CHAPTER 3
ENTRY BARRIERS AND TRADEABLE EMISSION PERMITS I

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-Sylos-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.
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 medallions 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 barriers².

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.

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 emissions 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 increases. In the remainder of this chapter, transaction costs are presented as an additional cost which increases 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.

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

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6 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.
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 *blocked* 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 $q^3$ 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 $q^3$ 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.\footnote{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 be negative.}

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
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:

\[
\pi_i = q_i(1-q_i-q_e) - f \quad q_i \leq G \tag{3.7}
\]

\[
\pi_i = q_i(1-q_i-q_e) - f - T \quad q_i > G \tag{3.8}
\]

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 \( q_i^b \). 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.

\(^8\) 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 \(q^i = \frac{1}{2} \) his profit in the Stackelberg equilibrium is \(1/8 - f - T\). The necessary condition for entry deterrence for the incumbent (equation 3.4) is:

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

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.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 analyze 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:

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

3.10

His reaction function is:

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

3.11

---

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):

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

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

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

Diagram 3.3 shows the effect of variable transaction costs for the entrant. Curves \( \pi^i \), \( \pi^a \), \( \pi^a' \), \( R^e \) 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 \( \pi^a \) to \( \pi^a' \) 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, \( \pi^a \) and \( \pi^a' \), are not defined beyond the point at which \( q^e < 0 \). Beyond this point the incumbent enjoys a monopoly profit, curve \( \pi^{\text{monopoly}} \).
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:

\[
C_{iK_i} < 0
\]

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.

\(^{12}\) 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 \( K^1 \) can be chosen the Nash equilibrium will shift to point \( C \) where the lowest possible isoprofit curve is tangent to \( R_e^2 \), isoprofit curve \( I_3 \). The optimal level of \( K^1 \) 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 \( q^1 \) (and \( M \)) is given. The first-order condition is:

\[
R^e_{q^e} - C^e_{q^e} = 0 \tag{3.17}
\]

The second-order condition is:

\[
R^e_{q^e q^e} - C^e_{q^e q^e} < 0 \tag{3.18}
\]

Total differentiation of 3.17 gives:
In equation 3.19 \( R_{qe} < 0 \) and \( C_{qeM} > 0 \). 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 entrant 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:

\[
R^i_{qi} - C^i_{qi} = 0 \tag{3.20}
\]

Totally differentiating (3.20) gives:

\[
[R^i_{qi} - C^i_{qi}] \quad dq^i = - R^e_{qiqi} dq^e + C^i_{qiK_i} dK^i
\]

\( dq^i/dq^e \) 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

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

\[
|r^j| = |\pi^j_{qiqj}/\pi^j_{qiqi}| < 1 \implies |\pi^j_{qiqi}| > |\pi^j_{qiqj}| \implies
\]

\[
|R^e_{qiqi}C^i_{qi}] > |R^e_{qiqj}C^i_{qij}|
\]

The absolute value of a change in marginal profit due to a change in it’s own quantity produced must exceed the change in it’s 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:

$$\pi^i(q^i(K^i),q^e(K^i),K^i) = R^i(q^i(K^i),q^e(K^i)) - C^i(q^i(K^i),K^i)$$  \hspace{1cm} 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:

$$d\pi^i/dq^i dq^i*/dK^i + d\pi^i/dq^e dq^e*/dK^i + d\pi^i/dK^i = 0$$  \hspace{1cm} 3.23

This can be written as:

$$\frac{d\pi^i}{dK^i} = (R^i_q - C^i_{q^i}) \frac{dq^i*/dK^i}{dK^i} + R^i_q \frac{dq^e*/dK^i}{dK^i} - C^i_{K^i} = 0$$  \hspace{1cm} 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:

$$\begin{bmatrix} R^i_{q^i q^i} & C^i_{q^i q^i} & R^i_{q^i q^e} \\ R^e_{q^e q^i} & R^e_{q^e q^e} & -C^e_{q^e q^e} \end{bmatrix} \begin{bmatrix} dq^i*/dK^i \\ dq^e*/dK^i \end{bmatrix} = \begin{bmatrix} C^i_{q^i K^i} & dK^i \\ C^e_{q^e M} & dM \end{bmatrix}$$  \hspace{1cm} 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, $\delta\pi^i/\delta q^i = 0$, therefore $dq^i$ does not enter into the equation (the envelope-theorem)):

$$\Delta = (R^i_{q^i q^i} - C^i_{q^i q^i})(R^e_{q^e q^e} - C^e_{q^e q^e}) - R^e_{q^e q^i} R^i_{q^i q^i}$$  \hspace{1cm} 3.26
\[
d\pi^i = -\left( \frac{R^i_{q^e} R^i_{q'^e} C^i_{q^i K^i}}{\Delta} + C^i_{K^i} \right) dK^i + \left( \frac{R^i_{q^e} (R^i_{q'^e} - C^i_{q^i q'}) C^e_{q^i M}}{\Delta} \right) dM
\]

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 \( q^i* \) 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 \( q^i* \) 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 \( q^i* \) and \( q^e* \) yields:

\[
dq^i* = -\frac{R^i_{q^i q^e} C^e_{q^e M}}{\Delta} dM > 0 \quad 3.27
\]

\[
dq^e* = \frac{(R^i_{q^i q'^e} - C^i_{q^i q'}) C^e_{q^e M}}{\Delta} dM < 0 \quad 3.28
\]

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 \( dq^i* \) and \( dq^e* \) the profit of the incumbent increases because in equation 3.26 \( d\pi^i/dM \) is positive: in the numerator \( R^i_{q^e} \) is negative, \( (R^i_{q^i q'^e} - C^i_{q^i q'}) \) is negative and \( C^e_{q^e M} \) 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 \( \frac{d\pi_i}{dK_i} \) in equation 3.26 is zero:

\[
\frac{d\pi_i}{dK_i} = G = -\left( \frac{R^i_q R^e_q}{\Delta} + \frac{C_i^q}{K^i} \right) = 0
\] 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 of the terms in equation 3.29 and therefore \( d\pi_i/dK_i \) 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:

\[
dG/dM = dG/dq^i dq^i/dM + dG/dq^e dq^e/dM
\] 3.30

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

\[
\left( R^i_{qeqi} R^e_{qiqe} C_i^{qi} / \Delta + C_i^{q_i K^i} \right) dq^i
\] 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 \( d\pi_i/dK_i \). Consequently \( d\pi_i/dK_i \) 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 \( C^i_K \) 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:
\[ dq^i = (R^{eqe}_q - C^{eqe}_q) C^{i}_{q Ki} / \Delta \ dK^i > 0 \]  

3.32

\[ dq^e = -R^{eqe}_q C^{i}_{q Ki} / \Delta \ dK^i < 0 \]  

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 $E(q')$ 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\textsuperscript{15}:

\[
\begin{align*}
C'(q',K') + P_p(E(q')-G) + P_p G & \quad E(q') \leq E, \ E \leq G \\
C'(q',K') + P_p(E(q')-G) + P_p G + t(E-G) & \quad E(q') \leq E, \ E > G \\
C'(q',K') + P_p(E(q')-G) + P_p G + t(E(q')-E) + t(E-G) & \quad E(q') \geq E
\end{align*}
\]

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:

\[
\begin{align*}
C'_{qi} + P_p E_{qi} & \quad E(q') < E, \ E \leq G \\
C'_{qi} + P_p E_{qi} & \quad E(q') < E, \ E > G \\
C'_{qi} + P_p E_{qi} + t E_{qi} & \quad E(q') \geq E
\end{align*}
\]

\textsuperscript{15} It is assumed here for the moment that abatement is less attractive than buying permits.
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 \( P_p \). The profit function of the incumbent in the second period is:

\[
\pi^i = R_i(q^1, q^e) - C_i(q^1) - P_p E(q^1) - t(E-G) \quad E(q^1) \leq E \tag{3.40}
\]

\[
\pi^i = R_i(q^1, q^e) - C_i(q^1) - P_p E(q^1) - t(E(q^1)-G) \quad E(q^1) > E \tag{3.41}
\]

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:

\[
C_{qi} + P_p E_{qi} \quad E(q^1) \leq E \tag{3.42}
\]

\[
C_{qi} + (P_p + t) E_{qi} \quad E(q^1) > E \tag{3.43}
\]

The entrant’s profit function is:

\[
\pi^e = R^e(q^e, q^1) - C^e(q^e) - (P_p + t) E(q^e) \tag{3.44}
\]

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 lower16. 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.

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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:

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

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 accommodation.

**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:

\[
C_i(q_i) + P_p E(q_i) + A(E(q_i)) + t
\]

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 if he buys more permits. Marginal costs are:

\[
C^i_{q_i} + P_p E_{q_i} + A_E E_{q_i} = 0 \quad E(q^i) \leq E
\]

\[
C^i_{q_i} + (P_p + t)E_{q_i} + A_E E_{q_i} = 0 \quad E(q^i) > E
\]

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.

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17 For the sake of clarity of the exposition, grandfathering is left out. Including grandfathering would not change the fundamental analysis and conclusions.
in the first period (E). This point is denoted \( q^* \). 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 \( q^* \), 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 \( q^* \), abatement costs start rising, up till they are equal to \( P_{t} + t \). It should be noted that marginal abatement costs do not rise directly to \( P_{t} + t \) at \( q^* \). At \( q^* \), marginal abatement costs equal \( P_{t} \), the permit price. Increasing production beyond \( q^* \) increases emissions. The incumbent can either buy more permits, at costs \( P_{t} + t \), 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 \( P_{t} + t \). At some point marginal abatement costs will have risen to \( P_{t} + t \): 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 \( q^i > q^* \). This is shown in diagram 3.8. Instead of jumping from reaction curve NN’ to reaction curve MM’ when q rises above \( q^* \), 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 necessarily 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 perfectly, 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.