \( R_1 \) represents this reaction of country 1, and \( R_2 \) for country 2 if country 1 changes its tax on \( x \). (It is assumed that an interior solution exists, for proof of the existence of the equilibrium see the appendix). The non-cooperative Nash equilibrium is point \( N \) in diagram 5.1.

![Diagram 5.1 Cooperative and non-cooperative equilibrium](image)

### 5.3.2 COOPERATIVE EQUILIBRIUM

In section 3.1 countries did not cooperate. Here it is assumed that countries negotiate in order to agree on abatement policies. Cooperation geared to a Pareto-optimal solution can be represented by the following function (see also Hoel 1991, p. 58):

\[
V_1(t_1, t_2) + D_1(x_1 + x_2) \text{ s.t. } t_1 x_1 + t_2 y_1 \geq R_1
\]

5.16
\[tx_2 x_2 + ty_2 y_2 \geq R_2\]
\[V_2 + D_2 \geq W_2^*\]

in which \(W_2^*\) is the welfare level of country 2 in the non-cooperative equilibrium. In other words, welfare in country 1 is optimised by setting taxes in both countries subject to the government revenue constraint and subject to welfare in the other country staying at least equal. The Lagrange function to be maximised is:

\[L = V_1(t_{x_1}, t_{y_1}) + D_1(x_1 + x_2) + \mu_1[x_1 x_{x_1} + y_1 y_{y_1} - R_1] + \gamma (V_2(t_{x_2}, t_{y_2}) + D_2(x_1 + x_2) - W_2^*) + \mu_2[x_2 t_{x_2} + y_2 t_{y_2} - R_2]\]

\(\gamma\) is the Lagrange multiplier of the welfare constraint for country 2.

The first-order conditions are:

\[L_{t_{x_1}} = V_1_{t_{x_1}} + D_1_{t_{x_1}} + \mu_1(x_1 + t_{x_1} x_{x_{x_1}} + t_{y_1} y_{y_{y_1}}) + \gamma D_2_{t_{x_1}} = 0\]

\[L_{t_{y_1}} = V_1_{t_{y_1}} + D_1_{t_{y_1}} + \mu_1(y_1 + t_{y_1} y_{y_{y_1}} + t_{x_1} x_{x_{x_1}}) + \gamma D_2_{t_{y_1}} = 0\]

\[L_{t_{x_2}} = \gamma (V_2_{t_{x_2}} + D_2_{t_{x_2}}) + \mu_2(x_2 + t_{x_2} x_{x_{x_2}} + t_{y_2} y_{y_{y_2}}) + D_1_{t_{x_2}} = 0\]

\[L_{t_{y_2}} = \gamma (V_2_{t_{y_2}} + D_2_{t_{y_2}}) + \mu_2(y_2 + t_{y_2} y_{y_{y_2}} + t_{x_2} x_{x_{y_2}}) + D_1_{t_{y_2}} = 0\]

\[L_{\mu_1} = x_1 t_{x_1} + y_1 t_{y_1} - R_1 = 0\]

\[L_{\mu_2} = x_2 t_{x_2} + y_2 t_{y_2} - R_2 = 0\]

\[L_{\gamma} = V_2 + D_2 - W_2^* = 0\]

The maximisation procedure can be pictured in fig. 5.1 as a movement, starting in N along the constant welfare curve \(I_2\) (where \(W_2 = W_2^*\)), searching for the point where \(W_1\) has its maximum. That is shifting \(I_1\) upwards until it has a point of tangency with \(I_2\).
This is point P. Given the form of the iso-welfare curves in figure 5.1 welfare in country 1 has been increased, while at the same time holding welfare in country 2 constant, by raising simultaneously both \( t_{x1} \) and \( t_{x2} \) as compared with the non-cooperative equilibrium. Therefore, pollution will be lower in the cooperative equilibrium than in the non-cooperative equilibrium.

The difference with the non-cooperative solutions (equation 5.13 and 5.14) is that the government of country 1 in choosing its tax level for \( t_{x1} \) and \( t_{y1} \) has to take into account its valuation of the marginal damage in country 2 (\( \gamma D_{2x1} \)) caused by consumption of \( x_1 \) (see 5.19 and 5.20). In the same way damage in country 1 caused by consumption of \( x_2 \) in country 2 is taken into account in setting \( t_{x2} \) and \( t_{y2} \). The Pareto-optimal solution (in point P in fig. 5.1) can be viewed as an agreement between the two governments to increase taxes on \( x \) reciprocally in order to reduce pollution further than in the non-cooperative case.

In the cooperative equilibrium, the Pigouvian taxes will increase, as can be seen by splitting the tax on good \( x \) in a Ramsey part and a Pigouvian part (see equation 5.9). Now, \( t_{x1} \) and \( t_{x2} \) can be written as:

\[
t_{x1} = t_{x1}^R - \frac{1}{\mu_1} (D_{1x1} + \gamma D_{2x1})
\]

5.25

\[
t_{x2} = t_{x2}^R - \frac{1}{\mu_2} (D_{1x2} + \gamma D_{2x2})
\]

5.26

The Pigouvian taxes include marginal damage caused in the other country in addition to the marginal damage of consuming \( x \) in the own country. The Pigouvian taxes will probably rise and pollution will fall when countries cooperate. However, \( \mu_1 \) and \( \mu_2 \) will change as well, it is therefore not straightforward that the Pigouvian taxes are higher when countries cooperate compared with non-cooperation. The Pigouvian taxes in both countries will not be equal (except when \( \mu_1 = \mu_2 \), which is not necessarily the case).

It should be noted that the cooperative game examined in this section can produce

\footnote{It should be noted that \( \mu_2 \) does not represent the shadow cost of taxation for country 2 in equation 3.9. Instead, it represents the effect a marginal change in the revenue requirement for country 2, \( R_2 \), has on the welfare of country 1. The constraint is not a constraint on the welfare of country 2 in this equation but a constraint on the welfare of country 1.}
more than one equilibrium. Solving optimisation problem 5.17 yield the highest attainable welfare level for country 1, given the welfare constraint $W_2^*$ for country 2. Varying this constraint $W_2^*$ generates a range of welfare levels for country 1. In diagram 5.1, the contract curve, lying in between the original iso-utility curves $I_1$ and $I_2$ represents these combinations. All the combinations of welfare levels which will leave both countries better off after cooperation than with non-cooperation are solutions to the cooperative game.

5.3.3 JOINT OPTIMUM AND THE USE OF SIDEPAYMENTS

The range of Pareto-optimal solutions with tax rates as the only instruments that are coordinated does not necessarily yield the highest attainable benefits of cooperation. In a first-best approach, the possibility to use side payments makes it possible to increase welfare in both countries by redistributing the abatement effort relative to the initial cooperative solutions and compensating the country which would be worse off in terms of welfare (see Nentjes 1994). The country which will lower its tax on $x$ and increase consumption of $x$ (and therefore its pollution) compared with the initial cooperative solution will have to compensate the other which increases its pollution tax and decreases its consumption of $x$. Without sidepayments this country would be worse off than when it did not cooperate.

However, sidepayments raise problems of their own. Sidepayments must be raised by way of the (distorting) taxes on $x$ and $y$. Therefore regard must be taken of the welfare effects of raising (and receiving) side payments by means of these taxes. The optimisation problem becomes:

$$\begin{align*}
\text{max} & \quad V_1 + D_1 \\
\text{s.t.} & \quad x_1tx_1 + y_1ty_1 - (R_1+S) \geq 0 \\
\text{s.t.} & \quad V_2 + D_2 - W_2^* \geq 0 \\
\text{s.t.} & \quad x_2tx_2 + y_2ty_2 - (R_2-S) \geq 0
\end{align*}$$

$W_2^*$ is the welfare level in country 2 in the non-cooperative Nash-equilibrium. $S$ is the
sidepayment made by one country to the other country. S can be positive or negative: if S is positive, country 1 will pay country 2. From the budget constraint for country 1, we can see that in that case the revenue requirement for country 1 increases with the sidepayment, while the revenue requirement for country 2 decreases by the same amount. An increase (decrease) of the revenue requirement has several effects. On the one hand, taxes on both goods will increase (decrease) because more (respectively less) revenue is to be raised. On the other hand the Pigouvian tax will decline (increase) because it becomes more (less) costly to levy an environmental tax. The net effect on aggregate pollution can be positive or negative, as will be seen in the next section.

In equation 5.27, the effects of sidepayments on tax levels and excess burden of taxation are taken into account explicitly. Comparing equation 5.27 with 5.17, the difference between the maximization problem in the cooperative equilibrium with and the cooperative equilibrium without sidepayments is the additional instrument of sidepayments, which makes it possible to acquire higher welfare levels through cooperation.

The first-order conditions of maximising 5.27 are mainly equal to the first-order conditions of the cooperative solution without sidepayments (5.18-5.24). Only equations 5.22 and 5.23 change:

\[
\begin{align*}
L_{\mu_1} &= x_1 t_{x_1} + y_1 t_{y_1} - (R_1 + S) = 0 \quad \text{5.22a} \\
L_{\mu_2} &= x_2 t_{x_2} + y_2 t_{y_2} - (R_2 - S) = 0 \quad \text{5.23a}
\end{align*}
\]

Furthermore, the first-order derivative of variable S, the sidepayment, is added:

\[
L_S = -\mu_1 + \mu_2 = 0 \quad \text{5.28}
\]

Again, we can split the taxes on good x in two parts, yielding the same formulas as in the cooperative optimum without sidepayments, see equation 5.25 and 5.26. However, the difference is that \(\mu_1 = \mu_2\) (equation 5.28), therefore the Pigouvian part of the tax is now equal in both countries. Both countries will levy the same Pigouvian or 'carbon' tax. It should be noted that the other part of the total tax on x will still differ
between the two countries. *Aggregate tax levels on the polluting good x will still differ between the two countries.* This is the main difference with the outcome in a first-best world (without tax revenue constraints) mentioned in section 1, where it was argued that in such a first-best world tax rates are equalised between countries.

Another point worthwhile repeating is that even though $\mu_1 = \mu_2$, shadow costs of taxation in both countries will still differ. As has been noted above, $\mu_2$ does not represent the shadow cost of taxation for country 2 in equation 5.26. Instead, it represents the effect which a marginal change in the revenue requirement for country 2, $R_2$, has on the welfare of country 1. The constraint is not a constraint on the welfare of country 2 in this equation but a constraint on the welfare of country 1. When the revenue requirement in country 2 is lower, that country can gear its tax structure more to reducing consumption of x, which increases welfare in country 1, given its welfare constraint $W_2^*$, than when $R_2$ is higher.

Who pays whom is determined by the Lagrange multipliers $\mu_1$ and $\mu_2$. When $\mu_1$ was lower than $\mu_2$ in the initial bargaining solution without transfers, country 1 will pay country 2, which in exchange will raise its tax on good x. However, when $\mu_1$ is initially higher than $\mu_2$, country 1 will receive the sidepayment. All other things being equal, a decrease in $R_1$ increases the attractiveness of making a sidepayment for country 1 (because $\mu_1$ declines). The higher the revenue requirement is, the higher will be the welfare loss (dead weight loss) of raising the revenue for the sidepayment). A higher $R_2$ increases $\mu_2$, increasing the attractiveness of a positive sidepayment (country 1 pays country 2) as well. It should however be noted that changes in the revenue requirement also affect the non-cooperative Nash equilibrium and therefore $W_2^*$, the welfare constraint on country 2 in equation 5.27. Consequently, comparing cooperative equilibria in situations with different initial revenue requirements is highly problematic and does not yield clear results.

As has been mentioned above (p.12), the cooperative game discussed in section 3.2 produces more than one equilibrium. The literature on cooperatives games does provide a number of solutions to cooperative games which do yield unique outcomes in which

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3 The fact that there are several possible approaches is in itself a weakness: there is no reason to prefer one of the approaches above the other.
both countries improve their welfare levels as compared with a non-cooperative solution. Examples of these are the Nash bargaining solution and the Raiffa-Kalai-Smorodinsky solution (Friedman 1986, chapter 5). The Nash bargaining solution (used also in the context of coordination of environmental policy between two countries by Hoel 1991) takes as a starting point for negotiations the welfare levels in the non-cooperative Nash equilibrium. In the Nash bargaining solution \((U_1-T_1)(U_2-T_2)\) is maximised subject to the revenue constraints where \(T_1\) and \(T_2\) are the welfare levels in the Nash equilibrium for country 1 and country 2. This approach has not been used in this general section because the second-best Nash bargaining model does not yield interpretable results.

In order to overcome these problems, in the next section the Nash-bargaining solution will be considered for a more specific functional form of the welfare function. It will be analyzed how different revenue requirements influence which country will make the sidepayment, how the tax structure in both countries is affected by cooperation with and without side-payments and what the consequences are of cooperation for the level of pollution.

5.4 SIMULATIONS

5.4.1 INTRODUCTION

As was stated in the introduction of this chapter, the aim of this research is to determine the equilibrium when two countries cooperate in reducing environmental pollution by means of coordinating taxation in a second-best world where polluting and non-polluting commodities are taxed. The general model considered in the former sections does not yield clear answers to the questions posed in the introduction of this chapter. In particular it does not answer how the tax structure will change when countries cooperate, how pollution is affected and in which way sidepayments can be used to increase welfare. In this section, the equilibrium will be simulated using a more specific model. The form chosen for the simulations is the following welfare function:

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\[ U_i(x_i, y_i, l_i) + D_i(x_i + x_j) = x_i^\alpha y_i^\beta l_i^\tau - a(x_i + x_j)^2 \] 5.29

The first term of 5.29 is a Cobb-Douglas utility function. Utility is derived from two goods, \( x \) and \( y \), and from the time not worked, leisure \( l \). It is assumed that \( \alpha = \beta = \tau = 1/3 \). The representative individual maximises this first term subject to his budget constraint:

\[ (1+t_x)x + (1+t_y)y = (M - l) \] 5.30

\( M \) is the maximum amount of time available to the consumer (his endowment). The wage level is set at unity. A Cobb-Douglas function is chosen because it has the characteristic that it yields demand functions for both goods \( x \) and \( y \) which are independent of the price of the other product (cf. Sandmo 1975). This assumption does not basically change the evaluation as we are interested in the interaction between the two countries, given the need for them to raise revenue by means of distorting taxation, and not in the cross effects of price changes per se.

The second term in 5.29 represents environmental damage. The marginal damage coefficient, \( a \), is positive. First and second-order derivatives are negative.

The individual consumers maximisation yields demand functions for \( x \) and \( y \) (\( l \) is fixed):

\[ x = \frac{M}{3*(1+t_x)} , \quad y = \frac{M}{3*(1+t_y)} \]

Using these demand functions, the authorities maximise welfare function 5.29 subject to their revenue constraint:

\[ x t_x + y t_y = R \] 5.31

The time endowment \( M \) is set at 1000. \( R \) is a fraction of \( M \). Both countries are assumed to have the same welfare functions and private budget constraints. The revenue requirements (\( R_1 \) and \( R_2 \)) and the marginal damage coefficients (\( a \) and \( b \)) are allowed to vary. This makes it possible to determine how the revenue requirements and marginal damage coefficients influence the sidepayment, the tax structure and the level
of pollution.

The specific cooperative solution with tax coordination as instrument examined is the Nash bargaining solution. The Nash bargaining solution is found by maximising the following function:

\[
(U_1(x_1,y_1,l_1)+D_1(x_1,x_2)-T_1) \cdot (U_2(x_2,y_2,l_2)+D_2(x_1,x_2)-T_2) = [x_1^{\alpha}y_1^{\beta}l_1^{\tau} - a(x_1+x_2)^2 - T_1] \cdot [x_2^{\alpha}y_2^{\beta}l_2^{\tau} - b(x_1+x_2)^2 - T_2]
\]

s.t. \( x_1 + y_1 \geq R_1 \)
\( x_2 + y_2 \geq R_2 \)

\( T_1 \) and \( T_2 \) are the welfare levels for country 1 and country 2 in the non-cooperative Nash equilibrium. Maximising 5.32 is equal to finding the hyperbole which has as asymptotes the utility levels \( T_1 \) and \( T_2 \), and has a point of tangency with the frontier of the set of possible solutions to the cooperative game. This is shown in figure 5.2. The y-axis shows the utility level for country 2, the x-axis the utility level for country 1. Line AA’ represents the possible welfare levels attainable when both countries cooperate by coordinating their taxes when no sidepayments are used. The non-cooperative welfare levels (the Nash solution, point N in fig. 5.1) are the origin of figure 5.2. Therefore, the x-axis and the y-axis are the asymptotes for the hyperboles which are the iso-utility curves of function 5.32. \( P_1 \) is the Nash bargaining solution for this case.

When the possibility of sidepayments is included, the maximisation problem 5.32 changes. In addition to setting the four taxes on both goods x and y in both countries,
the cooperating countries can also set the optimal sidepayment. The sidepayment enters equation 5.32 by way of the revenue constraints. $R_1$ becomes $R_1 + S$, $R_2$ becomes $R_2 - S$. $S$ can be both negative or positive. When $S$ is positive, country 1 pays country 2.

When sidepayments are possible in addition to tax coordination, the attainable utility levels will increase. This is shown in figure 4.1 by shifting line $AA'$, the cooperative possibilities curve when no sidepayments are used, outwards to line $BB'$. When the set of cooperative solutions increases, the Nash bargaining solution will also change, from point $P_1$ to point $P_2$ in diagram 5.24.

A striking feature of the Nash-bargaining solution with sidepayments is that the welfare level of one of the countries in the cooperative equilibrium with sidepayments can be smaller than its welfare level in the cooperative equilibrium without sidepayments. It might seem strange that the inclusion of an additional instrument (sidepayments) would result in a lower welfare level for one of the countries. However, one should realise that the Nash bargaining solution maximises a form of joint optimum subject to the constraints that both players realise a minimum welfare level, which is determined by the non-cooperative equilibrium. With the inclusion of the possibility of sidepayments, this maximum shifts. However, the initial welfare constraints will still be met: both with and without sidepayments each country will be better off.

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4 When both countries are equal in all respects, the optimal side-payment is zero in the Nash-bargaining solution and the equilibrium does not change.
Figure 5.3 provides an illustration of this point. Curve AA' shows the possible welfare combinations which leave both countries better off as compared with the non-cooperative equilibrium (the origin) with no sidepayments. The Nash-bargaining solution is point N, the point of tangency of curve AA' and the highest attainable hyperbole, H. Curve BB' gives the welfare combinations including sidepayments, H' the highest hyperbole and N' the new Nash-bargaining equilibrium. The value of the Nash-bargaining solution including sidepayments is necessarily equal to or higher than the Nash-bargaining solution without sidepayments. Country 1's welfare level rises compared with the Nash-bargaining solution without sidepayments, country 2's welfare declines.

However, it is not realistic that one country would accept lower welfare levels when sidepayments are allowed compared with the equilibrium without sidepayments. A more relevant approach therefore is to take the welfare levels of the Nash-bargaining solution without sidepayments as the threat-points for determining the new Nash-bargaining solution with sidepayments. This is illustrated in figure 5.3. Point N represents the new threat points. Consequently, the Nash-bargaining solution with sidepayments is determined by the intersection between the welfare possibilities curve BB' and the

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5 In negotiations which would include side-payments right from the start, this problem would not arise. The step from non-cooperative equilibrium to the cooperative equilibrium will necessarily increase welfare levels in both countries. Only when side-payments are allowed after the implementation of the Nash-bargaining solution without side-payments will the problem that one country can end up worse arise. It is assumed here that negotiations will follow this two step aproach.
highest attainable hyperbole which has as focus N instead of the origin. The Nash-bargaining solution with sidepayments which has these new threat-points as asymptotes is shown by N’’. Necessarily, neither of the two countries will be worse off when sidepayments are included compared with the N-B solution without sidepayments.

This two-stage negotiation process in which countries cooperate in a first stage without sidepayments, introducing sidepayments in the second stage, is taken as the starting point for the simulations. It will be determined how different revenue requirements and different marginal damage coefficients affect the Nash-bargaining equilibrium including sidepayments. The optimal sidepayment will be calculated and the change in tax structure and consumption of good x in both countries will be established when sidepayments are used in a second round as compared with the equilibrium without sidepayments. Initially, the first-best case will be analyzed which will serve as a benchmark for the subsequent second-best analysis.

5.4.2 FIRST-BEST ANALYSIS

In a first-best world, governments can levy revenue by means of non-distortionary taxation (proportional excise taxes on all goods) or lump sum taxes. These type of taxes are non-distortionary because revenue is raised by means of taxes on all goods and endowments or by a direct tax on income. Consequently, these taxes do not distort the price ratio’s between goods as would be the case in the second-best model in which taxes are levied on goods x and y and not on leisure. Such taxes distort the price ratio’s between the two goods and leisure and consequently they have an additional negative impact on welfare. In the model discussed in the former section, proportional excise taxes entail that leisure is also taxed in addition to x and y. Consequently the government budget constraint is:

\[ x t_x + y t_y + l t_l = R \]  \hspace{1cm} 5.33

Alternatively, a lump sum tax can be used instead of proportional excise taxes. In that case, the budget constraint for the consumer is:
in which $t_x$ follows from maximizing $V(t_x) + D(x(t_x))$. The required government revenue is raised by means of the lump sum tax $R$ which occurs in the consumer’s budget constraint. The tax on good $x$ is a Pigouvian tax which is levied solely to reduce consumption of $x$ because of the marginal damage resulting from the pollution caused by the consumption of $x$. The revenue raised by the tax, $x \cdot t_x$, is returned to the consumer by means of a lump sum transfer, see equation 5.34. The demand curve for $x$ is different from the second-best model because the revenue raised by the tax on $x$ is returned as a lump sum transfer. The demand curve for $x$ is:

$$x = \frac{M-R}{2t_x+3}$$  \hspace{1cm} 5.35

The demand curves for $y$ and $l$ (which are equal in the first-best case) now are (with $t_y = t_l = 0$):

$$y = l = \frac{1}{2}(M-R-x)$$  \hspace{1cm} 5.36

When a country makes a sidepayment in this first-best case, it is taken directly from the consumer’s budget through a lump sum tax. When a sidepayment is received, it is given to the consumer by means of a lump sum transfer.

The results of a number of simulations are presented in diagrams 5.4 to 5.6 (and their accompanying tables) at the end of the chapter. The $x$-axes show either the marginal damage coefficient or the revenue requirement for country 1. The $y$-axes show the changes for $x_1$, $x_2$ and $x_1+x_2$, which is equal to pollution in both countries, as compared with the equilibrium without sidepayments. Furthermore, the optimal sidepayments are shown.

In diagram 5.4, the revenue requirement for country 1 is varied from 150 to 450 while $R_2$ is set at 300. Marginal damage coefficients for both countries are set at 0.1. When both countries cooperate without sidepayments instead of non-cooperation, taxes on good $x$ increase in both countries and pollution declines. Allowing sidepayments reduces pollution further. The sidepayment is negative as long as $R_1$ is smaller than $R_2$. 

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therefore country 2 pays country 1 as long as government spending in country 1 is lower than in country 2. The reason for this can be found in table 5.1 which shows the consumption levels and tax rates for goods x and y in both countries in the Nash-equilibrium and the cooperative equilibria. In the Nash-equilibrium, the taxes on x are equal in both countries. In the cooperative equilibrium without sidepayments, the Pigouvian tax in the country with the lower revenue requirement is lower than in the other country. In the first-best model examined here, taxes on good x will be equal in the cooperative equilibrium, therefore the country with the lower tax on x in the equilibrium without sidepayments (the country with the lower revenue requirement) will raise its tax on good x while the other country reduces its. The result is that taxes on x will be equal in the cooperative equilibrium with sidepayments, see table 5.1.

It should be noted that the size and sign of the sidepayment depends on the cooperative equilibrium without sidepayments. Here, the Nash-bargaining equilibrium is chosen. However, there are other equilibria which will also leave both countries better off compared with the non-cooperative Nash equilibrium. With another equilibrium as starting point the size and possibly the sign of the sidepayment will change.

In the simulation presented in diagram 5.5, revenue requirements are both set at 300 while the marginal damage coefficient of country 1, a, is varied from 0.9 to 1.1. The marginal damage coefficient in country 2, b, is set at 1. The country with the lower marginal damage coefficient levies lower taxes on good x in both the non-cooperative and the cooperative equilibrium. Consequently this country receives the sidepayment, increases its tax on the polluting good and consumes less of it while the other country decreases the tax on x and consumes more of the dirty good. Using sidepayments will reduce pollution further compared with the cooperative equilibrium without sidepayments.

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6 This is the case because the marginal damage coefficient is set equal in both countries. Consequently, marginal damage is equal, given the levels of x consumed in both countries in the Nash equilibrium. In a first-best world, the Pigouvian tax is equal to marginal damage, therefore taxes are the same in both countries.

7 In the first-best model examined here, revenue is raised through a lump sum tax, therefore the only taxes levied on good x are the Pigouvian taxes. It has been shown in section 3.3 that the Pigouvian taxes are equal in both countries in the equilibrium with sidepayments.
In diagram 5.6, both the marginal damage coefficients and the revenue requirements differ. In country 2, government spending is set at 250. Country 1 has a marginal damage coefficient of 0.95, country 2 of 1. The revenue requirement of country 1 is allowed to vary from 220 to 420. Over the whole range of revenue requirements for country 1, country 2 makes a sidepayment to country 1. The advantage of the lower marginal damage coefficient for country 1 outweighs the higher revenue requirement of country 1, although the sidepayment from country 2 to country 1 becomes smaller the larger \( R_1 \) is (which confirms our earlier findings that an increase in \( R \) reduces the probability that the country will be on the receiving side of the transfer!). Country 2 pays the transfer, reduces \( t_x \) (and consumption of \( y \)). Therefore it can increase its consumption of good \( x \) and therefore its pollution; country 1 receives the transfer, increases \( t_x \) and reduces pollution.

A striking point is that as \( R_1 \) rises above 300, total pollution actually increases. Allowing for sidepayments can apparently mean that in the Nash-bargaining solution pollution is higher than in the equilibrium without sidepayments. This can be explained by looking more closely at what happens in both countries. Reducing pollution more in country 1 and less in country 2 is attractive because marginal damage in country 1 is lower: therefore the welfare costs of reducing pollution are lower in country 1. Consequently, country 2 pays country 1 and consumes more of good \( x \). However, this has the additional effect that the country with the higher revenue requirement (country 1) and therefore lower income increases its income. The positive income effect on consumption of \( x \) will partially offset the reduction in \( x \) brought about by the price effect of a higher tax on good \( x \). In total consumption of \( x \) by the consumers of the two countries will rise and therefore pollution increase. In country 1 welfare increases because it receives the sidepayment. In country 2 welfare increases because it focuses less on emission reduction. This compensates the increase in pollution.

### 5.4.3 Second-Best Analysis

In the second-best simulations, the model described in the introduction of this section is used; consumers maximise utility function 5.29 (which include two goods, \( x \) and \( y \), and leisure \( l \)) under the constraint of 5.30. This implies distortionary taxation:
revenue is raised only through taxing x and y while leisure remains untaxed, therefore prices are distorted and taxation causes a welfare loss in addition to the welfare loss of the income transfer. The first second-best simulation analyses the role of the revenue requirement. In diagram 5.7 (end of the chapter), R₂ is set at 300 while R₁ is allowed to vary from 100 to 500. Marginal damage coefficients are set at 0.1. As can be seen in table 5.4, in the non-cooperative equilibrium and the cooperative equilibrium without sidepayments the price ratio between good x and good y in the low revenue country, px/py (the price is equal to the tax plus the unity price of 1) is larger than the price ratio in the high revenue country. Therefore the low revenue country will pay the other country (the sidepayment is positive as long as R₁ is smaller than R₂) and reduce its tax on x while the other country increases its tax on x and decreases consumption of x. This is in contrast with the first-best case analyzed above (see diagram 5.4).

In this simulation pollution rises, which is in contrast with the first-best case (see page 21). The sidepayment has the additional effect of lowering aggregate deadweight loss of taxation because the country with the lower revenue requirement will raise more revenue while the other country will raise less. This results in an overall higher consumption of x and therefore a higher level of pollution as compared with the Nash-bargaining solution without sidepayments.

In diagram 5.8, the difference between first-best and second-best is illustrated. Both countries have equal marginal damage coefficients (set at 0.1), country 1’s revenue requirement is 200 which is lower than country 2’s (R₂ = 300). The x-axis shows on the left the first-best case and on the right side the second-best case (the whole revenue requirement has to be levied through distortionary taxation). On the left hand side (first-best) country 1, which has the lower revenue requirement, is paid by country 2. As we move towards the right, towards second-best, the sidepayment increases. On the right, country 2, the country with the higher revenue requirement, receives the sidepayment from country 1. Moreover, pollution increases when no lump sum taxes

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8 In this simulation, the revenue raised by the tax on x exceeds the revenue requirements in both countries. The percentage values shown on the x-axis are the percentage of the tax revenue (minus revenue requirement and sidepayment) returned to the consumers through a non-distortionary lumpsum tax. The part of the excess tax revenue which is not restored through the lumpsum tax is returned through a (distortionary) subsidy on good y (a negative tax tᵧ).
are used on the right side of the graph while it decreases on the left side, where lump sum taxes are used.

In diagram 5.9, revenue requirements are held equal at 300 while the marginal damage coefficient in country 1 is varied from 0.7 to 1.2. In country 2, the marginal damage coefficient is 1. The sidepayment is negative. The country with the higher marginal damage (country 2) pays the other country. Pollution declines. The results are the same as in the first-best case, which is not surprising. The country which has a high marginal damage will initially reduce emissions further than the other country, excepting higher abatement costs. When sidepayments are possible, it will do less while it pays the other country to do more.

### 5.4.4 Summary

In this section, simulations have been used to determine the changes in tax structures and pollution when countries cooperate in pollution control. Two types of cooperation have been examined: with and without sidepayments. The cooperative solution analyzed here is the Nash-bargaining equilibrium. Therefore the results derived here only show the role of sidepayments and the changes in tax structures for this specific cooperative solution. The most striking conclusion is that it is not necessarily the case that including sidepayments in cooperative agreements will lead to lower pollution levels compared with cooperative agreements without sidepayments. Simulations show that both in first-best and in second-best models the use of sidepayments can lead to higher pollution levels, although both countries will (necessarily) increase their welfare. This can occur in the first-best models in situations where the revenue requirement in one country is higher while marginal damage is lower than in the other country. In the second-best models, pollution increases when marginal damage coefficients are equal and the revenue requirements differ.

Furthermore, the simulations show that by introducing sidepayments starting from an initial Nash-bargaining equilibrium in terms of cooperatively set tax rates in the first-best case, ceteris paribus, the country with the higher revenue requirement will make the sidepayment. This country will reduce its tax on good x and consume more
of x (and raise its tax on y substantially), while the other country will raise its tax on good x. These conclusions are reversed in the second-best case. The country with the lower revenue requirement will pay the other country. When the two countries are equal except as regards the marginal damage done by the pollution, the country with the lower marginal damage will receive the sidepayment. This holds in both the first-best and the second-best case.

5.5 CONCLUSIONS

In this chapter, it has been investigated how countries can cooperate in reducing transboundary pollution like the enhanced greenhouse effect, which is caused to a large extent by CO2-emissions. In order to take into account the complicating problem that countries already tax fossil fuels, the main source of CO2 emissions, a two country second-best model has been used. The essence of this second-best model is that the authorities have to use distortionary taxation to raise the revenue they need because it is assumed that no first-best non-distortionary taxation can be used. Therefore, the polluting good is already taxed, like the existing taxes on fossil fuels, and an initial second-best solution is assumed to exist before the pollution problem is discovered and a pollution tax is introduced as an instrument to reduce environmental damage. The revenue requirement of each country is assumed to be an exogenous variable (which is not necessarily equal in both countries). The pollution which results from the consumption of the dirty good occurs in both countries, regardless of the country from which it emanates, and reduces welfare. The damage caused in the two countries can differ between the two countries.

The tax on the polluting good can be split up in a Pigouvian tax which is levied to reduce pollution and a Ramsey part which is intended to raise revenue. The main conclusion from the first sections (section 2 and 3) is that countries can increase their welfare when they cooperate in reducing emissions instead of acting on their own. With cooperation they will increase the Pigouvian part of the tax which they levy on the dirty good. However, these Pigouvian taxes differ between the two countries when
their revenue requirements differ.

Cooperation can be extended when countries use sidepayments when they cooperate. In that case, one country pays the other country, reduces its Pigouvian tax and consumes more of the dirty good (and therefore pollutes more) while the other country raises its Pigouvian tax and consumes less of the dirty good. With sidepayments, the Pigouvian taxes in both countries will be equal, even if the revenue requirements and the damage functions differ. The Ramsey taxes however will still differ (with different revenue requirements) therefore the aggregate taxes on the polluting good differ as well between the two countries (this in contrast with cooperation in a first-best world).

Unfortunately, the general model does not tell us how the tax structure in both countries will change when they cooperate (with and without sidepayments). Therefore a more specific functional form has been used (a Cobb-Douglas utility function) to run several simulations with different damage functions and revenue requirements. The cooperative equilibrium analyzed is the Nash-bargaining solution, the results therefore are specific for this cooperative equilibrium. Simulations have been done with both non-distortionary taxation (first-best) and distortionary taxation (the second-best case). An interesting conclusion is that including sidepayments in agreements on emission abatement can actually increase pollution compared with agreements which do not include sidepayments. This can occur both in a first-best and in a second-best world.

The simulations show that in the first-best case, ceteris paribus, the country with the higher revenue requirement (and the higher tax on x) makes the sidepayment. This country reduces its tax on the polluting good and consumes more of it, while the other country raises its tax on the dirty good. These conclusions are reversed in the second-best case. The country with the lower revenue requirement pays the other country and pollution will increase.

When the two countries are equal except as regards the marginal damage done by pollution, the country with the lower marginal damage will receive the sidepayment. This holds in both the first-best and the second-best case.
Diagram 5.4

Cooperation in a first-best world with sidepayments

Diagram 5.5

Coordination in a first-best world with sidepayments
Diagram 5.8

Diagram 5.9
### Table 5.1 Coordination with sidepayments in a first-best world.

<table>
<thead>
<tr>
<th>R1</th>
<th>x1</th>
<th>y1</th>
<th>tx1</th>
<th>x1</th>
<th>y1</th>
<th>tx1</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>419.77</td>
<td>39.16</td>
<td>7.19</td>
<td>421.41</td>
<td>57.63</td>
<td>7.02</td>
<td>-9.5</td>
</tr>
<tr>
<td>200</td>
<td>394.99</td>
<td>38.38</td>
<td>6.83</td>
<td>396.59</td>
<td>57.10</td>
<td>6.71</td>
<td>-6.4</td>
</tr>
<tr>
<td>250</td>
<td>370.20</td>
<td>37.60</td>
<td>6.45</td>
<td>371.77</td>
<td>56.60</td>
<td>6.40</td>
<td>-3.3</td>
</tr>
<tr>
<td>300</td>
<td>345.43</td>
<td>36.80</td>
<td>6.07</td>
<td>346.96</td>
<td>56.13</td>
<td>6.07</td>
<td>0</td>
</tr>
<tr>
<td>350</td>
<td>320.77</td>
<td>35.99</td>
<td>5.68</td>
<td>322.16</td>
<td>55.73</td>
<td>5.74</td>
<td>3.2</td>
</tr>
<tr>
<td>400</td>
<td>295.91</td>
<td>35.17</td>
<td>5.27</td>
<td>297.36</td>
<td>55.41</td>
<td>5.38</td>
<td>6.4</td>
</tr>
<tr>
<td>450</td>
<td>271.16</td>
<td>34.34</td>
<td>4.85</td>
<td>272.57</td>
<td>55.19</td>
<td>5.02</td>
<td>9.5</td>
</tr>
</tbody>
</table>

### Table 5.2 Coordination in a first-best world with sidepayments.

<table>
<thead>
<tr>
<th>MD1</th>
<th>x1</th>
<th>y1</th>
<th>tx1</th>
<th>x1</th>
<th>y1</th>
<th>tx1</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.90</td>
<td>498.25</td>
<td>190.86</td>
<td>1.77</td>
<td>498.67</td>
<td>281.24</td>
<td>1.64</td>
<td>-26</td>
</tr>
<tr>
<td>0.95</td>
<td>498.30</td>
<td>201.64</td>
<td>1.65</td>
<td>498.70</td>
<td>301.46</td>
<td>1.59</td>
<td>-12</td>
</tr>
<tr>
<td>1.00</td>
<td>498.33</td>
<td>212.69</td>
<td>1.54</td>
<td>498.73</td>
<td>322.54</td>
<td>1.54</td>
<td>0</td>
</tr>
<tr>
<td>1.05</td>
<td>498.37</td>
<td>223.89</td>
<td>1.44</td>
<td>498.75</td>
<td>344.52</td>
<td>1.49</td>
<td>12</td>
</tr>
<tr>
<td>1.10</td>
<td>498.40</td>
<td>235.32</td>
<td>1.35</td>
<td>498.77</td>
<td>367.42</td>
<td>1.45</td>
<td>24</td>
</tr>
</tbody>
</table>

---

Table 5.1: Coordination with sidepayments in a first-best world.

\[ R_2 = 300 \quad MD_1 = MD_2 = 0.1 \]

Table 5.2: Coordination in a first-best world with sidepayments.

\[ R_1 = R_2 = 300 \quad MD_2 = 1.0 \]
Table 5.3 Coordination in a first-best world with sidepayments.

<table>
<thead>
<tr>
<th>Country 1</th>
<th>Non-cooperative Nash-equilibrium</th>
<th>Cooperative equilibrium without sidepayments</th>
<th>Cooperative equilibrium with sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>x1</td>
<td>y1</td>
<td>tx1</td>
</tr>
<tr>
<td>220</td>
<td>2.60</td>
<td>388.70</td>
<td>148.67</td>
</tr>
<tr>
<td>260</td>
<td>2.51</td>
<td>368.75</td>
<td>146.20</td>
</tr>
<tr>
<td>300</td>
<td>2.41</td>
<td>348.80</td>
<td>143.73</td>
</tr>
<tr>
<td>340</td>
<td>2.31</td>
<td>328.84</td>
<td>141.23</td>
</tr>
<tr>
<td>380</td>
<td>2.21</td>
<td>308.89</td>
<td>138.71</td>
</tr>
<tr>
<td>420</td>
<td>2.11</td>
<td>288.95</td>
<td>136.14</td>
</tr>
</tbody>
</table>

| Country 2 | | | | | | | | | |
|-----------|------------------|-----------------|------------------|------------------|------------------|------------------|------------------|
| R1 | x2 | y2 | tx2 | x2 | y2 | tx2 | x2 | y2 | tx2 | side |
| 220 | 2.32 | 373.84 | 160.49 | 1.49 | 374.25 | 249.54 | 1.56 | 366.52 | 234.40 | 15.4 |
| 260 | 2.35 | 373.82 | 157.87 | 1.54 | 374.23 | 242.64 | 1.59 | 367.91 | 230.40 | 12.6 |
| 300 | 2.39 | 373.80 | 155.21 | 1.58 | 374.21 | 235.89 | 1.62 | 369.39 | 226.69 | 9.6 |
| 340 | 2.44 | 373.78 | 152.50 | 1.63 | 374.19 | 229.17 | 1.66 | 370.87 | 222.97 | 6.6 |
| 380 | 2.48 | 373.76 | 149.77 | 1.67 | 374.16 | 222.50 | 1.69 | 372.40 | 219.25 | 3.5 |
| 420 | 2.53 | 373.74 | 147.01 | 1.73 | 374.14 | 215.87 | 1.73 | 373.89 | 215.41 | 0.5 |

R2 = 250  MD1 = 0.95  MD2 = 1.0
Table 5.4 Coordination in a second-best world with sidepayments.

R2 = 300  MD1 = MD2 = 0.1
Table 5.5  Coordination with sidepayments, from first- to second-best.
R1 = 200  R2=300  MD1 = MD2 = 0.1

<table>
<thead>
<tr>
<th>Country 1</th>
<th>Non-cooperative Nash-equilibrium</th>
<th>Cooperative equilibrium without sidepayments</th>
<th>Cooperative equilibrium with sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FB x1  tx1  y1  ty1  px/py1</td>
<td>x1  tx1  y1  ty1  px/py1  Side</td>
<td>FB x1  tx1  y1  ty1  px/py1  Side</td>
</tr>
<tr>
<td>0.0</td>
<td>10.03 38.38 394.99 0.00 200</td>
<td>6.83 57.10 396.59 0.00 58.10</td>
<td>6.71 58.56 399.84 0.00 59.56 6.4</td>
</tr>
<tr>
<td>0.1</td>
<td>10.03 37.77 401.15 -0.03 400.00</td>
<td>6.82 55.26 409.24 -0.03 59.03</td>
<td>6.71 57.55 406.44 -0.03 60.53 -6.3</td>
</tr>
<tr>
<td>0.2</td>
<td>10.03 37.16 407.32 -0.06 406.20</td>
<td>6.82 54.35 415.57 -0.09 60.91</td>
<td>6.72 56.46 412.78 -0.06 61.40 -5.8</td>
</tr>
<tr>
<td>0.3</td>
<td>10.02 36.56 413.48 -0.09 412.25</td>
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</tr>
<tr>
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<td>10.02 35.96 419.65 -0.12 418.85</td>
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<tr>
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</tr>
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</tr>
<tr>
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<td>6.80 50.70 440.45 -0.20 64.65 0.5</td>
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<tr>
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<td>6.81 49.57 445.02 -0.22 65.09 2.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country 2</th>
<th>Non-cooperative Nash-equilibrium</th>
<th>Cooperative equilibrium without sidepayments</th>
<th>Cooperative equilibrium with sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FB x2  tx2  y2  ty2  px/py2</td>
<td>x2  tx2  y2  ty2  px/py2  Side</td>
<td>FB x2  tx2  y2  ty2  px/py2  Side</td>
</tr>
<tr>
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<td>5.67 60.18 347.16 0.00 61.18</td>
<td>5.78 58.51 343.91 0.00 59.51 6.4</td>
</tr>
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<td>5.78 58.35 345.02 -0.01 59.72 6.3</td>
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</tr>
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<td>5.76 58.25 347.94 -0.02 60.42 5.1</td>
</tr>
<tr>
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<td>5.68 59.17 352.69 -0.03 62.12</td>
<td>5.74 58.25 349.78 -0.03 60.89 4.1</td>
</tr>
<tr>
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<td>5.73 58.29 351.86 -0.04 61.45 2.9</td>
</tr>
<tr>
<td>0.6</td>
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<td>5.70 58.35 354.32 -0.04 62.21 1.4</td>
</tr>
<tr>
<td>0.7</td>
<td>8.78 37.36 354.20 -0.05 40.31</td>
<td>5.68 58.37 356.83 -0.05 62.77</td>
<td>5.69 58.35 355.27 -0.06 62.93 -0.5</td>
</tr>
<tr>
<td>0.8</td>
<td>8.78 37.20 355.42 -0.06 40.43</td>
<td>5.69 58.09 358.21 -0.06 62.97 -0.5</td>
<td>5.65 58.51 360.41 -0.07 63.77 -2.4</td>
</tr>
<tr>
<td>0.9</td>
<td>8.78 37.04 356.65 -0.06 40.56</td>
<td>5.69 57.81 359.59 -0.07 63.18 -2.9</td>
<td>5.62 58.57 364.03 -0.08 64.74 -4.6</td>
</tr>
<tr>
<td>1.0</td>
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<td>5.70 57.52 360.97 -0.08 63.37 -3.7</td>
<td>5.59 58.58 367.97 -0.09 65.77 -6.9</td>
</tr>
</tbody>
</table>
Table 5.6  Coordination in a second-best world with sidepayments.

R1 = R2 = 300  MD2 = 1.0

<table>
<thead>
<tr>
<th>Country 1</th>
<th>Non-cooperative Nash-equilibrium</th>
<th>Cooperative equilibrium without sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td>x1</td>
<td>tx1</td>
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<tr>
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<td>3.31</td>
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<td>2.92</td>
<td>113.31</td>
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<td>2.60</td>
<td>127.35</td>
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<td>1.0</td>
<td>2.33</td>
<td>141.94</td>
</tr>
<tr>
<td>1.1</td>
<td>2.11</td>
<td>157.05</td>
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</table>

<table>
<thead>
<tr>
<th>Country 2</th>
<th>Non-cooperative Nash-equilibrium</th>
<th>Cooperative equilibrium without sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td>x2</td>
<td>tx2</td>
</tr>
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<td>1.95</td>
<td>169.85</td>
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<tr>
<td>0.8</td>
<td>2.10</td>
<td>158.03</td>
</tr>
<tr>
<td>0.9</td>
<td>2.22</td>
<td>149.82</td>
</tr>
<tr>
<td>1.0</td>
<td>2.33</td>
<td>141.94</td>
</tr>
<tr>
<td>1.1</td>
<td>2.43</td>
<td>136.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country 1</th>
<th>Cooperative equilibrium with sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td>x1</td>
</tr>
<tr>
<td>0.7</td>
<td>2.02</td>
</tr>
<tr>
<td>0.8</td>
<td>1.83</td>
</tr>
<tr>
<td>0.9</td>
<td>1.67</td>
</tr>
<tr>
<td>1.0</td>
<td>1.54</td>
</tr>
<tr>
<td>1.1</td>
<td>1.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country 2</th>
<th>Cooperative equilibrium with sidepayments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td>x2</td>
</tr>
<tr>
<td>0.7</td>
<td>1.40</td>
</tr>
<tr>
<td>0.8</td>
<td>1.46</td>
</tr>
<tr>
<td>0.9</td>
<td>1.51</td>
</tr>
<tr>
<td>1.0</td>
<td>1.54</td>
</tr>
<tr>
<td>1.1</td>
<td>1.57</td>
</tr>
</tbody>
</table>
APPENDIX TO CHAPTER 5: NON-COOPERATIVE NASH-EQUILIBRIUM

Sign of the reaction curve in the non-cooperative Nash equilibrium (section 5.3)

The reaction curve of the non-cooperative Nash equilibrium is given by equation 5.7:

\[
\frac{dt_{x1}}{dt_{x2}} = (y_{1}+y_{ty1}t_{y1})D_{x1x2} x_{tx2} \left[ (y_{1}+y_{ty1}t_{y1})x_{lx1} - (x_{1}+x_{tx1}t_{x1})x_{ly1} \right] \tag{A.1}
\]

\((y_{1}+y_{ty1}t_{y1})\) and \((x_{1}+x_{tx1}t_{x1})\) are the changes in revenue of a marginal change in tax \(t_{x1}\) or \(t_{y1}\), \(\partial R/\partial t\). The Lagrange multiplier \(\mu\) is the change in welfare due to a slight change in the constraint \(R\). A lower revenue requirement means a higher welfare level, therefore \(\mu = \partial V/\partial -R > 0\). \(\mu\) can be written as:

\[
\mu = \frac{\partial V/\partial t}{-\partial R/\partial t} \geq 0 \tag{A.2}
\]

\(V_{t} \leq 0\), therefore \(\partial R/\partial t \geq 0\).

If revenue would rise with a fall in one of the taxes, this tax would not be optimal: lowering the tax would raise the welfare level while at the same time the revenue constraint would be fullfilled as well. Therefore, tax revenue will rise in equilibrium when one of the taxes is raised.

\(D_{x1x2}\) is equal to \(D_{x1x1}\) which was assumed to be negative. \(x_{tx}\) and \(y_{ty}\) are negative in both countries, \(x_{ly1}\) is assumed to be positive (a rise in the price of one good raises demand for the other good). As a result, \(dt_{x1}/dt_{x2}\) is negative.

Existence of the non-cooperative Nash equilibrium (section 5.3)

The existence of the non-cooperative Nash equilibrium is proven by showing that that the equilibrium is asymptotically stable (see Fudenberg and Tyrole 1993, p.24). Sufficient condition for this is that:
\[ U_{1tx1x2} < U_{1tx1x1} \quad U_{2tx2x2} \quad A.3 \]

\[ \Rightarrow D_{1tx1x2} x_{1tx1} x_{2tx2} D_{2tx1x2} x_{1tx1} x_{2tx2} < U_{1tx1x1} \quad U_{2tx2x2} \quad A.4 \]

The second derivatives of the welfare functions on the right hand side of equation A.4 also contain the second derivative of the damage functions. These cancel out the terms on the left hand side. Consequently, A.4 can be written as:

\[ [V_{1tx1x1} + D_{1x1} x_{1tx1x1} + \mu_1 (2x_{tx1} + x_{tx1tx1 tx1} + y_{tx1tx1 ty1})] * \]

\[ [V_{2tx2x2} + D_{2x2} x_{2tx2x2} + \mu_2 (2x_{tx2} + x_{tx2tx2 tx2} + y_{tx2tx2 ty2})] > 0 \quad A.5 \]

Both terms are negative when the utility functions are concave and the constraints are convex. Consequently, inequality A.5 holds and therefore the Nash equilibrium is asymptotically stable.
CHAPTER 6
TRADEABLE PERMITS AND COORDINATION OF ENVIRONMENTAL POLICY IN A SECOND-BEST WORLD

6.1 INTRODUCTION

In the former chapter a two-country model has been used to analyze coordination of environmental policy in a second-best world. In this model a damage function was included to reflect the damage done by polluting emissions like CO₂. However, one of the problems with the greenhouse effect is the uncertainty with regard to the future temperature rise and the even larger uncertainty as regards the damage caused by the rising temperature. Therefore in practice countries formulate their greenhouse policies not on the basis of damage functions; instead they set emission reduction targets. We can introduce these given emission targets in the model of the former chapter in place of the damage function (section 1). Subsequently, it can again be analyzed how the optimal tax structure changes when the two countries cooperate. Using simulations, it is studied how different government budgets and different initial emission quota influence the tax structures in both countries in the cooperative equilibrium (section 3 and 4).

Our main interest in the study of cooperation in a second-best world in the former and the current chapter is to examine the role which economic instruments and especially tradeable permits can play in attaining the optimal cooperative equilibria. This is the subject of section 5. It is studied how international agreements on CO₂ abatement must be designed to take into account the complexities of international cooperation when taxes or TCP’s must both reduce emissions and raise revenue. Another point of interest is one of the recurrent themes of this study: grandfathering vs. auctioning of the permits. At first sight it might be expected that auctioning is to be preferred because the authorities also have to raise revenue: grandfathering permits means that revenue has to be raised in another way. It is examined whether and under what conditions this intuition holds. The chapter ends with an overview of the main conclusions (section 6).
6.2 THE MODEL

The two countries are assumed to be equal except with respect to their (initial) emission limit and the government budget. Our interest is in how these two variables affect the tax structure and the sidepayment when countries cooperate. For one country, the maximisation problem then becomes:

\[
\max V + \mu(x_t + y_t - R) - \eta(x-q)
\]

\(q\) is the limit to the emissions, and thus the limit to the consumption of good \(x\) (as emissions are directly related to the consumption of \(x\)).

The first-order conditions are:

\[
V_{tx} + \mu (x + x_t (t_x - \eta/\mu) + y_{tx} y_t) = 0
\]  
\[6.2\]

\[
V_{ty} + \mu (y + x_{ty} (t_y - \eta/\mu) + y_{ty} t_x) = 0
\]  
\[6.3\]

\[
x_t + y_t - R = 0
\]  
\[6.4\]

\[
x - q = 0
\]  
\[6.5\]

Tax \(t_x\) can be split in the Ramsey tax \(t_x^R\) which is the tax levied when there is no emission ceiling, and a 'Pigouvian' tax \(t_x^p\):

\[
t_x = t_x^R + \eta/\mu
\]  
\[6.6\]

where \(\eta/\mu = t_x^p\). \(\eta\) is the shadow price of the emission reduction, that is of reducing consumption of \(x\) with one unit. In a second-best world, the Pigouvian tax is equal to the shadow price of the emission limit divided by the shadow price of taxation.

The next step is to extend the model and include a second country. An important difference with the analysis in the former sections which included damage functions
is that the first-order conditions for the non-cooperative Nash equilibrium and the cooperative equilibrium without sidepayments are the same. The countries do not affect each other’s welfare level because there are no damage functions and therefore they have no incentive to cooperate by changing the tax structure. The exogenously determined emission ceilings of the two countries, $q_1$ and $q_2$, can be interpreted either as the result of uncoordinated policies: each country sets its own emission quota independently, or as the result of a coordinated policy. As it does not matter how the emission quota are arrived at for the following analysis, no specific assumption will be made.

Although there is no difference between the non-cooperative Nash equilibrium and the cooperative equilibrium without sidepayments, there is still scope for improving welfare in both countries by allowing the use of sidepayments. Such a form of cooperation is nowadays termed Joint Implementation: one country abates less and pays the other country which in turn will reduce its emissions further. Total emissions necessarily remain the same. The consequences for the optimal tax structures in both countries can be determined by establishing the cooperative equilibrium with sidepayments:

$$\max V_1 + \mu_1 (x_1 t_{x1} + y_1 t_{y1} - (R_1 + S)) + \mu_2 (x_2 t_{x2} + y_2 t_{y2} - (R_2 - S)) + \gamma (V_2 - W_2^*) - \eta (x_1 + x_2 - (q_1 + q_2))$$

The first-order conditions are:

$$L_{tx1} = V_{tx1} + \mu_1 (x_1 + t_{x1} x_{ix1} + t_{y1} y_{ix1}) - \eta x_{tx1} = 0$$

$$L_{ty1} = V_{ty1} + \mu_1 (y_1 + t_{y1} y_{iy1} + t_{x1} x_{iy1}) - \eta y_{ty1} = 0$$

$$L_{tx2} = \gamma V_{tx2} + \mu_2 (x_2 + t_{x2} x_{ix2} + t_{y2} y_{ix2}) - \eta x_{tx2} = 0$$

$$L_{ty2} = \gamma V_{ty2} + \mu_2 (y_2 + t_{y2} y_{iy2} + t_{x2} x_{iy2}) - \eta y_{ty2} = 0$$

$$L_{\mu1} = x_1 t_{x1} + y_1 t_{y1} - R_1 = 0$$
When $S > 0$, country 1 pays country 2 (a positive $S$ increases $R_2$ and decreases $R_1$ [equation 6.7]: a transfer from country 1 to country 2). With a negative $S$ it is the other way around. $S$ is positive if initially $\mu_1 < \mu_2$, because a positive $S$ increases $\mu_1$ and decreases $\mu_2$ (equation 6.7) and because $\mu_1 = \mu_2$; the first-order derivative of 6.7 with respect to $S$, equation 6.16. Splitting the tax on good $x$ in a Ramsey and a Pigouvian part, the Pigouvian taxes can be written as:

$$t_{xi}^p = \frac{\eta}{\mu_i}, \quad i=1,2$$  \hspace{1cm} 6.17

As $\mu_1 = \mu_2$ (equation 6.16), the Pigouvian taxes will be equal in both countries. However, the Ramsey taxes will still differ. Therefore total tax on the dirty good will not be the same in both countries. This conclusion is similar to the result in the second-best model with damage functions, section 3. It is in contrast with the result in a first-best world as is indicated in the introduction of this chapter.

How will the sidepayment affect taxes in both countries? When country 1 pays country 2, tax $t_{x2}$ will necessarily increase. A decrease in the revenue constraint on country 2, $R_2$, must raise welfare in country 1. This is only possible when $t_{x2}$ increases and therefore $x_2$ decreases because it allows country 1 to increase consumption of $x$ relative to its initial consumption level of $x$, given the fixed emission limit. In country 1, $t_{x1}$ will fall and consumption of $x_1$ will rise.

Optimisation problem 6.7 yields an equilibrium point in which country 2 has welfare level $W_2^*$ (the constraint on its welfare) and country 1 the highest achievable welfare. Choosing another welfare constraint for country 2 will yield another welfare level for...
country 1. There is a range of equilibria which will leave both countries better off compared with the situation in which no sidepayments are used. This is illustrated in diagram 6.1.

One specific solution is the Nash-bargaining solution, which maximises:

\[(U_1 - T_1)(U_2 - T_2) \text{ s.t. } x_1t_1 + y_1y_1 \geq (R_1 + S) \]
\[x_2t_2 + y_2y_2 \geq (R_2 - S) \]
\[x_1 + x_2 \leq q_1 + q_2 \]

The threat points $T_1$ and $T_2$ are the welfare levels in the equilibrium without sidepayments. Assuming that the Nash-bargaining solution represents the outcome of negotiations on the use of sidepayments and the allocation of its benefits, it can be analyzed who pays whom for different revenue requirements and different initial quota. However, formal analysis does not yield interpretable results. In the next section, simulations will be done using a specific welfare function in order to determine the Nash-bargaining equilibrium for cooperation with sidepayments.

6.3 SIMULATIONS OF THE NASH-BARGAINING EQUILIBRIUM

In the simulations, the Cobb-Douglas function from section 5.4 is used to determine the cooperative Nash-bargaining solution with sidepayments (see for more details section 5.4):
\[
\max (U_1-T_1) (U_2-T_2) \quad \text{s.t. } x_1 t_{x1} + y_1 t_{y1} \geq R_1 + S \quad 6.19 \\
\text{s.t. } x_2 t_{x2} + y_2 t_{y2} \geq R_2 - S \\
\text{s.t. } x_1 + x_2 \leq q_1 + q_2 \\
\]

\[U_i = x^\alpha y^\beta \gamma \quad \alpha=\beta=\gamma=\frac{1}{3} \quad 6.20\]

T_i is each country's welfare level when both countries achieve their emission targets without J.I.

First, the effect of different revenue requirements on the sidepayment is analyzed in a first-best setting. Instead of distortionary taxation, a lump sum tax is used to raise revenue. The result of this simulation is shown in diagram 6.2 (see page 157). The initial emission ceilings or quota for both countries are set at 10, revenue requirement in country 2 is 25, the revenue requirement for country 1 is varied from 20 to 30. As can be seen in table 6.1 (see page 160), the country with the lower revenue requirement levies a higher tax on good x in the initial situation than the other country: given the higher income left for the consumer, the tax on x has to be higher to achieve the quota. When sidepayments are introduced it is therefore more efficient for the country with the higher tax on x to reduce its tax on x and pay the other country to reduce its consumption of x further. Moreover, the country with the lower revenue requirement can afford it better to pay the other country than vice versa because the marginal utility of income is lower as its income is higher.

The second simulation is similar to the first except that revenue has to be raised by distortionary taxation. The result is shown in diagram 6.3 and table 6.2. The price ratio’s between good x and good y (the full price is the tax plus the unity price of 1) show that good x is taxed relatively more in the low revenue country. Consequently the country with the lower revenue requirement pays the other country as in the case of non-distortionary taxation.

Its lower revenue requirement makes it less costly in welfare terms for the low revenue country to make a payment to the other country than it would be the other way round. This argument holds more weight in a second-best world than in a first-best world because the sidepayment has to be raised by distortionary taxation. Indeed, a sidepayment made by the country with the low R to the country with the high R will
have the additional benefit of reducing the overall deadweight loss of taxation. This is shown in diagram 6.4 and table 6.3, which shows the result of a simulation in which country 1 has a RR of 20 and country 2 of 25. The emission quota for both countries are set at initially 10. The x-axis shows the percentage of the revenue which is raised (returned) by lump sum taxes. On the lefthand side of the graph revenue is raised (returned) by a non-distortionary lump sum tax, on the right side distortionary taxation is used. The more distortionary taxation is, the larger is the sidepayment, reflecting the additional benefit of sidepayments in a second-best world. This is shown in table 6.3 in the columns titled ‘ΔU₁’ and ‘ΔU₂’. In these columns the increase in welfare in both countries is given when sidepayments are allowed. In both countries the welfare increase rises as the sidepayment increases. Moreover, the higher the sidepayment is, the larger is the shift in emission reduction from the low revenue country to the high revenue country.

Not only the revenue requirements can differ, but also the emission limits set by both countries. Diagram 6.5 shows the result of a simulation in which country 1 has a lower quota than country 2 (q₁ = 8, q₂ = 10). The revenue requirements are equal at 30. Both first-best and second-best is considered, the percentage of the revenue which is raised by non-distortionary taxation is shown on the X-axis. In both a first-best and a second-best world, the country with the lower emission ceiling and therefore lowest initial consumption of x will pay the other country. As this country faces higher abatement costs in terms of foregone utility of consuming x, it will be advantageous to pay the other country to take on a larger part of the aggregate emission reduction. The burden shift and the sidepayment is smaller the more distortionary taxation is. In a second-best world, the sidepayment has to be raised by distortionary taxation, increasing the welfare costs for the paying country. Because both countries have the same revenue requirement, this is not compensated by a reduction in overall deadweight loss of taxation as is the case when revenue requirements differ.
6.4 SUMMARY OF THE SIMULATION RESULTS

Instead of a damage function exogenously determined emission limits, i.e. consumption quota for x, can be introduced in the model. The Pigouvian tax will then be equal to the shadowprice of this emission limit divided by the shadowprice of taxation. The exogenously determined emission quota of the two countries can be interpreted either as the result of uncoordinated policies or as the outcome of coordination of policy. The countries can achieve higher welfare levels when they jointly implement their reduction of emissions (and consequently consumption of good x). Under J.I., one country makes a sidepayment to the other country which in turn will reduce its emissions further. The Pigouvian taxes will then be equal in both countries.

The simulations show that, ceteris paribus, both in a first-best and in a second-best setting the country which has the lower initial quorum of x and therefore has the highest tax on the polluting commodity or the lower revenue requirement will be the country which makes the sidepayment. This country will lower tx and therefore increase consumption of x while the other country will raise tx and reduce consumption of good x. The sidepayment will be larger in the second-best world when revenue requirements differ because it has the additional benefit of reducing overall deadweight loss of distortionary taxation. This benefit does not occur when only the quota differ and the revenue requirement is equal in both countries. In that case the sidepayment will be lower the more distortionary taxation is.

There is a noticeable difference between the results from the model analyzed in the former chapter (with damage function) and the model considered here (exogenously determined emission ceilings) in the case were marginal damage or emission ceilings are equal and revenue requirements differ. In the "damage" model, the country with the lowest revenue requirement receives a sidepayment from the other country in the first-best case while it pays the sidepayment in the second-best case. With exogenous emission limits, the country with the low revenue requirement makes the sidepayment in both the first-best and the second-best case. This is summarised in table 6.5 below.
Table 6.5 Overview of results

<table>
<thead>
<tr>
<th></th>
<th>first-best</th>
<th>second-best</th>
</tr>
</thead>
<tbody>
<tr>
<td>damage function</td>
<td>high revenue country makes sidepayment</td>
<td>low revenue country makes sidepayment</td>
</tr>
<tr>
<td>emission ceiling</td>
<td>low revenue country makes sidepayment</td>
<td>low revenue country makes sidepayment</td>
</tr>
</tbody>
</table>

Two remarks can be made concerning this difference. First, there is a difference between the non-cooperative Nash equilibrium in the "damage" model and the initial situation in the "emission limit" model. In the "damage" model, the Nash equilibrium is the result of the interaction between the two countries. Therefore, this interaction influences the welfare levels in the non-cooperative equilibrium and therefore the threat points in the Nash-bargaining solution. In the "emission limit" model, the initial situation is not influenced by actions in the other country. Consequently, comparing the two models is not straightforward.

Second, it should be realised that there is a difference between equal marginal damage coefficients and equal emission ceilings. In the latter case, the country with the lower revenue requirement and therefore higher real income has to tax x considerably more to limit emissions. In the former case, equal marginal damage coefficients means that Pigouvian taxes will be equal, given a total consumption of x in both countries. The difference in relative abatement effort is therefore determined by the difference in revenue requirement and not by initial abatement efforts which differ considerably, as is the case in the model with equal emission targets. The two situations, equal ceilings and equal marginal damage functions, are not comparable. The emission ceiling case is better comparable with the case in the damage function model where one country has a higher marginal damage coefficient. That country abates more in the non-cooperative equilibrium and in the cooperative equilibrium without sidepayment.
6.5 THE INSTITUTIONAL SETTING

In the former sections optimal cooperative equilibria and the mechanics and consequences of sidepayments have been examined. In this section we will be concerned with the institutional settings which will make the optimum possible. Deriving the formula’s for an optimum might be an interesting exercise in itself, but it is also important to study how such an optimum can be achieved and what the real world obstacles to such an optimum are. Two types of instruments will be considered: taxes and tradeable emission permits. The cooperative equilibrium studied here is the equilibrium from the quatum case of the former section. This case is more realistic in that countries formulate their greenhouse policies not on the basis of damage functions but by setting emission limits. This implies that we study a world in which the benefits of coordination consist of two elements: reduction of the opportunity costs of scarified consumption of x (abatement costs) and next to that reduction of the costs of raising revenue.

6.5.1 TAXES

In order to achieve (one of) the range of cooperative equilibria determined by the first-order conditions of equation 6.7 (e.g. the Nash-bargaining equilibrium), countries will have to use specific instruments. In the former section, both countries used taxes in order to achieve the agreed upon emission targets. In the cooperative equilibrium of the quatum case, this means that countries agree on a distribution of the abatement effort between them, given their initial reduction quota, and on the necessary sidepayment. Simultaneously, both countries will have to change their tax rates in order to realise their respective emission targets. As has been shown, the new taxes on good x in both countries consist of a (changed) Ramsey tax and a Pigouvian tax which is uniform in both countries.

One way to realise the optimum is to specify in detail in an agreement how countries should change their taxes. It is however difficult to envisage countries accepting such an interference with their sovereignty (see Hoel 1993). A much more acceptable agreement would be to specify the emission reduction targets and the sidepayment, leaving it to the countries themselves to set the tax rates for realising

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their targets. It is straightforward to show that both countries, maximising welfare subject to their new emission constraints and revenue constraints (including the sidepayment), will choose the optimal tax rates\(^1\).

6.5.2 TRADEABLE PERMITS: NATIONAL SYSTEM

In the agreement mentioned above it is not necessary to specify that countries use taxes to realise their emission target. Another possibility is for countries to use a national tradeable emission permit system instead of taxes. The number of permits available is determined by the emission quota. Of course, countries will have to levy taxes as well because they have to raise revenue. Their optimisation problem is:

\[
\text{max } V_i' + \mu_i(x_i t_{xi} + y_i t_{yi} - (R_i + S)) - \eta_i(x_i - q_i) \quad 6.21
\]

where \(S\) is the agreed sidepayment to be made (\(S>0\)) (or received, \(S<0\)). From the first-order conditions for 6.21 (see equations 6.2 - 6.5), the optimal tax \(t_i\) will consist of a tax determined by the Ramsey tax rules, \(t_{xi}\), and a tax equal to \(\eta_i/\mu_i\). This second part of the tax, \(\eta_i/\mu_i\), the 'Pigouvian' part of the tax, is the price of the permits which the consumer would be willing to pay if the authorities would levy the Ramsey taxes and auction the permits.

Another option is to grandfather the permits. This alters the analysis. In the case of auction the consumers’ optimization does not change compared with the taxation case: the price he pays for the permits plus the revenue raising tax on \(x\) is equal to the tax he would have to pay if emissions were limited by means of a tax. However, when he is given permits for free which give him the right to consume a limited amount of \(x\), his maximisation problem will change:

\[
\text{max } U(x,y,l) \quad \text{s.t. } x(1+t_x) + y(1+t_y) + l = M \quad 6.22
\]

\[
q - x = 0
\]

\(^1\) It should be noted that both countries in deciding and agreeing on optimal quota and transfers, simultaneously have decided for themselves (given their tax regime) what their optimal tax rates \((t_x \text{ and } t_y)\) will be.
The quantity of \( x \) is fixed at \( q \) by the number of permits grandfathered, as long as the constraint on \( x \) is binding. This is the case as long as \( t_x \), the tax which the government levies in order to raise revenue, is not higher than the Ramsey tax plus the price which the consumer is willing to pay for the permits (the Pigouvian tax)\(^2\). This tax, \( t_x r + \eta/\mu \), is denoted \( t_x^* \). The first-order conditions are:

\[
U_x - \lambda (1+t_x) - \rho = 0 \quad 6.23
\]

\[
U_y - \lambda (1+t_y) = 0 \quad 6.24
\]

\[
U_l - \lambda = 0 \quad 6.25
\]

\[
y(1+t_y) + 1 = M - q(1+t_x) \quad 6.26
\]

\( \rho \) is the shadowprice of the constraint on \( x \). Conditions 6.24 and 6.25 can be combined, yielding the standard result:

\[
U_y/U_l = (1+t_y)/1 \quad 6.27
\]

Condition 6.27 is the budget constraint. A higher tax on \( x \) means a lower real income for the consumer which he can spend on \( y \) and on leisure \( l \). With \( x \) fixed at \( q \), the tax on \( x \) has the character of a lump sum tax, reducing real income directly. From these first-order conditions demand functions can be constructed for \( y \) and \( l \), \( y(t_y,t_x) \) and \( l(t_y,t_x) \). The authorities maximise the indirect utility function \( V'(t_x,t_y) \) (denoted \( V' \) because it differs from the indirect utility function \( V \) used in the tax model) subject to the revenue constraint \( q t_x + y t_y \geq R+S \). The permit price does not enter as a variable in the indirect utility function which the government maximises: the permits are grandfathered, not sold. The government only has the two taxes on good \( x \) and good \( y \) as variables.

---

\(^2\) Levying a higher tax would be suboptimal. The consumer would take into account the price of good \( x \) as the constraint is no longer binding. In that case, the optimal tax is the combined Ramsey and Pigouvian tax determined in the tax model.
Two cases can be distinguished. The first possibility is that at $t_x = t_x^*$, where $t_x^*$ is the maximum tax which can be levied without reducing consumption of $x$ below $q$, the revenue of the tax on $x$, $(q \cdot t_x^*)$ is lower than $R+S$. In order to fulfil the revenue requirement, a positive tax $t_y$ must be levied next to the tax on good $x$. In this case, the optimal tax $t_x$ is equal to the maximum tax $t_x^*$ which can be levied because it is a lump sum tax which is levied directly on income; a 'Pigouvian' tax is non-distortionary. Setting $t_x$ at a lower level means that $t_y$ must be raised. Tax $t_y$ is a distortionary tax because it is only levied on $y$ and does not affect $l$, it is not a 'lump sum' tax like the tax on good $x$ which affects income and therefore the consumption of both $y$ and $l$. Raising $t_y$ and reducing $t_x$ below $t_x^*$ reduces welfare: less is consumed of good $y$ when $q \cdot t_x^* \leq (R+S)$.

This is illustrated in table 6.6 which presents the result of a simulation. The simulation is done using the Cobb-Douglas function introduced in section 3 of this chapter. The revenue requirement is set at 30 ($S$ is assumed to be zero) and the emission limit is 10. At a tax on good $x$ of 2.333, the consumer will consume exactly this limit quantity; at a higher level of the tax, he will reduce the quantity of $x$ consumed and his welfare will decline. Lowering the tax on $x$ will not increase the quantity of $x$ consumed because of the limit set on consumption by the permits. The tax on good $y$ will rise and less will be consumed of good $y$ (and slightly more of leisure $l$). The consequence is that welfare declines.

Under the condition that $q \cdot t_x^* \leq (R+S)$ the optimal tax rate on good $x$ is therefore $t_x^*$ and tax $t_y$ will be equal to the tax levied in the tax case or when permits are auctioned. In effect, grandfathering permits to the consumer does not differ from selling

<table>
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</tr>
</tbody>
</table>

Table 6.6 Grandfathering in a one-country second-best model I

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them: the tax on x will be raised up to the point where it is equal to the combined price and Ramsey tax in the auction (or tax) case. The income transfer to the consumer of the grandfathered permits will therefore be fully taxed away. In other words the (shadow)price of tradeable permits is zero.

<table>
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<tr>
<th>tx</th>
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<th>y</th>
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<td>23,046</td>
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</table>

Table 6.7 Grandfathering in a second-best model II

The other possibility is that the revenue of the maximum tax $t_x^*$ exceeds $R+S$. The excess revenue could be returned to the consumer either by means of the tax on good y (which would be negative, a subsidy) or by lowering tax $t_x$. A subsidy on good y would distort the price ratio between good y and good l and therefore reduce welfare compared with grandfathering: grandfathering raises the income of the consumer directly and therefore affects consumption of both y and l. Therefore, when $q t_x^* > R+S$, the tax on x should be lowered while $t_y$ is set at zero. A simulation similar to the one presented above illustrates this, see table 6.7 The simulation is the same except that the revenue requirement is now set at 20 instead of 30. Consequently, tax $t_x^*$ (2.333) now raises excess revenue which has to be refunded to the consumer through a subsidy on good y of 0.091. Welfare is 23.035. Increasing the tax on x reduces consumption of x, consequently welfare decreases. Decreasing the tax on x does not increase consumption of x because of the limit imposed by the permit system. It does increase welfare because more of l is consumed and less of y. The optimal tax on x is such that no excess revenue is raised. At this point, the tax (or subsidy) on good y is zero and equal quantities of y and l are consumed.

The conclusion is that (under the condition that $q t_x^* > R+S$) grandfathering permits is more attractive than a full tax on good x because the excess revenue which would be raised by the tax needed to reduce emissions can be avoided. Instead, a lower tax
can be levied on x to raise revenue because the quantity of x which is consumed is now limited by the number of permits made available.

Which of the two situations occurs depends on emission ceiling $q$ and the revenue requirement $R$. In the case of carbon emission reduction, it is plausible to assume that the revenue of the carbon tax needed to achieve the emission targets which have been accepted by several countries (stabilisation of emissions) will not exceed their budgets. *Consequently, there is no difference between either selling the permits or grandfathering them and charging the full tax.*

### 6.5.3 Tradeable Permits with Auctioning: An International System

Instead of a national system of tradeable permits, trade in permits can be allowed between the countries. International tradeability means that the government in each country sells a number of permits that equals its internationally agreed quota. The consumer of one country can buy permits in both its own and in the other country. In that case the price of the permits will be equal in both countries. An optimal solution is that both countries levy taxes on the consumption of x equal to the taxes which they would levy in a national system (these taxes on x are equal to the Ramsey taxes in a tax system). In that case the permit price is equal to the "Pigouvian tax", which as was shown above is equal in both countries (see equation 6.17).

How could such an equilibrium come about? A first possibility is that countries cooperate and have agreed on the following items: (1) sidepayments to be made and received, (2) (redistribution of) quota, (3) the level of Ramsey taxes for each country. Since the permit price would equal the Pigouian tax level in separate national permit markets the same permit price will be realised if the two markets are integrated to one international market. We shall compare this outcome with a second possible solution

---

3 In a first-best world, it doesn’t matter whether permits are auctioned or grandfathered. If auctioning yields excess revenue, it can be returned through either a lumpsum tax or proportional excise taxes on good y and l. If the revenue of auctioning is less than the government revenue requirement, or if the permits are grandfathered, revenue can be raised through lumpsum or excise taxes. In each instance, the optimal levels of y and l will be consumed.

4 They can either be bought directly from the other government, on the primary market, or indirectly from the consumer in the other country, the secondary market (see chapter 2).
where both countries make an agreement on sidepayments and quota, but make no binding agreement on the level of their respective (Ramsey) taxes.

The question which arises is whether in this second case there would be an incentive to levy a tax which is different from the optimal ramsey taxes. To explore this question, assume that the two countries cooperate in limiting emissions and agree on quota and sidepayments but are left to free to set their own taxes. Let $q_1$ be the quota allotted to country 1 and $S$ the sidepayment it will receive (or pay if it is negative). Consequently, country 1 will maximise:

$$W_1(t_{x1},t_{y1},P(t_{x1},t_{x2},q_1^1+q_2^1)) + \mu_1[x_{11}t_{x1} + y_{11}t_{y1} + P(t_{x1},t_{x2},q_1^1+q_2^1)q_1 - (R_1+S)]$$

Country 2 will maximise a comparable welfare function, given its agreed upon quota and the sidepayment. The indirect welfare function has changed, because welfare will also be a function of $P$, the permit price. An increase in $P$ will decrease demand for the permits and for good $x$ and consequently influence the welfare level. The revenue constraint includes the sidepayment and the revenue of the sale of the permits, $Pq_1$.

The price of the permits $P$ is determined by the demand and supply for the permits:

$$x_{11}(t_{x1},P) + x_{22}(t_{x2},P) = q_1 + q_2$$

From this implicit function, price $P$ is determined as a function of the emission limit and the taxes levied in both countries on good $x$, $t_{x1}$ and $t_{x2}$. Differentiating the market equilibrium condition yields:

$$\frac{dP}{dt_{x1}} = - \frac{x_{11}t_{x1}}{(x_{1p}+x_{2p})} < 0 \quad (>-1)$$

Equation 6.30 states that a rise in tax $t_{x1}$ decreases the equilibrium permit price on the international market (see the appendix to this chapter for the necessary conditions for

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5 It's assumed that demand is independent, therefore a change in tax $t_{y1}$ does not affect demand for $x_1$.  

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and proof of the existence of an equilibrium). One might view this process as a two-stage game, the first game being a cooperative game yielding permit quota (to be sold by each of the governments) and sidepayment, the second game being a non-cooperative game in which countries react to changes on the permit market resulting from changes in each other’s taxes.

In order to see whether this second stage non-cooperative game yields a different equilibrium from the first cooperative stage or not, the Cobb-Douglas utility functions from the former section are used to simulate this two-stage game (see section 3 of this chapter). Consequently, in the first stage of the game, the two countries maximise:

\[(V_1 - T_1)(V_2 - T_2) \text{ s.t. } x_{1,t_1} + y_{1,t_1} \geq R_1 + S \]
\[x_{2,t_2} + y_{2,t_2} \geq R_2 - S \]
\[x_1 + x_2 \leq q_1 + q_2 \]

with \[V_i = x(t_{x} + P)^\alpha y(t_{y})^\beta l^\gamma \] \[\alpha = \beta = \gamma = \frac{1}{3} \text{ i=1,2} \]

The demand functions for \(x\) and \(y\) are found by maximising \(U(x,y,l)\) subject to the consumers’ budget constraint \(x(1+t_{x} + P) + y(1+t_{y}) + l = M\) (M is set at 100). This optimisation yields the cooperative (Nash-Bargaining) equilibrium, analyzed in section 5 given the welfare levels in the non-cooperative Nash equilibrium \(T_1\) and \(T_2\).

In the second stage, both countries maximise their own welfare, given the emission quota \(q_1^*\) and \(q_2^*\) and the sidepayment \(S^*\) agreed upon in the cooperative equilibrium in the first stage (see equation 6.28):

\[\max V_1 = x(t_{x1}, P(t_{x1,t_2}))^\alpha y(t_{y1})^\beta l^\gamma \text{ s.t. } x_{1,t_1} + q_1^* P + y_{1,t_1} \geq R_1 + S^* \]
\[x_1 + x_2 \leq q_1^* + q_2^* \]

The second constraint is the permit market equilibrium condition (see equation 6.29). For the Cobb-Douglas function used here, \(x_1 = M/(1+t_{x1}+P)\). The permit market equilibrium becomes:

---

6 The sign of the reaction curves can be both positive or negative (see appendix). It is not possible to determine analytically whether the two equilibria differ.
\[
\frac{M_1}{(1+t_{x_1}+P)} + \frac{M_2}{(1+t_{x_2}+P)} = q_1^* + q_2^*
\]

Equation 6.33 is an implicit function which determines \( P \) as a function of \( t_{x_1} \) and \( t_{x_2} \). Therefore, changing tax \( t_{x_1} \) will have consequences for the permit price, as is described above (page 45). Governments do not set the permit price directly, it is a result of the tax level they choose and the level of the tax on good \( x \) in the other country. Each country maximises welfare by choosing the level of taxes \( t_x \) and \( t_y \), given the level of \( t_x \) in the other country. The non-cooperative Nash-equilibrium is at the point where neither country can improve welfare, given the other country’s tax on good \( x \).

Table 6.8 shows the results of the first simulation, in which initially (before the first cooperative stage) \( R_1 = 40, R_2 = 20, q_1 = q_2 = 10 \). With cooperation, the sidepayment \( S \) is -3.01: country 1 is paid to reduce consumption of \( x \) further (see section 3). The first column for each country gives the values for \( x, t_x, P, y, t_y \) and the welfare level \( U \) in the initial non-cooperative Nash-equilibrium. The second column shows the results in the cooperative (Nash-bargaining) equilibrium, the first stage of the game defined above. In these first two equilibria, there is no international permit market. In both countries, either a tax is levied or permits are sold. Tax \( t_x \) is the full tax on \( x \) (the Ramsey tax and the Pigouvian tax) or the Ramsey tax and the permit price \( P \) (which is equal to the Pigouvian tax). Necessarily, cooperation increases welfare as can be seen in the table; country 2 pays country 1 and increases its own consumption of \( x \) while country 1 reduces the quantity of \( x \) consumed.

The third columns shows the consequences of allowing trade in permits between the two countries after they have agreed to cooperate (the last column for each country is explained below). This is the second (non-cooperative) stage, in which countries maximise welfare given the agreed upon emission quota and the sidepayment of the first cooperative stage. The final equilibrium does not differ from the first-stage cooperative equilibrium. Both countries consume the same amount of \( x \) and the combined tax and permit price equals the tax on good \( x \) which they levied in the first stage. Welfare achieved is equal to the welfare level in the first stage. Tax competition by means of the influence of their taxes on the permit price does not lead to lower welfare levels. Consequently, agreements on emission reduction in a second-best world can include a system of international tradeable permits without welfare loss. (It should
however be noted that there is no incentive to trade: the consumer in each country uses a number of permits equal to the quota of its own country and the price of the permits is equal in both countries without the need of arbitrage between the permit markets. Allowing trade in permits between the two countries might not decrease welfare, but neither does it increase welfare.

Table 6.8 Simulations of international tradeable permit systems I

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<th></th>
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</tr>
</thead>
<tbody>
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</tr>
<tr>
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</tr>
<tr>
<td>transfer</td>
<td>-3.01</td>
<td>-3.01</td>
</tr>
</tbody>
</table>

Why is the non-cooperative equilibrium of the second stage of the game equal to the cooperative equilibrium of the first stage? First of all, when the permits are tradeable, countries will have an incentive to lower their tax on good x. This will increase the price of the permits (see equation 6.29), reducing consumption of x in the other country. The impact of the tax decrease on revenue will outweigh the price increase:

\[
\frac{d(t\textsubscript{x}+P)}{dt\textsubscript{x}} = -\left(1+\frac{dp}{dt\textsubscript{x}}\right) = -\left(1 - \frac{x\textsubscript{1t}\textsubscript{x}}{(x\textsubscript{1P}+x\textsubscript{2P})}\right) < 0
\]

Consequently, x\textsubscript{i} increases and, up to a certain point, welfare increases. The burden of limiting the consumption of x (and emissions) can be shifted more towards the other country by reducing the tax on x. An increase in t\textsubscript{x} would have the opposite effect: it would reduce x and therefore reduce welfare.

However, there is a limit to the welfare increase which can be realised by reducing the tax on x. This limit occurs here because of the revenue which has to be raised through taxes and the auctioning of the permits. At a certain point, a further reduction
in $t_{x1}$ increases $x_1$ above the permit quota of the own country, $q_1^*$. Consequently, the revenue raised by the tax on $x$ and the auction will not only fall because of the fall in $(t_{x1} + P)^7$, but also because some permits have to be bought from the other country: $P(x_1 - q_1^*)$ is going abroad. This loss of revenue has to be compensated by higher taxes on $y$ and a lower consumption of $y$, which will have a negative influence on welfare. In the simulation presented above (and in those presented below) this negative welfare consequence is such that reducing the tax on $x$ beyond this point decreases welfare and therefore is not attractive.

It is now straightforward to see why the first stage cooperative equilibrium is the point at which it is not attractive any more for either country to reduce its tax on $x$ further. In the first stage cooperative equilibrium, the permit market is in equilibrium and each country consumes the quantity of $x$ which is covered by the quota agreed upon for that country. Reducing $t_x$ would increase consumption of $x$ above this quota and result in a loss of revenue to the other country. Therefore neither country can increase its welfare level by reducing $t_x$ at this point. Increasing tax $t_x$ also reduces welfare, therefore neither country can improve welfare at this point, given the tax on good $x$ levied in the other country. The first stage cooperative equilibrium is therefore also the second stage Nash equilibrium.

In the two-stage game described above, countries first agree to cooperate in realising the combined emission limit while subsequently trade is allowed, given the agreed upon emission quota and sidepayment. Another option is that instead of cooperating first on quota and sidepayment, both countries simply allow trade in permits between the two countries. In a first-best analysis, emission trading will minimise abatement costs (and maximise welfare) in both countries. This option is simulated as well, using the same functions and procedure as above with this difference that the emission quota are the initial non-cooperative quota and that there is no sidepayment. In the simulation presented above, $q_1 = q_2 = 10$. The results are shown in the last column (for both countries) in table 6.1. In both countries, the welfare levels achieved are higher than without trade (the first columns) but neither country realises a welfare level as high as in the coordinated equilibrium (second and third column). In this equilibrium, country

---

7 Revenue increases with a rise in taxes $t_x$ and $t_y$, see appendix.
1 consumes less than its initial quota while country 2 consumes more. As a result, there is a "sidepayment" from country 2 to country 1: country 2 consumes 11.15 of x and therefore has to buy 1.15 permits in the other country. At the price of 1.53 per permit this is a transfer of 1.76 from country 2 to country 1. This transfer however is less than the sidepayment in the cooperative agreement (which is -3.01). Allowing trade in the permits is an improvement to no trade, but it does not realise the welfare increase which is achievable under a cooperative agreement.

Table 6.9 and 6.10 present the results of two other simulations which underwrite the conclusions from the first simulation. The initial quota, revenue requirements and the transfer (sidepayment) between the countries are shown in the tables. A positive sidepayment or transfer means that the country pays the other country, a negative transfer indicates the receipt of a sidepayment.

<table>
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Table 6.9  Simulations of international tradeable permit systems II
Table 6.10  Simulations of international tradeable permit systems III

<table>
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<td>-2.53</td>
<td>-1.49</td>
<td>2.53</td>
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6.6 CONCLUSIONS

In the second-best two-country model of the former chapter, the optimal level of consumption of the polluting good, and therefore of pollution, was determined endogenously, given the damage function. Another approach, followed in this chapter, is to assume exogenously set emission ceilings for both countries instead of damage functions. The only way in which welfare can be increased is by joint implementation: the countries jointly implement their emission targets. One country makes a sidepayment to the other country which in turn will reduce consumption of the dirty good (and therefore its emissions) further. The Pigouvian taxes, which in this model are based upon the shadow price of the emission limit, are equal in both countries when they use joint implementation. It is shown that, like in the case of welfare maximisation, the Pigouvian taxes will be equalized but total tax on the polluting good will differ in a second-best world.

Again, simulations have been used to analyze the consequences of different revenue requirements and different initial emission quota on the sidepayment and the tax structure. These simulations show that, ceteris paribus, both in a first-best and in a second-best setting the country which has the most stringent emission limit and
therefore the highest tax on the polluting commodity is the country which makes the sidepayment. This country will lower the tax on the polluting good and therefore increase consumption while the other country will raise its tax and reduce consumption and pollution.

When only the revenue requirements differ, the country with the lower revenue requirement and the highest absolute tax on the polluting good will pay the other country, both in the first-best and in the second-best case. In both cases, realising the same emission limit is more costly in welfare terms in the country with the lower revenue requirement. Given the higher real income in this country, a higher tax on good x is needed to realise the emission limit. It is therefore more attractive for this country to pay the country with the higher revenue requirement and to consume more of good x itself. In the second-best world, the sidepayment will be larger because it has the additional benefit of reducing overall deadweight loss of distortionary taxation. This benefit does not occur when only the quota differ, therefore in that case the sidepayment will be lower the more distortionary taxation is.

Our main objective of the study of international coordination of environmental policy in a second-best world is to establish which institutions are necessary to realise the optimal tax structures. Can taxes and systems of tradeable emission permits be used, either alone or in combination, and be designed in such a way that the optima are realised? The analysis of the institutional requirements for an optimal agreement yields several insights. The first conclusion is that both in national and international systems of tradeable emission permits there is no difference between auctioning or grandfathering of the permits. In the case of grandfathering the optimal tax on the polluting good equals the tax plus the price of the permits when they are sold. To put it in a different way, the rent obtained by the gift of the permits is fully taxed away and the permit price is zero under grandfathering. Therefore, the welfare effects of either grandfathering or auctioning are similar in this second-best model. One qualification should be mentioned; this conclusion only holds as long as the revenue of the maximal tax which can be levied on the dirty good without reducing consumption below the consumption limit does not exceed the total revenue requirement of the government. When the revenue of auctioning (which is equal to the
revenue of the maximal tax) exceeds the revenue requirement, welfare can be increased by grandfathering the permits and taxing the polluting good at a lower rate. However, in the case of carbon taxes (and other environmental taxes) this reservation will not be a problem.

Second, it suffices to specify the sidepayment and emission targets in a cooperative agreement; it is not necessary to specify the taxes which each country has to levy. It can be left to the countries themselves to set taxes or use a national system of tradeable permits. Given the emission targets and the sidepayment agreed upon, each government will set the optimal tax rates and the national permit markets will be in equilibrium at the optimal permit price. This is one of the attractive points of specifying emission limits in international agreements. Countries will ‘automatically’ set optimal taxes as long as they fulfil their treaty obligations.

In the second-best model considered here, an international permit system can be used which allows trade in permits between the two countries. It has been shown that with internationally tradeable permits countries have to agree only on the sidepayment and (redistribution of) quota and can be left free in setting their revenue raising tax. Although tax competition is allowed governments will set the tax at the level of the (optimal) Ramsey tax. Allowing trade in permits between the two countries does not reduce welfare. However it should be noted that in each country the quantity of the polluting good consumed is equal to that countries’ emission limit. Allowing transboundary trade in emission permits may not be harmful, but neither is it useful in reducing the welfare costs of pollution abatement.

Instead of this two-stage approach, trade in permits between the two countries could be allowed starting from national emission limits for each country without first agreeing on emission limits and sidepayments. Simulations show that, as might be expected, this will increase welfare in both countries compared with the situation in which countries do neither coordinate their emission reduction policies nor allow trade in permits. However, in neither country does it achieve the welfare levels which are realised when countries explicitly cooperate. In the second-best model studied here an international system of tradeable emission permits without initial coordination might therefore be termed a second-best policy, second-best to explicit coordination of emission reduction policies.
Diagram 6.4

Diagram 6.5
Table 6.1 Coordination with sidepayments, emission limits in a first-best world. \( R_2 = 25 \quad q_1 = q_2 = 10 \)

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In the initial situation, \( x_1 \) and \( x_2 \) equal \( q_1 \) and \( q_2 \).
Table 6.2 Coordination with sidepayments, emission limits in a second-best world.

In the initial situation, $x_1$ and $x_2$ equal $q_1$ and $q_2$.  

$R_2 = 25$  \quad $q_1 = q_2 = 10$  

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Table 6.3 Coordination with sidepayments, emission limits, from first- to second-best.

\[ R_1 = 20 \quad R_2 = 25 \quad q_1 = q_2 = 10 \]

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In the initial situation, \( x_1 \) and \( x_2 \) equal \( q_1 \) and \( q_2 \)  
* fraction second-best; 0 = firstbest, 1 = secondbest
Table 6.4 Coordination with sidepayments, emission limits, from first- to second-best.

<table>
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</tbody>
</table>

* \(frc^*\) is fraction secondbest
in the initial situation, \(x1\) and \(x2\) equal \(q1\) and \(q2\)

Table 6.4 Coordination with sidepayments, emission limits, from first- to second-best.

\[ R1 = R2 = 30 \quad q_1 = 8 \quad q_2 = 10 \]
APPENDIX TO CHAPTER 6: TWO-STAGE PERMIT GAME

Sign of the reaction curve in the two-stage coordination and permit market game

The reaction curve for country 1 can be determined by looking at the effects on the first-order conditions for problem 6.28 of a small change in tax \( t_{xj} \). The optimisation problem (equation 6.28) is:

\[
W_1(t_{x1}, t_{y1}, P(t_{x1}, t_{x2}, \Sigma q)) + \mu_1[x_1 t_{x1} + y_1 t_{y1} + P(t_{x1}, t_{x2}, q_1 + q_2) \cdot q_1 - (R_i + S)]
\]

B.1

The first-order conditions are (assuming independent demand):

\[
W_{tx1} + \mu_1[x_{tx1} t_{x1} + x_1 + P_{tx1} \cdot q_1] = 0
\]

B.2

\[
W_{ty1} + \mu_1[y_{ty1} t_{y1}] = 0
\]

B.3

\[
x_1 t_{x1} + y_1 t_{y1} + P_1 q_1 - (R_i + S) = 0
\]

B.4

Totally differentiating the first-order conditions yields the Hessian matrix:

\[
H = \begin{bmatrix}
a & x & b \\
y & c & d \\
b & d & 0
\end{bmatrix}
\]

B.5

with the following notation (for the signs see above):

\[
a = W_{tx1tx1} + \mu(2x_{tx1} + x_{tx1tx1} t_{x1} + P_{tx1tx1} q_1) < 0
\]

\[
c = V_{ty1ty1} + \mu(2y_{ty1} + t_{y1} y_{ty1ty1}) < 0
\]

\[
b = x + x_{tx1} t_{x1} + P_{tx1} q_1 > 0
\]

\[
d = y + y_{ty1} t_{y1} > 0
\]

\[
x = W_{tx1ty1} > 0
\]
\[ y = W_{tylx1} > 0 \]

\[ x^1_{lx2} > 0, x^1_{lx1lx2} < 0, P_{tx1} < 0, P_{tx1lx2} = P_{tx1lx1} > 0 \]

Assuming concavity of both the utility function \( W_1 \) and the revenue function \( x_1 + t x_1 + y_1 + t y_1 + P q_1 \) in \( t x_1 \) and \( t y_1 \); \( a \) and \( c \) are negative and \( b, d, x \) and \( y \) are positive. The determinant of the Hessian is \( bd(x+y)-(ad^2+b^2c) \), which is positive (which it should be if the optimum is to be a maximum).

Differentiating the first-order conditions with respect to \( t x_2 \) yields:

\[ [W_{tx1lx2} + X_{tx1lx2} + x_{tx2} + P_{tx1lx2} q_1] dt x_2 = p_1 dt x_2 = 0 \]  \( B.6 \)

\[ [x^1_{tx2} t x_1 + P_{tx2} q_i] dt x_2 = p_2 dt x_2 = 0 \]  \( B.7 \)

\[ W_{tx1lx2} = U_{x1} [x_{tx1} x_p P_{tx2} + x_p P_{tx2} P_{tx1} + x_p P_{tx1lx2}] < 0 \]  \( B.8 \)

Using comparative statics, the effect of a change in \( t x_2 \) on \( t x_1 \) is given by:

\[ \frac{dt x_1}{dt x_2} = \frac{(dx-bc)p_2 - d^2 p_1}{H} \]  \( B.9 \)

\( p_1 \) and \( p_2 \) can be either positive or negative. It can therefore not be established whether \( \frac{dt x_1}{dt x_2} \) is positive or whether it is negative.

**Existence of the market equilibrium**

Under certain conditions the non-cooperative Nash equilibrium exists in this second game. Following the theorem formulated by Debreu, Glicksberg and Fan (Fudenberg & Tirole 1993), sufficient conditions for the existence of a Nash equilibrium are that the pay-off functions, the utility functions of each player, are continuous in the strategies which can be played (the taxes on good \( x \) and \( y \) in both countries) and quasi-
concave in each country’s own strategies $t_{xi}$ and $t_{yi}$. Furthermore, the strategy spaces should be compact and convex.

It was assumed above that the utility functions are concave. Moreover, they will be continuous. The strategy space will be compact and convex if it is closed and bounded. Or, there should be an upper and a lower bound to the possible strategies. Let the revenue function $(x_{t_{xi}} + y_{t_{yi}})$ be concave with $\partial R/\partial t > 0$ up to a certain point and $\partial R/\partial t < 0$ for higher taxes. Consequently, at a certain tax level a further tax raise decreases the revenue raised. There will therefore be tax levels which are so high that they cannot be best responses. Moreover, there will also be a lower limit because if taxes are set too low, the revenue constraint will not be met either. The strategy space is therefore closed and bounded.
CHAPTER 7
CONCLUSIONS

Economists have pointed out the suitability of economic instruments like taxes and tradeable emission permits for reducing CO₂ emission because with these instruments emissions are abated at minimum costs. Less attention has been paid to the practical design of instruments, in particular to the design of a system of tradeable carbon permits. One of the aims of this study has been to fill this gap, describing in detail the requirements of a feasible system of tradeable carbon permits for the European Union. In addition to the design of a system of TCP’s, the consequences of implementing such a system have been studied, concentrating on the effect which TCP’s might have on entry into industries, a subject which so far has received little attention in the literature.

The enhanced greenhouse effect occurs worldwide, therefore the problem arises of coordination of policies. As a third subject it has been analyzed whether and how countries can cooperate in reducing emissions and what the role of taxes and TCP’s can be in an international setting, taking into account the complication that fossil fuels are already taxed in most countries. Moreover, it has been studied how this might affect the optimal design of a system of TCP’s.

Two themes are recurrent in this study. The first theme is the choice between grandfathering and auction of the permits. This choice is important in designing a feasible system of TCP’s, it can affect entry barriers and it has consequences for the revenue which governments raise when they use tradeable permits. The other theme is the comparison between on the one hand TCP’s and on the other hand carbon taxes and command-and-control type of regulation like emission standards.

A main conclusion is that it is possible to design a feasible system of TCP’s. An important element of such a system is the distribution of the permits. From a political economy point of view it is attractive to grandfather permits to sources of CO₂ because the negative impacts on the cash flow of firms will be considerably
smaller with grandfathering than with auction of the permits or with emission charges. With grandfathering firms as a group will only have to make expenditures for the abatement costs. Especially for the energy intensive sectors of industry, permit expenditure will be several times larger than the abatement costs. Therefore, tradeable carbon permits will be politically more acceptable than a tax or auction of permits, making a system more feasible. However, a distinction is made between industrial and other sources. The permits for the other sources are auctioned by the government. In order not to trouble households and other small fuel users with the necessity to buy permits these can be sold instead to suppliers of fossil fuels, who can subsequently mark up their fossil fuel prices with the price of the permits.

A system of tradeable permits, and indeed any other instrument, is only feasible when there is adequate monitoring and enforcement. Our system of TCP’s can be monitored and enforced by obliging importers and producers of fossil fuels to hand over carbon permits to the authorities for the carbon contained in the fossil fuels which they bring onto the market. This considerably limits the number of firms which have to be monitored and makes it possible to use existing procedures for levying excise taxes on fossil fuels.

Within the context of the EU, the question arises whether TCP’s can be implemented in one MS of the EU or whether it should be implemented at the European level. Introducing the TCP-system at the European level poses no problems. It also seems to be possible to implement a system in one MS because so far there is no European CO₂ reduction policy. TCP’s will probably fall under the ‘rule of reason’ which allows exemptions to article 30 EG which deals with free movement of goods.

The second question dealt with in this study is whether tradeable permits will create entry barriers. The conclusion is that entry barriers can occur when tradeable permits are introduced. Three types of entry barriers have been identified which in theory are affected by tradeable permits. First, transaction costs on the permit market can have consequences for entry in the limit pricing model. Second, capital markets might not work perfect, in which case grandfathering puts incumbent firms at an advantage. Third, firms can try to make it more expensive for entrants to
acquire permits by driving up the price of the permits, thereby reducing entry.

It should be noted that grandfathering permits to the established firms does not necessarily create entry barriers in the sense of creating a cost advantage for the firms. Grandfathered permits have an opportunity cost when they are used. These opportunity costs are equal to the price for which they can be sold and therefore established firms do not have a cost advantage over entrants just because they received permits for free.

Transaction costs, which can occur on the permit market (born by either the buyer or the seller of permits or both), can affect entry barriers in the limit pricing model. The limit pricing model is a two-period (Stackelberg) game in which the incumbent firm invests in the first period, taking into account how the potential entrant will react in the second period. In this way he influences the output of the entrant in the second period. It might also be profitable for the incumbent to deter entry completely. The occurrence of transaction costs on the permit market can make it more attractive for the established firm to deter entry or it can reduce the size at which the entrant will enter.

An extreme form of entry barrier can occur when a firm or group of firms controls a vital input and excludes other firms from the use of this input. This will force these firms to use less optimal and more expensive substitutes and reduce their competition, or even exclude them completely from the market. Exclusionary manipulation can also occur on the permit market when one or a small group of established firms can control the price of permits and thereby drive up the costs of potential entrants.

Neither the transaction cost barrier nor exclusionary manipulation do seem to be very relevant for our system of TCP’s. The main reason for this is that the market for carbon permits is a large market with many potential actors from most sectors of industry. It is therefore probable that a well-functioning market will develop with low transaction costs, reducing the effect transaction costs might have on entry barriers. Moreover, it will be very costly for a firm to use the permit market to drive up the costs of rivals because of the large size of the market.

The most relevant type of entry barrier with respect to our system of TCP’s occurs when capital markets do not work perfectly and established firms receive
their permits through grandfathering. According to the long purse theory, an incumbent firm can drive a potential entrant out of the market by means of a price war if its financial resources are larger. Ceteris paribus, grandfathering permits to established firms and selling them to newcomers means that the incumbent has larger financial resources because grandfathering permits is in effect equal to making a capital gift. Therefore an incumbent firm can outlast the entrant in a price war. Given imperfect capital markets, grandfathering can effectively reduce entry.

In empirical studies it is found that capital requirements are a significant determinant of entry barriers. It has been estimated for the Dutch economy by how much a system of tradeable carbon permits will increase the capital requirements of new firms, assuming that entrants acquire at least one year’s stock of permits before they enter a market. As is to be expected, energy intensive industries are most affected although the increase in their capital requirements is modest, at most 1.7 percent (in the petroleum industries). Entry might be reduced when capital markets do not work perfect and permits are grandfathered, but probably only to a small extent.

The last question posed at the start of this study was how countries can cooperate in reducing transboundary pollution like CO₂-emissions and how cooperation of environmental policies will influence the optimal design of instruments like taxes and TCP’s. A two country model has been used which takes into account the complicating problem that countries already tax fossil fuels for other reasons than reducing CO₂ emissions. The simple economy modelled consists of one consumer who can consume two goods, one of which causes pollution when it is consumed. In addition the consumer chooses how much time he will work (and earn income) and how much leisure he will enjoy. The government has to raise an exogenously determined amount of revenue and reduce pollution by means of taxes (or tradeable permits) on the two goods. This second-best model is used to establish which combinations of instruments will maximise welfare in the two countries.

Two variants of the model have been used. In the first variant a damage function is included and therefore the optimal emission reduction level, the optimal level of CO₂-abatement, is determined endogenously. The two countries can
increase their welfare when they cooperate in reducing emissions. Cooperation can be extended further when they use sidepayments: one country pays the other country and reduces its emissions less. The other country diminishes its emissions further. An interesting conclusion is that including sidepayments in agreements on emission abatement can actually increase pollution compared with agreements which do not include sidepayments.

In the second variant it has been assumed that emission ceilings are set exogenously. In this variant countries can only cooperate when they use sidepayments. This form of cooperation, where one country pays another country for reducing its emissions, is also called Joint Implementation. The model with exogenously determined emission ceilings has been used to establish which institutions are necessary to realise the optima and to determine the role of taxes and tradeable permits. This analysis yields several insights.

First, in the second-best model used here, there is no difference between grandfathering or auctioning of the permits in either national or international systems of tradeable emission permits. In the case of grandfathering the optimal tax on the polluting good equals the tax plus the price of the permits when they are sold. To put it in a different way, the rent obtained by the gift of the permits is fully taxed away and the permit price is zero under grandfathering. Therefore, the welfare effects of either grandfathering or auctioning are similar in this second-best model.

Second, it suffices to specify the sidepayment and emission targets in a cooperative agreement; it is not necessary to specify the taxes which each country has to levy. It can be left to the countries themselves to set taxes or use a national system of tradeable permits. Given the emission targets and the sidepayment agreed upon, each government will set the optimal tax rates and the national permit markets will be in equilibrium at the optimal permit price.

Third, instead of taxes an international permit system can be used which allows trade in permits between the two countries. Given agreed upon emission ceilings and sidepayments, countries can be left free to set revenue raising taxes. Although tax competition is allowed, both countries will set (welfare) optimal taxes. In this case in each country the number of permits used is equal to that country’s emission
Fourth, it is not welfare optimal to allow trade in permits between the two countries without first agreeing on emission limits and sidepayments. Simulations show that, as might be expected, this will increase welfare in both countries compared with the situation in which countries do neither coordinate their emission reduction policies nor allow trade in permits. However, in neither country does it achieve the welfare levels which are realised when countries explicitly cooperate. In the second-best model studied here an international system of tradeable emission permits without initial coordination might therefore be termed a second-best policy: second-best to explicit coordination of emission reduction policies.

In all chapters the choice between grandfathering and auction of the permits was part of the analysis. Overlooking the results, is it possible to give a final verdict on this choice, given our central question of how to design a feasible system of TCP’s? Our conclusion in the institutional chapter 2 is that grandfathering should be preferred for industrial sources, or at least for the energy intensive sectors of industry, while the permits for the other sources should be sold. The main reason is that this makes a carbon reduction policy more acceptable to these sources than would be the case when permits are auctioned or when a tax is levied. The choice between grandfathering or auction does not affect relocation decisions of industries, therefore from this point of view there is no preference for either of the two methods. Grandfathering could increase barriers to entry but even for the energy intensive sectors the increase in entry barriers appears to be small. In contrast with the conclusion that a policy of grandfathering should be applied when the government’s aim is to increase political acceptability of tradeable carbon permits stands the conclusion from our second-best analysis which indicates that in case welfare maximisation is the aim grandfathering is not useful because the authorities would completely tax this capital gift away. Therefore different criteria lead to different policy advice. next to that it should be realised that the second-best model used is a very simple one which only focuses on the revenue aspect of taxes and permits.
The second recurrent issue in this study is the comparison between TCP’s and other instruments like taxes and direct regulation. A system of TCP’s seems to be just as feasible as a carbon tax. Monitoring and enforcement will not pose larger problems than a tax, although in a European-wide system insufficient enforcing might lead to larger excess emission when TCP’s are used compared with a tax (or standards). Tradeable permits have the advantage over a tax that permits can be grandfathered to (part of) the sources of CO₂ emissions which will reduce their expenditures. Furthermore the emission reduction level is set, which is not the case with a tax or with standards.

Tradeable permits can increase entry barriers through imperfect capital markets. This problem does not arise with taxes or standards, however the problem is relatively small and seems to be more theoretical than practical. Both taxes and tradeable permits can be used in international agreements on emission reduction. Whichever instrument is used, cooperating countries should first agree on emission reduction ceilings and monetary compensations in order to realise maximal welfare gains. In this respect there is no difference between the two instruments.

Our final conclusion is that a system of TCP’s is an attractive and feasible instrument for reducing CO₂ emissions, both at national and international levels. The system described in this study can be implemented in the European Union at the Union level and it might also be possible to introduce it in one Member State. Entry barriers might be affected by TCP’s when capital markets do not work perfect, but the effect is small and limited to a few sectors of industry.
SAMENVATTING

Vanaf het moment dat het versterkte broeikaseffect op de milieu-agenda verscheen hebben economen gewezen op de geschiktheid van economische instrumenten zoals belastingen en verhandelbare emissierechten voor het terugdringen van de CO₂ emissies (een van de belangrijkste broeikasgassen). Veel aandacht is besteed aan de efficiëntie van deze instrumenten. De uitvoerbaarheid en het ontwerp van dit soort instrumenten, in het bijzonder van verhandelbare CO₂ emissierechten, heeft minder aandacht gekregen. Deze studie wil in deze leemte te voorzien door het ontwerp en de institutionele kenmerken van een werkbaar systeem van verhandelbare CO₂ emissierechten voor de Europese Unie te beschrijven. In aanvulling daarop is bestudeerd wat de gevolgen zijn van de invoering van zo een systeem, waarbij vooral is gekeken naar de consequenties voor de toetreding van nieuwe bedrijven, een onderwerp dat tot nu toe weinig aandacht heeft gekregen in de literatuur.

Het versterkte broeikaseffect is een probleem dat zich wereldwijd voordoet. Daarom is het laatste onderwerp van deze studie hoe landen kunnen samenwerken in het terugdringen van CO₂ emissies en wat de consequenties zijn van samenwerking voor het ontwerp van een systeem van verhandelbare CO₂ emissierechten. Hierbij is rekening gehouden met de complicerende factor dat fossiele brandstoffen, de belangrijkste bron van CO₂ emissies, in de meeste landen reeds worden belast.

Een van de hoofdconclusies van deze studie is dat het mogelijk is om een uitvoerbaar systeem van verhandelbare CO₂ emissierechten te ontwerpen. De verhandelbare CO₂ rechten in het systeem zijn het equivalent van 1 ton koolstof, hetgeen betekent dat een emissierecht het gebruik toestaat van een hoeveelheid fossiele brandstoffen die een ton koolstof bevat. Men kan dus alleen fossiele brandstoffen gebruiken indien men over CO₂ rechten beschikt. De rechten zijn onbeperkt bruikbaar, ze behouden hun waarde totdat ze zijn ’opgebruikt’. Eenmaal verkregen rechten kunnen worden opgespaard totdat ze worden gebruikt of verkocht (het zogenaamde ’banking’ van rechten).

Fossiele brandstoffen zijn een belangrijke grondstof voor de economie. Het moet daarom worden vermeden dat er tijdelijke tekorten optreden die de economie onnodig
verstoren. Dit kan worden bereikt door bij de start van het systeem rechten uit te geven voor bijvoorbeeld een periode van vijf jaar. De rechten voor de volgende vijf jaar kunnen worden uitgegeven bij het begin van het laatste jaar van de eerste vijf-jaar periode. Zo is er ten alle tijde een reserve van emissierechten die een exceptionele stijging van de brandstof consumptie kan opvangen (zoals bijvoorbeeld strenge winters), zonder dat de totale hoeveelheid beschikbare emsisierechten de emissie limiet overschrijft.

Een belangrijk onderdeel van zo’n systeem is de verdeling van de emissierechten. De rechten kunnen worden verkocht door de overheid of ze kunnen gratis worden toegeedeeld, hetgeen in de literatuur wordt aangeduid met ’grandfathering’. Een voordeel van grandfathering is dat de industrie als geheel alleen kosten hoeft te maken voor emissiereductie, ze hoeft geen uitgaven te doen voor de aanschaf van emissierechten. Dit is wel het geval als de rechten worden verkocht of als er een belasting wordt geheven op CO₂ emissies. Met name bij de energie intensieve bedrijven zijn de uitgaven voor de aanschaf van rechten een veelvoud van de uitgaven voor emissiereductie. ’Grandfathered’ verhandelbare CO₂ emissierechten zijn daarom politiek haalbaarder dan een belasting of veiling van emissierechten.

Het ligt voor de hand om een onderscheid te maken tussen industriële en andere CO₂ emissie-bronnen. De rechten benodigd voor de emissies van deze andere bronnen worden verkocht door de overheid aan de leveranciers van fossiele brandstoffen, die op hun beurt de prijs van de fossiele brandstoffen kunnen verhogen met de prijs van de emissierechten. Het voordeel van dit systeem is dat de consumenten en kleine gebruikers van fossiele brandstoffen geen emissierechten hoeven aan te schaffen.

In het hierboven geschetste systeem kan de controle en handhaving op een relatief eenvoudige wijze plaatsvinden. De controle vindt plaats bij de importeurs en producenten van fossiele brandstoffen. Zij zijn verplicht om CO₂ emissierechten aan de autoriteiten over te dragen voor de fossiele brandstoffen die zij op de markt brengen. De af te dragen emissierechten moeten de CO₂ emissies dekken die vrijkomen bij de verbranding van de op de markt gebrachte fossiele brandstoffen. Het aantal bedrijven dat moet worden gecontroleerd is hierdoor beperkt; in Nederland zo’n 40 à 50. Een bijkomend voordeel is dat gebruik kan worden gemaakt van de bestaande systemen voor het heffen van accijnsen op fossiele brandstoffen.
Het verhandelbare CO\(_2\) emissierechten systeem kan functioneren als een systeem dat geldt in de hele Europese Unie. Het lijkt tevens mogelijk om het systeem in te voeren in één lidstaat van de Unie omdat er momenteel nog geen Europees beleid is voor de reductie van CO\(_2\) emissies. Verhandelbare CO\(_2\) emissierechten vallen waarschijnlijk onder de ‘rule of reason’ welke uitzonderingen toelaat op artikel 30 EG dat het vrij verkeer van goederen regelt.

Het tweede onderwerp van deze studie is de vraag of verhandelbare emissierechten toetredingsbarrières kunnen opwerpen voor nieuwe bedrijven. Het gratis toedelen van emissierechten aan de gevestigde bedrijven leidt niet automatisch tot hogere toetredingsbarrières voor nieuwe bedrijven. Het gebruik van gratis ontvangen rechten betekent dat ze niet voor een ander doel kunnen worden aangewend zoals bijvoorbeeld verkoop; de rechten hebben daarom ‘opportunity costs’. Deze kosten zijn gelijk aan de prijs waarvoor de emissierechten kunnen worden verkocht. De gevestigde bedrijven hebben daardoor geen kostenvoordeel ten opzichte van bedrijven die hun rechten moeten kopen.

Dat grandfathering niet per sé toetredingsbarrières creëert wil niet zeggen dat verhandelbare emissierechten de toetreding niet kunnen belemmeren. Er zijn drie vormen van toetredingsbarrières geïdentificeerd die in theorie kunnen worden veroorzaakt door verhandelbare emissierechten:

- Transactiekosten op de markt voor emissierechten kunnen consequenties hebben voor toetreding in het ‘limit pricing’ model.
- Gevestigde bedrijven kunnen de kosten van potentiële toetredeers verhogen als ze de prijs van de emissierechten kunnen beïnvloeden.
- Als kapitaalmarkten niet perfect werken zijn de gevestigde bedrijven in het voordeel wanneer de emissierechten worden gegrundfathered.

Het ‘limit pricing’ model is een twee-perioden (Stackelberg) spel waarin het gevestigde bedrijf in de eerste periode investeert, rekening houdend met de reactie van een potentiële toetreder in de tweede periode. Door deze reactie mee te nemen in zijn investeringsbeslissing kan het gevestigde bedrijf de omvang van de produktie van het nieuwe bedrijf beïnvloeden. Het is tevens mogelijk dat de toetreder volledig kan
worden geweerd door het gevestigde bedrijf. Transactiekosten op de markt voor verhandelbare emissierechten maken het aantrekkelijker voor het gevestigde bedrijf om de toetreder volledig te weren of ze reduceren de omvang waarmee het nieuwe bedrijf de markt betreedt.

Een extreme vorm van toetredingsbarrières kan zich voordoen als één of een groep van bedrijven een belangrijke produktiefactor controleert en daardoor de prijs van deze produktiefactor voor andere bedrijven kan opdrijven. Dit verhoogt de kosten voor de andere bedrijven waardoor de competitie wordt verminderd of waardoor nieuwe bedrijven niet meer toetreden. Verhandelbare emissierechten kunnen eveneens voor dit doel worden gebruikt als gevestigde bedrijven de prijs van de rechten kunnen beïnvloeden en daardoor de kosten van toetreders kunnen verhogen.

Noch de transactiekosten barrière noch beïnvloeding van de prijs van de emissierechten lijkt erg relevant voor het systeem van verhandelbare CO₂ emissierechten dat in deze studie is beschreven. De belangrijkste reden hiervoor is dat de markt voor CO₂ rechten een ruime markt is met veel potentiële deelnemers uit verschillende sectoren van de industrie. Het is daarom te verwachten dat zich een goed werkende markt ontwikkelt met lage transactiekosten zodat de mogelijke consequenties van transactiekosten voor toetredingsbarrières klein zijn. Het zal kostbaar zijn om de prijs van CO₂ rechten op te drijven op een ruime, goed werkende markt met veel marktpartijen die geen directe concurrenten zijn. Ook deze methode om de competitie van nieuwe bedrijven te verminderen zal daarom weinig aantrekkelijk zijn in het systeem van verhandelbare CO₂ emissierechten.

De meest relevante vorm van toetredingsbarrières voor het systeem van verhandelbare CO₂ emissierechten doet zich voor wanneer kapitaalmarkten niet perfect werken en de gevestigde bedrijven hun rechten gratis ontvangen. De 'long purse' theorie stelt dat een gevestigd bedrijf een nieuw bedrijf uit de markt kan drijven door middel van een prijsoorlog als het gevestigde bedrijf over meer financiële middelen beschikt. Het gratis toedelen van rechten aan de gevestigde bedrijven en aankoop van de rechten door nieuwkomers betekent, ceteris paribus, dat een bestaand bedrijf grotere financiële reserves heeft dan een nieuwkomer omdat grandfathering equivalent is aan een kapitaalgift. De consequentie is dat een gevestigd bedrijf een nieuw bedrijf van de
markt kan weren als emissierechten worden gegrandonderd aan de gevestigde bedrijven.

Uit verschillende empirische studies is gebleken dat de hoeveelheid kapitaal die nodig is voor een bedrijf om een nieuwe markt te betreden van invloed is op de toetredingsbarrière. Voor de Nederlandse economie is geschat in welke mate een systeem van verhandelbare CO₂ emissierechten de benodigde hoeveelheid kapitaal vergroot, waarbij ervan uit is gegaan dat nieuwkomers CO₂ rechten aanschaffen voldoende voor 1 jaar produktie. De toename van de benodigde hoeveelheid kapitaal is, zoals is te verwachten, het grootst in de energie intensieve sectoren, maar toch niet meer dan maximaal 1,7 procentpunt. De toetreding van nieuwe bedrijven kan verminderen als de gevestigde bedrijven hun rechten gratis ontvangen maar waarschijnlijk slechts in beperkte mate.

De laatste vraag die in deze studie is beantwoord is hoe landen samen kunnen werken in het reduceren van grensoverschrijdende vervuiling zoals CO₂ emissies en hoe dit het ontwerp van een systeem van verhandelbare emissierechten beïnvloedt. Hiervoor is gebruik gemaakt van een twee-landen model waarin rekening wordt gehouden met het feit dat fossiele brandstoffen reeds worden belast voor andere redenen dan het terugdringen van de CO₂ emissies. De eenvoudige economie in het model bestaat uit één representatieve consument die twee goederen kan consumeren. De consumptie van een van de goederen veroorzaakt vervuiling. De consument kiest tevens hoeveel tijd hij wil besteden aan werken (en het verdienen van een inkomen) en hoeveel vrije tijd hij neemt. In het gehanteerde model moet de overheid een exogeen bepaalde hoeveelheid inkomsten realiseren door middel van belastingen op de twee goederen; of door verkoop van verhandelbare emissierechten. Tevens beperkt de overheid de vervuiling door op het vervuilende goed een vervuilingsbelasting te heffen. Met behulp van dit zogenoemde ’second-best’ model is vastgesteld welke combinaties van instrumenten de welvaart maximaliseren in de twee landen.

In een variant van het model is aangenomen dat de emissieplafonds exogeen zijn vastgesteld. Samenwerking tussen de twee landen is in deze variant alleen mogelijk wanneer een van de twee landen het andere land betaalt. Het land dat de betaling ontvangt vermindert zijn emissies terwijl het land dat betaalt de vervuiling minder ver
reduceert. Deze vorm van samenwerking wordt ook wel Joint Implementation genoemd. De variant met exogeen bepaalde emissieplafonds is gebruikt om te bepalen wat in welvaartsmaximaliserende internationale overeenkomsten de invloed van zowel belastingen als van CO₂ emissierechten kan zijn op de welvaart en emissieplafonds in de twee landen. Deze analyse heeft een aantal conclusies opgeleverd:

- In het hier gebruikte second-best model is er geen verschil tussen grandfathering en publieke verkoop van de rechten in nationale of internationale systemen van verhandelbare rechten. Bij grandfathering is de optimale belasting op het vervuilende goed gelijk aan de inkomensgenererende belasting op dit goed plus de prijs van de rechten als ze publiek worden verkocht. Oftewel, de gratis gift van de rechten wordt volledig wegbelast en de marktprijs van de rechten bij grandfathering is nil. In het gehanteerde model zijn dan de welvaartseffecten van gratis uitgifte en verkoop van de rechten gelijk.

- In internationale overeenkomsten kan worden volstaan met aan te geven hoeveel een land aan een ander land moet betalen en wat de emissie plafonds zijn voor elk land. De overheden in beide landen zullen vervolgens de optimale belastingen heffen en de markt voor emissierechten is in elk land in evenwicht bij de optimale prijs voor de rechten.

- Een internationaal systeem van verhandelbare rechten kan worden gehanteerd waarin de rechten vrij verhandelbaar zijn tussen de twee landen. Gegeven de overeengekomen betalingen tussen de landen en de emissieplafonds staat het de landen vrij om aanvullende belastingen te heffen. Hoewel het formele is toegestaan dat de landen elkaar gaan beconcurreren in de belastingtarieven is het resultaat desalniettemin dat beide landen de welvaartsoptimale belastingen heffen. In deze situatie is de uitstoot in beide landen gelijk aan de overeengekomen emissieplafonds.

Het toelaten van handel in emissierechten tussen de twee landen zonder eerst tot overeenstemming te komen over wederzijdse emissieplafonds en compenserende betalingen tussen de twee landen resulteert in lagere welvaartsniveau’s dan het toelaten van handel nadat een overeenkomst is gesloten. Simulaties laten zien dat, zoals te verwachten is, de welvaart stijgt als handel tussen de landen wordt toegelaten.
vergeleken met de situatie waarin de landen niet samenwerken en er geen handel mogelijk is in emissierechten tussen de landen. Echter, de welvaartsstijging in beide landen is kleiner dan in de situatie waarin de landen eerst een overeenkomst sluiten over emissieplafonds en compenserende betalingen alvorens handel toe te laten. In het second-best model dat hier is gehanteerd kan een systeem van internationaal verhandelbare emissierechten zonder overeenkomst worden getypeerd als een second-best oplossing; second-best vergeleken met overeenkomsten over gecoördineerde emissiereductie.

Afsluitend kan worden geconcludeerd dat een systeem van verhandelbare CO₂ emissierechten een aantrekkelijk en uitvoerbaar instrument is voor het terugdringen van CO₂ emissies op zowel nationaal als internationaal niveau. Verhandelbare rechten kunnen toetredingsbarrieres vergroten als de rechten worden gegrandfathered en als kapitaal markten niet perfect werken maar dit effect is echter klein.
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