Investment Incentives under Emission Trading: An Experimental Study[*]

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Abstract

This paper presents an experimental investigation of environmental policy instruments on the incentives to adopt advanced abatement technology in tradable permit markets. Our design, based on Requate and Unhold (2001), involves an industry with small regulated asymmetric firms. We consider three auction-allocation policies: auctioning off permits through an ascending clock auction, grandfathering permits and relocating them through an ascending clock auction, and grandfathering permits and relocating them through a single unit double auction. We conducted two series of treatments, the single-period treatments where firms have to decide whether to invest in the advanced technology or not in each period, and the multi-period treatments where firms may first wait and observe the other firms' behavior before deciding whether to invest. Our results confirm Requate and Unholds' theoretical prediction that auctioning and grandfathering do not yield different results regarding investment in advanced abatement technology. In particular, the different treatments yield similar results regarding investment in advanced technology and regarding the total social welfare of the economy. We find, however, weak evidence that the double auction outperforms the ascending clock auction in terms of efficiency in allocating permits.

JEL Classification: C92; D44; L51; Q28; Q55

Keywords: environmental policy; abatement technology; taxes; permit trading; auctions

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1 Introduction

Policy-makers are often required to make a selection among different policy instruments for protecting the environment. In this field, it is meanwhile widely acknowledged that 'market-based' pollution control instruments, such as emission taxes and tradable permits, are powerful and efficient tools to regulate pollution. Early on, Kneese and Schultze (1975) emphasized that, among all available criteria to judge the efficiency of the different pollution control policies, one of the most important is the extent to which a given policy encourages firms to develop or adopt low-pollution technologies. Since then, a large avenue of research started to analyze, from theoretical and empirical viewpoint, the impact of different policy instruments on technological change. The first attempts to rank environmental policy instruments, taking the adoption of advanced technology as an efficiency criterion, were made by Downing and White (1986), Malueg (1989), and Milliman and Prince (1989).[1] Using aggregate cost saving as investment criteria, these studies, however, focus on the effect on the whole industry and not on the incentives of a single firm to adopt the new technology. Consequently, Kennedy and Laplante (2000) and Requate and Unhold (2003, 2001) (for the case of adoption of new technology), and Montero (2002a,b) and Fischer *et al.* (2003) (for the case of technology innovation) suggested that equilibrium considerations should be taken into account when studying the incentives to adopt (or develop) new technology. In other words, the number of firms that adopt the new technology in equilibrium should be endogenously determined.

Since Plott's (1983) first laboratory experiment on emission trading, numerous experimental studies have been published on permit trading.[2] However, only a few considered the adoption of advanced technology in permit markets. Ben-David *et al.* (1999) considered a market where firms are producing a good using capital and permits. In their setting, firms can use one of three possible production technologies where permits and capital costs are inversely related (i.e. the cleanest technology is the most expensive in terms of capital). Each period the firms choose their technology for the next period (however, choosing a 'cleaner' technology is irreversible). Ben-David *et al.* (1999) introduce heterogeneity via the marginal abatement cost of switching from one technology to another. They find that heterogeneity leads to lower efficiency from trade. Hizen *et al.* (2001) and Kusakawa and Saijo (2003) investigated emission trading using either bilateral trading, or double auction. They define investment irreversibility such that when a firm is abating one unit of emission and then emitting this unit, it incurs a cost. They find that investment irreversibility and time lag in abatement reduce efficiency. Finally, Gangadharan *et al.* (2005) examine the interaction between banking of permits and (irreversible) investment in a cleaner technology. They consider a market with six types of firms differing with respect to production capacity and cleanliness, when production

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[1] See Requate (2005) for a survey about incentives provided by environmental policy instruments to adopt and develop advanced abatement technology.

[2] A summary of the literature is given in Muller and Mestelman (1998) and in Bohm (2003).

capacity and cleanliness are inversely related. Permits were freely allocated to those firms, which could relocate them through a double auction. Moreover, the firms could invest a fixed amount, the same for all types, to produce more for the same amount of pollution emitted. The effect of investment, however, is asymmetric, such that dirty firms gain more by investing. Gangadharan *et al.* (2005), in contrast to our design, held the amount of pollution emitted fixed and varied the quantity of output produced. Additionally, information about investment was announced publicly in their experiment. They find that firms tend to over-invest and over-bank. In other words, not only 'dirty' firms invest in advanced technology but also 'cleaner' firms that could otherwise invest in more productive alternatives. The result is sub-optimal market efficiency.

This paper centers on the case investigated by Requate and Unhold (2001), when the regulator takes into account the potential technological change when deciding on the environmental policy to be applied. This is the case of the European countries as a result of the application of the Integrated Pollution Prevention and Control (IPPC) Directive 96/61. The IPPC legislation requires emission reduction and environmental improvements on the basis of what is achievable with the best techniques available to individual industrial sectors. The analysis of Requate and Unhold (2001) in the case of industry characterized by many (a continuum of) asymmetric firms demonstrates that in a subgame perfect equilibrium when the regulator sets the optimal Pigouvian tax, or alternatively, issues the optimal number of permits the share of firms adopting the new technology is socially optimal.

Testing the behavior of firms in the laboratory under a Pigouvian tax[3] does not make much sense, since even when a firm deviates from the theoretical allocation it does not affect the maximization considerations of the others. However, this is not the case when the government issues emission permits, since expectations about the price of permits depend on the other firms' behavior. Thus, auctioned permits may yield different results than grandfathered permits. This study tests, in the laboratory, the theoretical findings of Requate and Unhold (2001) that in an industry characterized by many small asymmetric firms, when the regulator issues the socially optimal number of permits, auctioning and grandfathering provide the same incentives to invest in advanced technology. Although Requate and Unhold (2001) did not specify an auction design, we investigate the behavior of firms under two allocation policies, free allocation of permits (grandfathering) vs. auctioned permits, and under two different auction designs (ascending clock auction vs. single unit double auction). Besides testing the investment behavior, we evaluate the efficiency of the policies in allocating permits and in maximizing the total social welfare of the economy. Moreover, we employ the low-payoff menu of paired lottery (Holt and Laury, 2002) to see whether attitudes towards risk affect subjects' performance in the laboratory.

Our results confirm Requate and Unholds' proposition that auctioning and grandfathering do not yield different results regarding investment in advanced abatement technology. In particular, the different treatments yield similar re-

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[3] Under the condition of perfect information.

sults regarding investment in advanced abatement technology and regarding the total social welfare of the economy. However, regarding efficiency in allocation of permits, the double auction outperforms the ascending clock auction.

This paper is organized as follows: In Section 2 we present the theoretical model. In section 3 we describe the experimental design and procedure. In Section 4 we present the results. Section 5 concludes.

2 Theoretical Background

This section portrays the theoretical model serving as a basis for our experiment. The model outlined here is a discrete version of the model proposed by Requate and Unhold (2001).

Let us consider an industry consisting of n polluting firms, and K different initial technologies. Each firm $i = \{1, ..., n\}$ is endowed with one of these initial technologies and can invest to adopt the advanced technology a, the same for all firms. The firms' technologies are represented by their abatement cost function $C^i(e_i, k)$ with $k = 1, ..., K, a$. We assume that for any targeted emission level e we have $C^i(e, k) > 0$ for $e < \bar{e}_k$, where $\bar{e}_k$ is the baseline emission level of technology $k = 1, ..., K$. Investment in advanced abatement technology leads to both lower abatement and lower marginal abatement costs, i.e. $C^i(e, k) > C^i(e, a) > 0$ and $-C^i_e(e, k) > -C^i_e(e, a)$ for all $e \leq \bar{e}_k$, where $-C^i_e(e, k) = -\partial C^i_e(e, k)/\partial e$ is the marginal abatement cost. We denote by $k(i)$ the technology initially owned by firm i. Without a loss of generality we assume that the firms' abatement cost functions are ordered from the dirtiest to the least dirty: $C^i(e, k(i)) \geq C^{i+1}(e, k(i+1)$ and $-C^i_e(e, k(i)) \geq -C^{i+1}_e(e, k(i+1)$. Installing the new technology causes a fixed cost, $F > 0$, for simplicity it is the same for all firms. Moreover, when setting the optimal policy, the regulator uses an increasing and convex social damage function, $D(E)$, that evaluates emissions in monetary terms, where $E = \sum_{i=1}^{n} e_i$ denotes aggregate emissions.

A social planner minimizes total social costs with respect to emissions and the number of firms. When the fixed investment cost is independent of the initial technology, it is always optimal that, if not all firms are supposed to adopt the advanced technology, at least those firms with the highest abatement costs should invest, i.e. there will be some index j, such that the firms $i = 1, ..., j$ will invest. Exploiting that $C^i(e_i, a) = C^j(e_j, a)$ and $e_i = e_j$ for all $i \leq j$, the social planner's problem can therefore be written as:

$$\min_{\{j, e_1, ... e_j, e_a\}} \{j[C^j(e_j, a) + F] + \sum_{i=j+1}^{n} C^i(e_i, k(i)) + D(E)\}$$

where $E = je_j + \sum\limits_{i=j+1}^{n} e_i$. Clearly for $i > j$, e_i depends only on the type of technology k.

Denoting the optimal *aggregate marginal abatement cost* when the first j firms have adopted the advanced abatement technology by $AMAC^*(E, j)$, the regulator will choose the optimal aggregate emission level, E^*, satisfying

$$D'(E^*) = AMAC^*(E^*, j) \tag{1}$$

We assume that a regulating authority uses tradable permits to control emissions. Therefore, it will issue of a number of permits, $L = E^*$, to enforce the aggregate emission level E^*. Denoting the market price for permits by σ, a firm with technology i chooses an emission level $e_i(\sigma)$ such that its marginal abatement cost equals the price of permits: $-C_i'(e_i(\sigma)) = \sigma$.

Now a firm with original technology i has an incentive to adopt the advanced technology a if:

$$C^i(e_i(\sigma, a), a) + F + \sigma[e_i(\sigma, a) - \hat{e}_i)] < C_i(e_i(\sigma, k), k) + \sigma[e_i(\sigma, k) - \hat{e}_i] \tag{2}$$

where $\hat{e}_i$ is firm i's initial endowment of permits, if there is any. Condition (2) indicates that investment is profitable if the total cost consisting of abatement cost, expenditures on permits, and investment cost is lower than the abatement cost plus expenditures for permits without investment. This condition depends crucially on the permits' price. Even for identical firms it can be the case that in equilibrium some firms adopt the new technology and some do not (see Requate and Unhold, 2003). In fact, the price of permits and the number of firms are both determined endogenously. These authors show that the socially optimal allocation can be theoretically implemented, by issuing the *ex-ante* socially optimal number of emission permits for both, a completely symmetric model (see Requate and Unhold, 2003), and an asymmetric model (see Requate and Unhold, 2001). In our experimental study, we therefore assume that the regulator issues the optimal number of permits. Requate and Unhold (2001, 2003) also show that the social optimum can be decentralized irrespective of permits being allocated for free (grandfathered) or being auctioned off. In these papers, the auction design is not specified. It is just assumed that the auction induces the competitive market clearing price.

3 Experimental Design and Procedure

This section thoroughly describes the experimental design and procedure. The experiment was programmed and conducted using the z-Tree experimental software (Fischbacher, 2007) and was held at the experimental laboratory of the University of Kiel. We aim at testing the theoretical predictions by Requate and Unhold (2001) by issuing the *ex-ante*, socially optimal number of emission permits, and hypothesize that the socially optimal level of investment would be achieved regardless of (i) the way emission allowances are initially allocated, and of (ii) the auction design. We therefore conduct several treatments, varying the way of initial allocation (free vs. costly) and varying the auction design.

Typically, under a system of grandfathering, firms can bilaterally trade permits. To mimic this it is natural to implement a single unit double (oral) auction. Under the so called auctioning-system of permits, several designs are possible.

We chose an ascending clock auction because of its simplicity. By doing so, two features are different between the treatments: The allocation mechanism and the auction design. Thus, in order to investigate the effect of the initial allocation of permits, or of the auction design on firms' performance, we had to conduct a treatment with only one feature different from each of the other two treatments. Therefore, we conducted an additional treatment where permits are initially allocated for free, but the price is determined by an ascending clock auction.

Furthermore, we conducted two types of treatments, the single-period and the multi-period treatments. The single-period treatments consist of two phases: In the first phase subjects decide whether or not to invest and in the second phase they participate in an auction. This auction will determine their number of permits and, thus, their emission level (=abatement level). In the real world, however, investment does not always happen simultaneously. Firms might first wait and observe the other firms' behavior, and only then decide whether or not to invest in the new technology. In this sense, we conducted a further series of treatments where the relevant time horizon is four periods. As in the single-period treatments each period consists of two phases: In the first phase subjects decide whether or not to invest (only if they did not invest in the previous periods), and in the second phase they participate in an auction. We refer to these treatments as the multi-period treatments. In total we refer to the different treatments as follows:

- SAAC = single period auctioning off permits through an ascending clock auction
- SGAC = single period grandfathering and relocating permits through an ascending clock auction
- SGDA = single period grandfathering and relocating permits through a single unit double auction
- MAAC = multi period auctioning off permits through an ascending clock auction
- MGDA = multi period grandfathering and relocating permits through a single unit double auction

The SGAC treatment was conducted to investigate whether possible differences in performance between the policy instruments are due to the initial allocation of permits or due to the choice of auction design. Since we did not observe a difference between the instruments, we did not conduct a multi-period treatment with grandfathering and ascending clock auction

We consider an industry consisting of 18 firms of five different types $k = \{T_1, ..., T_5\}$ characterized by their marginal abatement technologies. In each period each firm earns an unconditional default profit of $\Pi^0 = 1200$. The fixed investment cost is $F = 580$ in the single-period, and $F = 2000$ in the multi-period treatments. Profits are indicated in experimental currency units

(ECU), which were then converted into € at an exchange rate of ECU40=€1 in the single-period treatments, or ECU160=€1 in the multi-period treatments. Finally, we set the social damage function by ,$D(E) = E^2/4$, leading to the marginal damage $E/2$, where $E = \sum_{i=1}^{18} e_i$ denotes aggregate emissions.[4] The marginal abatement technologies of the different types are given in Table 1, while the number of firms and the allocation of permits (in the treatments with grandfathering) per type are given in Table 2.

- Table 1 about here -

MAC	Emissions (e_i) per technology type					
	T_1	T_2	T_3	T_4	T_5	a
0	20	18	16	14	12	7
10	19	17	15	13	11	6
20	18	16	14	12	10	5
30	17	15	13	11	9	4
40	16	14	12	10	8	3
50	15	13	11	9	7	2
60	14	12	10	8	6	1
70	13	11	9	7	5	0
80	12	10	8	6	4	0
90	11	9	7	5	3	0
100	10	8	6	4	2	0
110	9	7	5	3	1	0
120	8	6	4	2	0	0
130	7	5	3	1	0	0
140	6	4	2	0	0	0
150	5	3	1	0	0	0
160	4	2	0	0	0	0
170	3	1	0	0	0	0
180	2	0	0	0	0	0
190	1	0	0	0	0	0
200	0	0	0	0	0	0

Table 1: *Marginal Abatement Cost (MAC) per technology type.* $T_1, ..., T_5$ *denote the conventional technologies, while* a *denotes the advanced abatement technology.*

- Table 2 about here -

Since we have conducted both single and multi-period treatments, we define a *run* as the phase consisting of one period in the single-period treatments, and of four successive periods (i.e., periods 1-4, 5-8, 9-12) in the multi-period treatments. In all treatments, once a firm has decided to invest in the new technology, it is assigned the new technology for the remaining periods of the run.[5] Table 3 presents the experimental design.

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[4] Alternatively, from reasons that are explained bellow, our analysis includes the case of a flat MD curve (MD=55).

[5] However, in each period during a run, a firm can invest in the advanced technology if it did not invest before.

Firm type	T_1	T_2	T_3	T_4	T_5
Number of firms	4	3	4	3	4
Permits alloctaed	8	7	6	5	4

Table 2: *Firm type (according to the initial technologies), number of firms per type, and permits allocated to each firm (in the treatments with grandfathering.)*

- Table 3 about here -

Treatment	L*	Allocation mechanism	Auction design	Investment sustainability	Permits validity	Periods	Runs
SAAC	110	A	AC	each period	each period	6	-
SGAC	108	GR	AC	each period	each period	4	-
SGDA	108	GR	DA	each period	each period	6	-
MAAC	110	A	AC	each run	each period	12	3
MGDA	108	GR	DA	each run	each period	12	3

Every treatment includes 2 sessions with 18 participants
Common to all treatments: Π^0=1200, j^*=7, n=18, k=5

Table 3: *The experimental design, a total of 5 treatments: three single-period treatments and two multi-period treatments. "A" denotes auctioning off permits, "GR" denotes grandfathering, "AC" denotes ascending clock auction, "DA" denotes double auction. run=period in the single-period treatments but not in the multi-period treatments.*

For our parameters, the optimal allocation is characterized as follows: All firms assigned the technologies T_1 and T_2 should invest, while the others should not, as is illustrated by Figure 1. The optimal number of permits to be issued is $L = 110$, and the optimal marginal damage is equal to 55.

- Figure 1 about here -

To ensure that subjects understand the economic situation, only students with at least a Bachelor's degree in Economics were recruited to participate in the experiment. Second, every experimental session starts with a tax treatment and is then followed by a permit treatment. This means that instead of trading permits, emissions were taxed. The purpose of conducting the tax treatment before the permit treatment was to make subjects familiar with the pure investment decision without facing the uncertainty induced through the outcome on the permit market, in particular regarding permit price. Finally, we did not impose an automatic time limit on the investment decision, giving the subjects enough time to consider their decisions. When, however, some subjects did not make their decision after 15 minutes, we told them to reach a decision.

3.1 The tax treatments

Assuming that the regulator anticipates the new technology, we set the *ex-ante* optimal tax rate equal to $\tau = 55$. According to the above settings, the profit of firm i, in period t, is the following:

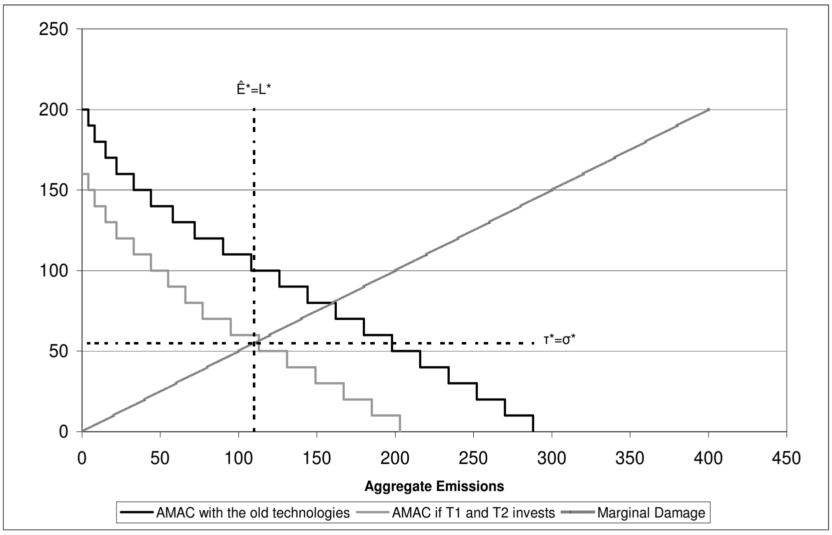

Figure 1: *Socially optimal instrument level: tax and emission permits*

$$\Pi_{i,t} = \begin{cases} \Pi^0 - C^i\left(e_{i,t}, a\right) - \tau e_{i,t} & \text{if invested in period } t \text{ (or earlier),} \\ \Pi^0 - C^i\left(e_{i,t}, k\right) - \tau e_{i,t} & \text{if not invested in period } t \text{ (or earlier),} \end{cases}$$

where $k = T_1, ..., T_5$. Total profit is then given by $\Pi_i^{total} = \sum_{t=1}^{T} \Pi_{i,t} - F$, if the firm invested during the run, or otherwise $\Pi_i^{total} = \sum_{t=1}^{T} \Pi_{i,t}$, where $T = 1$ for the single-period treatment and $T = 4$ for the multi-period treatment.

3.2 The permit treatments

As soon as the tax treatment had been finished and after a short break, the permit treatment started. In all three permit treatments we announce that the regulator issues (auctions off or grandfathers) a number of permits equal to $L = 110$[6].

When **permits are auctioned off through an ascending clock auction** (in the SAAC and MAAC treatments), we set the initial price equal to 5 ECU, the firms have 40 seconds to place their demand for permits (their requested number of permits) at that price. If the aggregate permits' demand is higher than the permits' supply (110 permits), the price is increased by 10 ECU (such that the next price is 15 ECU, then 25 ECU, and so on). The auction then continues until the demanded quantity placed by the firms is smaller or equal to the permits' supply of 110. If this is the case, the auction ends and each firm obtains its demanded quantity at this last price.[7]

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[6] or 108 due to allocation considerations in the treatments with grandfathering.

[7] If a subject does not submit her demand at the given price when the time is over, the computer program automatically submits the subject's demand from the previous price. If the subject does not submit her demand in the initial price, (5 ECU), the computer program automatically submits her maximum emission level. However, this has rarely occurred.

When the **grandfathering is followed by an ascending clock auction** (SGAC), the procedure is similar to the SAAC treatment, except that now for the given price, the subjects have 40 seconds to place their demand (their requested number of permits) or their supply (the number of permits they offer). If the aggregate demand is smaller or equal to the aggregate supply, the auction ends and each bidder gets his or her demanded quantity at this last price.[8]

The profit of firm i in period t, for the treatments with ascending clock auction (SAAC, SGAC, MAAC), is the following:

$$\Pi_{i,t} = \begin{cases} \Pi^0 - C^i\left(e_{i,t}, a\right) - \sigma e_{i,t} Z_{i,t} & \text{if invested in period } t \text{ (or earlier)}, \\ \Pi^0 - C^i\left(e_{i,t}, k\right) - \sigma e_{i,t} Z_{i,t} & \text{if not invested in period } t \text{ (or earlier)}, \end{cases}$$

where $k = T_1, ..., T_5$. Here $Z_{i,t} = 1$ in the case of auctioning off permits, and $Z_{i,t} \in \{1, -1\}$ in the case of grandfathering, depending on whether the firm buys ($Z_{i,t} = 1$) or sells ($Z_{i,t} = -1$) permits at the given period. Total profit is defined the same as in the tax treatment (section 3.1).

When the **grandfathering is followed by a single unit double auction** (in the SGDA, and MGDA treatments), the subjects have 3 minutes to buy and sell permits in the market. They can buy and sell permits either by submitting a bid or an ask, or by accepting a standing bid or an ask. The bids (asks) are ordered from highest to lowest (lowest to highest). If two bids (asks) are tied, the one entered first has priority. After a permit has been traded the auction continues for the next permit. The profit to firm i in period t is given by

$$\Pi_{i,t} = \begin{cases} \Pi^0 - C^i\left(e_{i,t}, a\right) - x & \text{if invested in period } t \text{ (or earlier)}, \\ \Pi^0 - C^i\left(e_{i,t}, k\right) - x & \text{if not invested in period } t \text{ (or earlier)}, \end{cases}$$

where $k = T_1, ..., T_5$, and x is defined as $x = \sum_{j=1}^{J} \sigma_{i,j,t} Z_{i,j,t}$, where J is the number of trades, $\sigma_{i,j,t}$ is the price subject i pays or receives in trade j, and $Z_{i,j,t} \in \{1, -1\}$ indicates whether he or she buys ($Z_{i,j,t} = 1$) or sells ($Z_{i,j,t} = -1$) a permit. Net trade sum up to $\sum_{j=1}^{J} Z_{i,j,t} = e_{i,t} - \hat{e}_i$ where $\hat{e}_i$ is subject $i's$ initial endowment of permits. Total profit is defined the same as in the tax treatment (section 3.1).

3.3 Attitude towards risk and subjects' performance

An interesting question is whether risk attitude of subjects could account for their investment and speculative behavior. For this purpose, we employ the low-payoff menu of paired lottery (Holt and Laury, 2002). This menu measures attitudes toward risk in levels indicating a risk-attitude coefficient ranging from 1 (high degree of risk-loving) to 10 (high degree of risk-aversion). A coefficient

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[8] If the demand is equal to the supply, then also each asker sells her offered quantity. However, if the demand is smaller than the supply, a random mechanism determines who of the askers will sell her offered quantity and who will not.

of 4 denotes risk neutrality. Appendix A provides a detailed description of the menu. The distribution of risk coefficients of our sample is given in Figure 2.

- Figure 2 about here -

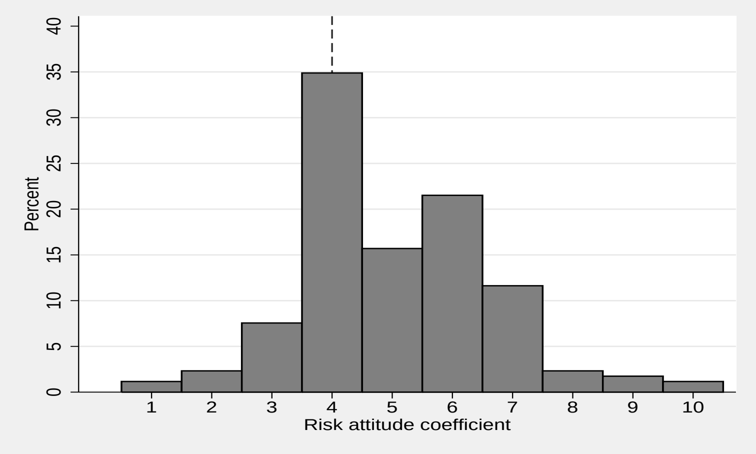

Figure 2: *The distribution of the risk-attitude coefficients, a total of 173 subjects (average: 5.02, standard deviation: 1.58). Coefficients in the range 1-3 indicate risk loving, coefficient of 4 indicates risk neutrality, and coefficients in the range 5-10 indicate risk aversion*

4 Results

This section starts by reporting the results of the tax treatment and then proceeds with the examination of the different regulation policies (SAAC, SGAC, SGDA, MAAC, MGDA). We are interested in possible deviations from (i) the optimal investment in advanced abatement technology, (ii) the efficient allocations of permits (reflected in the total abatement costs given the investment decision), and (iii) the optimal total social welfare in the economy.

4.1 The tax treatments

Since the tax treatment is basically a maximization problem, non-optimal decisions of the subjects are considered as 'mistakes'. Consequently, we identify three types of mistakes: (i) A non-optimal abatement decision, i.e., a firm abates more or less units than optimal under the given tax rate; (ii) non-optimal timing of investment in the multi-period treatments, i.e., a firm invests after the first period of a run; (iii) non-optimal investment decision, i.e., either a firm that should not invest, does invest, or a firm that should invest, does not invest. Table 4 presents the percentage of mistakes in the first and last runs of the treatment:

- Table 4 about here -

(a) The single-period tax treatment (126 subjects)

	% of investment mistakes	% of timing mistakes	% of abatement mistakes
The first run	19.12	–	26.87
The last run	7.85	–	8.79

(b) The multi-period tax treatment (72 subjects)

	% of investment mistakes	% of timing mistakes	% of abatement mistakes
The first run	25.00	5.55	29.16
The last run	8.33	4.16	8.33

Table 4: *Percentage of mistakes in the first run compared with the last run of the tax treatments. In the multi-period treatment we refer to abatement mistakes in the first and last periods of the corresponding runs.*

Table 4 illustrates that the percentage of mistakes is substantially lower in the last run compared with the first run, indicating that at the end of the treatment the subjects understand the economic situation in a much better way. At the end of the treatment, less than 10% of the decisions taken by the subjects are considered as mistakes. Note that timing mistakes were almost never observed, even in the first run.

Result 1: *At the end of the tax treatment subjects significantly improve their understanding of the economic situation. Less than 10% of their decisions are considered as mistakes.*

4.2 Investment decisions in permit markets

Figure 3 presents the distribution of investment depending on the initial technology assigned to the firms in the different treatments.[9]

- Figure 3 about here -

We start by testing whether the observed distributions of investments according to the firms' initial technologies are different from the socially optimal distribution (where only firm types T_1 and T_2 invest in the new technology). Using a Chi square (goodness of fit) test[10] for each of the single-period and multi-period treatments, we cannot reject the null hypothesis of no difference between the observed investment pattern and the expected investment pattern, at the 10% s.l.

Using a Flinger and Policello robust rank order test (F-P test) to compare between the single-period SAAC and SGAC treatments, we cannot reject the

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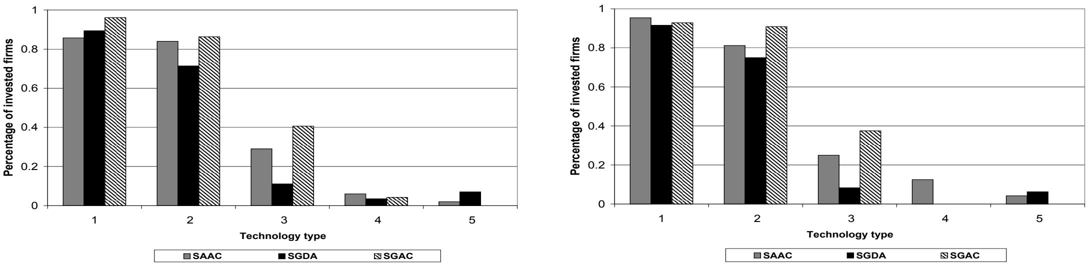
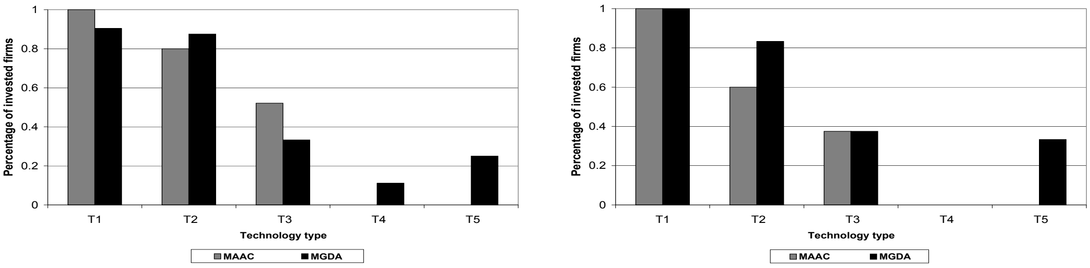
[9] This figure present the 'clean' data, after omitting subjects who made more than a single mistake in the last two periods of the tax treatment - on average 2 subjects per treatment.

[10] The test procedure is as follows: we divide the firms into 10 types: type T_1 that invested, type T_1 that did not invest, type T_2 that invested, type T_2 that did not invest, etc. Then we compare the observed frequencies with the expected theoretical frequencies.



(a) The single-period treatments (all periods)

(b) The single-period treatments (last 2 periods)



(c) The multi-period treatments (all runs)

(d) The multi-period treatments (last run)

Figure 3: *Percentage of firms investing in the new technology per conventional technology type*

null hypothesis that the initial allocation of permits does not affect the investment pattern, at the 10% s.l.

Result 2a: *The initial allocation of permits (auctioning vs. grandfathering) does not affect the pattern of investment.*

This is a remarkable result because economic theory predicts final permit allocation to be invariant to the initial allocation when the number of firms is sufficiently large (see Kennedy and Laplante, 2000; Requate and Unhold, 2003, 2001; Montero, 2002a,b).

Comparing the single-period SGAC and SGDA treatments by using an F-P test, we cannot reject the null hypothesis that the auction design does not affect investment decision at the 10% s.l.

Result 2b: *The auction design (an ascending clock auction vs. a single unit double auction) does not affect the pattern of investment.*

This result is notable since it justifies abstraction from the particular auction design as is done in many theoretical papers and textbooks on competitive permit trading (for instance Baumol and Oates, 1988; Kolstad, 2000; Tietenberg, 2006).

Finally, comparing the single-period SAAC and SGDA treatments to their corresponding multi-period treatments using an F-P test, we cannot reject the null hypothesis of no significant difference between the treatments at the 10%

level.

Result 2c: *The single-period treatments and the multi-period treatments yield similar patterns of investment.*

In line with result 2c we also observe that only 10% and 3% of the firms who invested during the MAAC and the MGDA treatments, respectively, invested in a different period than the first period of each run. This means that, by and large, firms do not observe the market before investing in the multi-period treatments, but rather decide whether to invest or not at the beginning of each run as in the single-period treatments.

4.3 Characteristics of the permit markets

In this section we investigate the different permit markets with respect to prices and volumes. We proceed by analyzing the relationships between prices, the risk-attitude coefficients, the initial technology assigned, investments, and speculative behavior.

Table 5 compares the observed average prices[11] and volumes with their expected values depending on the observed pattern of investment. Recall that market prices and volumes of trade reflect the size of demand and supply of permits in the market (which depend on the investments).

- Table 5 about here -

Treatment	Observed		Expected	
	Price	Volume	Price	Volume
SAAC	55.00	103.81	45.45 – 53.63	110
	(11.83)	(5.32)	(8.20 – 9.24)	(–)
SGAC	60.00	32.87	49.16 – 59.16	35
	(10.69)	(5.66)	(8.86)	(3.42)
SGDA	64.84	44.16	49.16 – 59.16	35.41
	(10.01)	(10.56)	(7.93)	(3.77)
MAAC	53.33	102.39	36.66 – 46.66	110
	(6.37)	(5.00)	(5.16)	(–)
MGDA	58.21	41.25	43.33 – 53.33	35.66
	(11.82)	(3.77)	(5.16)	(2.42)

Table 5: *Comparison of observed average prices and trade volumes of permits with the expected average prices and trade volumes given the observed pattern of investment (standard deviations are given in brackets)*

Table 5 shows that the observed prices are higher than the expected prices in all treatments. Moreover, we find too little trading in the treatments using

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[11] The price range is a result of the stepwise aggregate marginal abatement cost function which we are using. For example, when we allocate 110 (or 108) permits and only firms of type T_1 and T_2 invest in the advanced technology, we expect the permit price to range between 50 and 60.

the ascending clock auction and excessive trading in the treatments using the double auction. A possible explanation for over-trading in the treatments with double auction is that these treatments allow for speculative trading (defined as buying and selling permits by the same firm in a given period). Table 6 presents the net trading in the DA treatments, defined as the absolute value of permits at the end of the period minus initial permits.

- Table 6 about here -

Treatment	Observed volume		Expected volume
	Net trading	Total trading	(net trading)
SGDA	30.83	44.16	35.41
	(7.95)	(10.56)	(3.77)
MGDA	33.04	41.25	35.66
	(3.16)	(3.77)	(2.42)

Table 6: *Comparison of the observed average net trading volume and the total average trading volume of permits with the expected average volume given the observed pattern of investment in the DA treatments (standard deviations are given in brackets)*

Table 6 illustrates that there is also too little-(net) trading in the DA treatments compared with the expected trading volume according to the theoretical prediction.

4.3.1 Factors influencing investment

To better understand what factors are influencing the investment behavior in the different treatments, we estimate a Probit model (using the pooled data across firms and over time) for the single-period treatments.[12] The explanatory variables are the following: investment in the previous period (a dummy variable obtaining the value of 1 when the firm invested in the previous period), the initial technology assigned (a discrete variable ranging between 1 for the least efficient technology and 5 for the most efficient technology), the average price in the previous period, and the risk-attitude coefficient (see Holt and Laury, 2002) ranging between 1 and 10. The estimation results are given in Table 7.

- Table 7 about here -

We find that the initial technology and investment in the previous period are significantly correlated with investment in all treatments. The result that the initial technology affects investment stems from the asymmetric effect of investment according to the firms' initial technologies (i.e. the least efficient firms gain more by investing). The result that investment in the previous period is

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[12] We also estimated a random-effect panel Probit model to account for individual heterogeneity, but a likelihood ratio test indicates that the pooled model is preferred.

Treatment	SAAC	SGAC	SGDA
Investment $(t-1)$	1.17***	0.89**	1.00***
	(0.25)	(0.42)	(0.26)
Technology	-0.48***	-1.23***	-0.76***
	(0.08)	(0.23)	(0.11)
Risk-attitude coef.	0.01	-0.19	0.19*
	(0.06)	(0.16)	(0.11)
Average price $(t-1)$	0.02***	0.02	0.01
	(0.00)	(0.01)	(0.01)
Cons	-0.82	2.86***	-0.46
	(0.66)	(1.56)	(0.1.28)
LR test (K-1)	77.97***	95.34***	115.46***
McFadden's Pseudo R^2	0.33	0.67	0.49
McFadden's Pseudo adj. R^2	0.29	0.60	0.44

* =10% s.l, **= 5% s.l, ***=1% s.l

Table 7: *Probit estimations of the different single-period treatments. The dependent variable: Investment at period t.*

correlated with current period investment may indicate state dependence (Heckman, 1981). This means that, for the single-period treatments, once a subject has invested (has not invested) in a certain period, there is a higher probability that he will invest (not invest) in the following period, *ceteris paribus*. Prices in previous periods significantly affect investment only in the SAAC treatment.[13] This result is puzzling since the expected price of permits is a crucial factor when a firm is considering whether or not to adopt the advanced technology. Therefore, we expected that the previous period price would have a significant effect on investment in all treatments. Finally, the risk-attitude coefficient is significantly correlated with investment only in SGDA treatment. We can summarize our findings as follows:

Result 3a: *A dirtier initial technology and investment in the previous period are positively correlated with investment in all treatments. A tendency towards risk aversion is positively correlated with investment in the SGDA treatment (the risk attitude coefficient was not significant in the other treatments). A high permit price in the previous period is positively correlated with investment in the SAAC treatment (the previous period permit price coefficient was not significant in the other treatments).*

4.3.2 Factors influencing speculative behavior

Lets us define a *speculator* as a trader who sells and buys permits within the same period. In order to reveal the factors influencing speculative behavior we

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[13] For the DA treatment, we also estimated other models including the average selling price per subject and the average buying price per subject (including only the transactions that were made by the specific subject). However, the corresponding coefficients are not statistically significant.

estimate the Probit model presented in Table 8.[14]

- Table 8 about here -

Variable name	Speculation (t)
Speculation ($t-1$)	1.00***
	(0.24)
Technology	-0.12
	(0.011)
Risk-attitude coef.	-0.16*
	(0.08)
Investment (t)	-0.44
	(0.34)
Average price ($t-1$)	0.02*
	(0.01)
Cons	-1.24
	(1.12)
LR test (K-1)	35.24***
McFadden's Pseudo R^2	0.19
McFadden's Pseudo adj. R^2	0.12

* =10% s.l, **= 5% s.l, ***=1% s.l

Table 8: *Probit estimation of the SGDA treatment. The dependent variable: Speculation at period t.*

Table 8 indicates that speculation in the previous period, average price in the previous period, and a low risk-attitude coefficient (a tendency towards risk-loving) are positively and significantly correlated with the current period speculation. These findings are quite intuitive since the incentives to speculate depend on the average buying and selling price, moreover, we expect speculators to have a tendency towards risk loving. Finally, we also observe state dependence (Heckman, 1981) as in the case of investment behavior.

Result 3b: *Speculative behavior in the previous period, a high average price in the previous period, and a tendency towards risk-loving are positively correlated with speculative behavior in the current period.*

4.4 Efficiency in allocation of permits

Besides optimal investment, an additional measure of efficiency in permits market is the efficiency in allocation of permits. This is measured by the total abatement cost (TAC) given the observed pattern of investment. In other words, we test whether firms (subjects) make efficient use of the auction to minimize the

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[14] As in section 4.3.1, We also estimated a random-effect panel Probit model to account for individual heterogeneity, but a likelihood ratio test indicates that the pooled model is preferred.

TAC of the industry. Table 9 presents the average observed TAC with the average efficient TAC given the observed pattern of investment. The efficiency ratio (*observed TAC/efficient TAC*) is a measure of efficient allocation of permits. The lower the ratio, the higher is the efficiency of the market. When permits are allocated efficiently (and the marginal abatement costs are balanced between all firms)[15] the efficiency ratio is equal to 1.

- Table 9 about here -

Treatment	Observed TAC	Efficient TAC	Efficiency ratio
SAAC	3679.09	2782.72	1.32
	(1426.94)	(963.68)	(0.26)
SGAC	3957.50	3294.16	1.30
	(1117.63)	(976.97)	(0.11)
SGDA	3328.75	2577.50	1.20
	(1084.25)	(955.77)	(0.09)
MAAC	2800.41	2038.33	1.36
	(799.82)	(333.07)	(0.26)
MGDA	3094.58	2643.33	1.17
	(674.28)	(505.29)	(0.09)

Table 9: *Average observed and efficient TAC (given the observed pattern of investment) in the different treatments (standard deviations are given in brackets). The efficiency ratio is defined as observed TAC/efficient TAC*

Using a Kruskall-Wallis test to compare between the series of efficiency ratios, we do not find a significant difference between the three single-period treatments at the 10% level. Using an F-P test to compare between each pair of treatments, we find that the SGDA outperforms the SGAC treatment at the 10% s.l. We, however, do not find differences between the SGDA and the SAAC treatments at the 10% s.l. Using an F-P test, comparing between the two the multi-period treatments, we find that the MGDA treatment outperforms the MAAC treatment at the 10% level (all the results reported are of two-sided test).

Result 4: *Regarding efficiency in allocation of permits, the SGDA treatment outperforms the SGAC treatment, and the MGDA treatment outperforms the MAAC.*

4.5 Total social welfare in permit markets

Finally, we evaluate the regulation policies through comparing the total social welfare (TSW) defined as the sum of the unconditional profits minus the investment and abatement costs across firms, minus the total damage to the society from pollution. We consider two cases: an increasing marginal damage

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[15] Since the number of permits in our experiment is an integer, it can happen that the marginal abatement cost is different between the firms (by at most one unit).

(MD) schedule ($MD = E/2$), and a constant marginal damage schedule with $MD = 55$. A flat MD schedule is chosen following Tol's (2005) estimation of Carbon Dioxide emissions.[16] Table 10 presents the average efficiency ratios (defined as: *observed TSW/efficient TSW*) for each treatment. Note that, in this case, in contrast to the efficiency measure on the total abatement costs, the higher the efficiency ratio the higher the efficiency in the market.

- Table 10 about here -

Treatment	Efficiency ratio (flat MD function)	Efficiency ratio (increasing MD function)
SAAC	0.89	0.92
	(0.07)	(0.05)
SGAC	0.89	0.91
	(0.03)	(0.02)
SGDA	0.87	0.91
	(0.06)	(0.04)
MAAC	0.93	0.94
	(0.05)	(0.03)
MGDA	0.89	0.94
	(0.03)	(0.01)

Table 10: *Mean (and standard deviations) of the 'efficiency ratio' (defined as, observed TSW/efficient TSW) series of the Total Social Welfare (TSW), calculated assuming a flat marginal damage (MD=55) schedule or assuming an increasing marginal damage schedule (MD=E/2), in the different treatments.*

Regarding a flat MD schedule, comparing the series of efficiency ratios between the different single-period treatments, using a Kruskall-Wallis test and an F-P test for each pair of treatments, we do not find differences between treatments at the 10% s.l. However, using an F-P test, comparing between the multi-period treatments, we find that the MAAC treatment outperforms the MGDA treatment at the 10% s.l. Applying the same tests for the TSW with increasing MD schedule we do not find a difference between the single-period and between the multi-period treatments, respectively, at the 10% s.l.

Result 5: *Overall, the different treatments do not perform differently with respect to total welfare losses.*

5 Concluding Remarks

This study aims at testing, by means of a laboratory experiment, whether both methods of initial allocation of permits and the choice of auction design affect

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[16] Tol (2005) estimates a rather flat MD schedule (under a 4-5% social rate of discount, he estimates the MD as \$16/tC, not exceeding \$62/tC with a probability of 95%).

the incentives to invest in advanced abatement technology in tradable permit markets with small asymmetric firms. Altogether, we conducted a total of five treatments, varying the way the permits are initially allocated (costly vs. free), the auction design (ascending clock auction vs. single unit double auction), and the relevant time horizon within the treatments (single-period vs. multi-period).

Regarding investment in advanced technology, we do not find significant differences between the treatments, a result in line with many theoretical predictions. We also observed, as in Gangadharan *et al.* (2005), that at least some firms of each initial technology invest in the new technology (even firms with the cleanest technology). In particular, we find under-investment by the inefficient firms and over-investment by efficient firms.

Regarding the total social welfare, we do not find significant differences between the treatments. However, regarding optimal allocation of permits we find weak evidence that the single unit double auction outperforms the ascending clock auction. Thus, we deliver a further argument in favor of the double auction trading institution. The result that grandfathering is not inferior to auctioning in any of the evaluation criteria[17], is particularly interesting in light of the tendency of economists to prefer auctioning on grandfathering (see, for instance, Cramton and Kerr, 2002).

In summary, this paper's novelty comes from testing the effect of initial allocation of permits on adoption of advanced technology. Moreover, it also tests the effect of two alternative auction designs on adoption of advanced technology. Our results confirm that in a market consisting of a sufficiently large number of firms, the initial allocation of permits does not affect the investment behavior. Our findings also indicate that, by and large, both auction designs perform similarly. Thus, we support the abstraction from the auction design when evaluating the effect of emission permits as a policy instrument. Finally, although laboratory experiments were often used to investigate the static efficiency of alternative environmental policy instruments under various conditions, there was not much use of experiments to investigate the dynamic efficiency of adopting (or developing) advanced technologies. Thus, experimental economics should still clarify issues relating to the incentives to adopt or develop advanced technologies.

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[17] Our analysis does not include political economy considerations such as the costs of lobbying when grandfathering is implemented, or that grandfathering may set up an entry barrier, etc.

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A Holt and Laury's (2002) Menu of Paired Lottery

Holt and Laury's (2002) low payoff menu of paired lottery (see Figure 4) requires subjects to choose between two lotteries: A and B. The 'solid' lottery A includes a probability to win a high payoff of €2 and a (complementary) probability to win a low payoff of €1.6.[18] Similarly, the 'riskier' lottery B includes a probability to win a high payoff of €3.85 and a (complementary) probability to win a low payoff of €0.1. The probabilities to win the high (and low) payoffs are the same for both lotteries A and B. The probability to win the high payoff increases gradually during the lottery choice menu in increments of 10%, such that from a probability of 10% to win the high payoff and a probability of 90% to win the low payoff in the first lottery-choice it reaches a probability of 100% to win the high payoff and 0% to win the low payoff in the last choice of the menu. As the probability to win the high payoff in both lotteries increases, subjects are expected to switch from A to B. For instance, a risk neutral subject, who chooses the lottery according to the highest expected value, will choose 4 times A before switching to B. Consequently, from the pattern of choices observed, a risk-attitude coefficient which corresponds to the number of consecutive choices of lottery A before switching to lottery B, is computed.

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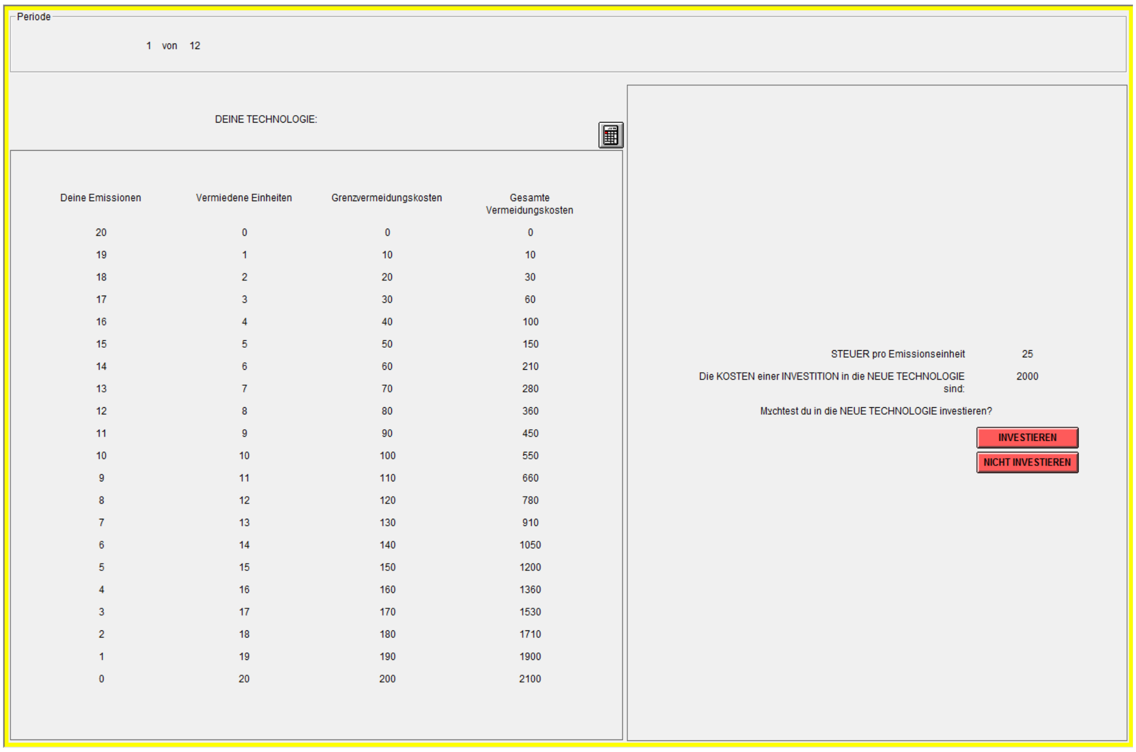
[18] In the original study by Holt and Laury (2002) the payoffs are in US$.

Name____________________ Date___________________________

Number	Option A	Option B	Your Decision (A or B)
1	1/10 of €2.00, 9/10 of €1.60	1/10 of €3.85, 9/10 of €0.10	
2	2/10 of €2.00, 8/10 of €1.60	2/10 of € 3.85, 8/10 of €0.10	
3	3/10 of €2.00, 7/10 of €1.60	3/10 of €3.85, 7/10 of €0.10	
4	4/10 of €2.00, 6/10 of €1.60	4/10 of € 3.85, 6/10 of €0.10	
5	5/10 of €2.00, 5/10 of €1.60	5/10 of €3.85, 5/10 of €0.10	
6	6/10 of €2.00, 4/10 of €1.60	6/10 of €3.85, 4/10 of €0.10	
7	7/10 of €2.00, 3/10 of €1.60	7/10 of €3.85, 3/10 of €0.10	
8	8/10 of €2.00, 2/10 of €1.60	8/10 of €3.85, 2/10 of €0.10	
9	9/10 of €2.00, 1/10 of €1.60	9/10 of €3.85, 1/10 of €0.10	
10	10/10 of €2.00, 0/10 of €1.60	10/10 of €3.85, 0/10 of €0.10	

Figure 4: *Holt and Laury's (2002) menu of paired lottery*

B Computer screens



Periode

1 von 12

DEINE TECHNOLOGIE:

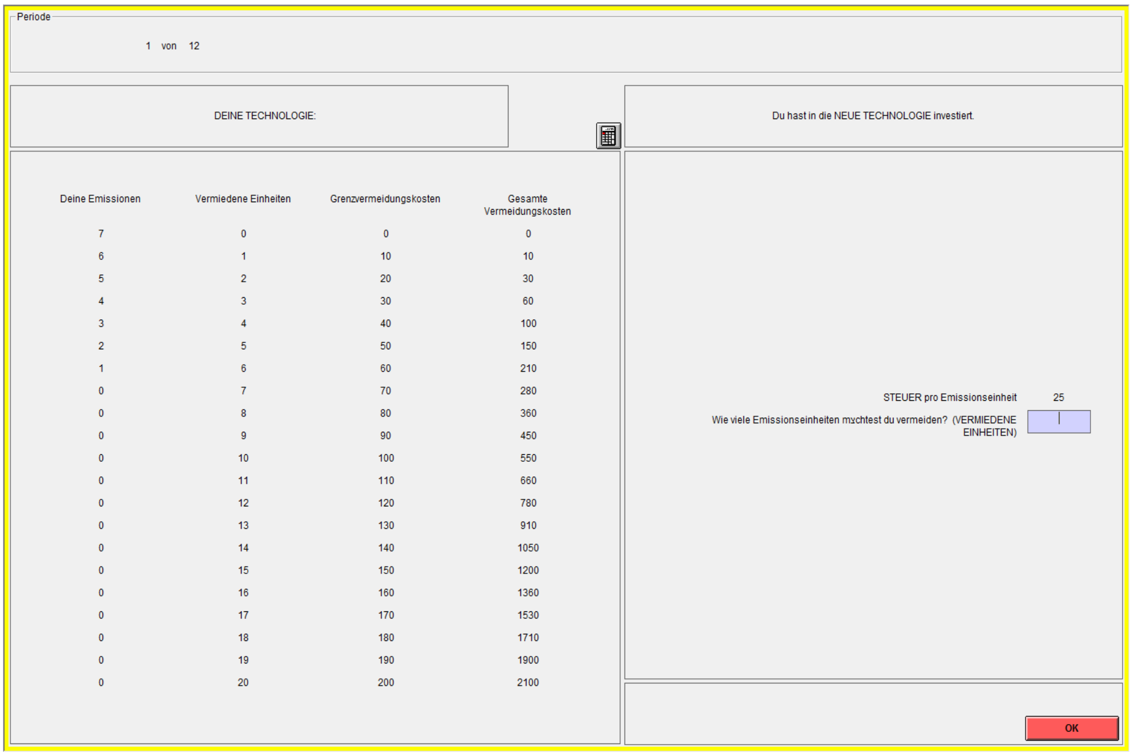
Deine Emissionen	Vermiedene Einheiten	Grenzvermeidungskosten	Gesamte Vermeidungskosten
20	0	0	0
19	1	10	10
18	2	20	30
17	3	30	60
16	4	40	100
15	5	50	150
14	6	60	210
13	7	70	280
12	8	80	360
11	9	90	450
10	10	100	550
9	11	110	660
8	12	120	780
7	13	130	910
6	14	140	1050
5	15	150	1200
4	16	160	1360
3	17	170	1530
2	18	180	1710
1	19	190	1900
0	20	200	2100

STEUER pro Emissionseinheit 25

Die KOSTEN einer INVESTITION in die NEUE TECHNOLOGIE sind: 2000

Mxchtest du in die NEUE TECHNOLOGIE investieren?

Figure 5: *The 'investment' screen in the multi-period tax treatment*


Periode

1 von 12

DEINE TECHNOLOGIE:

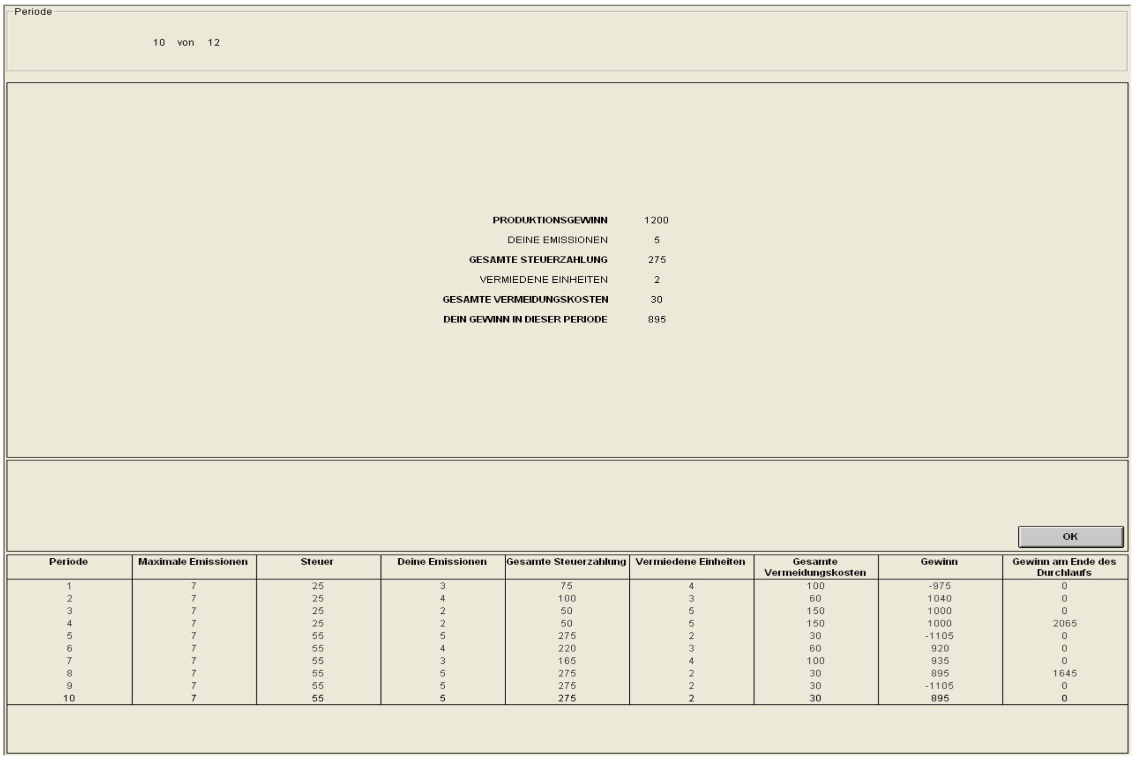
Du hast in die NEUE TECHNOLOGIE investiert.

Deine Emissionen	Vermiedene Einheiten	Grenzvermeidungskosten	Gesamte Vermeidungskosten
7	0	0	0
6	1	10	10
5	2	20	30
4	3	30	60
3	4	40	100
2	5	50	150
1	6	60	210
0	7	70	280
0	8	80	360
0	9	90	450
0	10	100	550
0	11	110	660
0	12	120	780
0	13	130	910
0	14	140	1050
0	15	150	1200
0	16	160	1360
0	17	170	1530
0	18	180	1710
0	19	190	1900
0	20	200	2100

STEUER pro Emissionseinheit 25

Wie viele Emissionseinheiten mxchtest du vermeiden? (VERMIEDENE EINHEITEN)

Figure 6: *The 'abatement' screen in the multi-period tax treatment*


Periode

10 von 12

PRODUKTIONSGEWINN 1200

DEINE EMISSIONEN 5

GESAMTE STEUERZAHLUNG 275

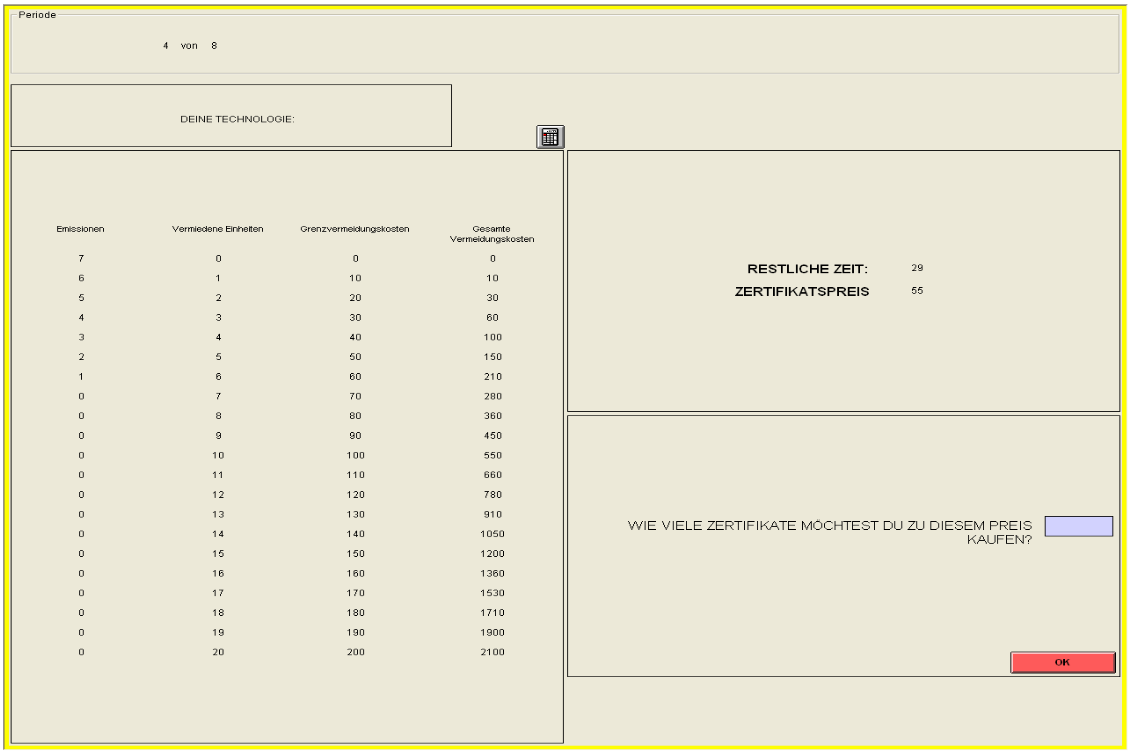
VERMIEDENE EINHEITEN 2

GESAMTE VERMEIDUNGSKOSTEN 30

DEIN GEWINN IN DIESER PERIODE 895

Periode	Maximale Emissionen	Steuer	Deine Emissionen	Gesamte Steuerzahlung	Vermiedene Einheiten	Gesamte Vermeidungskosten	Gewinn	Gewinn am Ende des Durchlaufs
1	7	25	3	75	4	100	-975	0
2	7	25	4	100	3	60	1040	0
3	7	25	2	50	5	150	1000	0
4	7	25	2	50	5	150	1000	2065
5	7	55	5	275	2	30	-1105	0
6	7	55	4	220	3	60	920	0
7	7	55	3	165	4	100	935	0
8	7	55	5	275	2	30	895	1645
9	7	55	5	275	2	30	-1105	0
10	7	55	5	275	2	30	895	0

Figure 7: *The 'results' screen in the multi-period tax treatment*



Periode

4 von 8

DEINE TECHNOLOGIE:

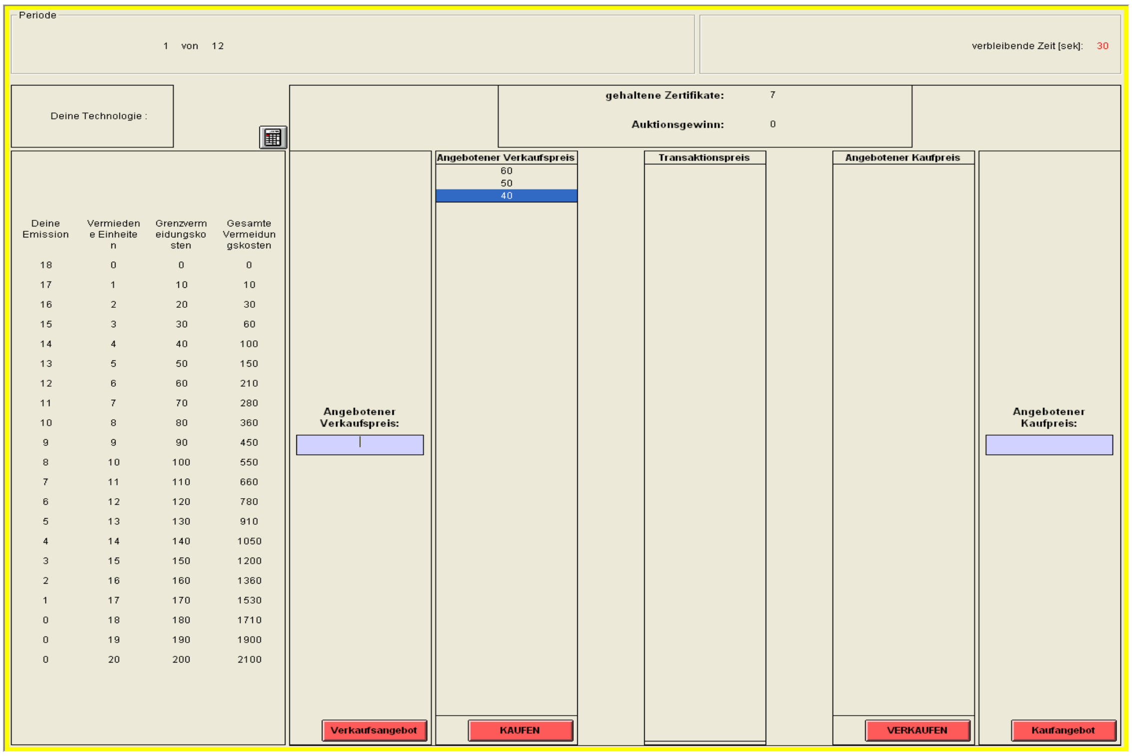
Emissionen	Vermiedene Einheiten	Grenzvermeidungskosten	Gesamte Vermeidungskosten
7	0	0	0
6	1	10	10
5	2	20	30
4	3	30	60
3	4	40	100
2	5	50	150
1	6	60	210
0	7	70	280
0	8	80	360
0	9	90	450
0	10	100	550
0	11	110	660
0	12	120	780
0	13	130	910
0	14	140	1050
0	15	150	1200
0	16	160	1360
0	17	170	1530
0	18	180	1710
0	19	190	1900
0	20	200	2100

RESTLICHE ZEIT: 29

ZERTIFIKATSPREIS 55

WIE VIELE ZERTIFIKATE MÖCHTEST DU ZU DIESEM PREIS KAUFEN?

Figure 8: *The 'auction' screen in the SAAC and MAAC treatments*



Periode

1 von 12

verbleibende Zeit [sek]: 30

Deine Technologie :

gehaltene Zertifikate: 7

Auktionsgewinn: 0

Deine Emission	Vermiedene Einheiten	Grenzvermeidungskosten	Gesamte Vermeidungskosten
18	0	0	0
17	1	10	10
16	2	20	30
15	3	30	60
14	4	40	100
13	5	50	150
12	6	60	210
11	7	70	280
10	8	80	360
9	9	90	450
8	10	100	550
7	11	110	660
6	12	120	780
5	13	130	910
4	14	140	1050
3	15	150	1200
2	16	160	1360
1	17	170	1530
0	18	180	1710
0	19	190	1900
0	20	200	2100

Angebotener Verkaufspreis:

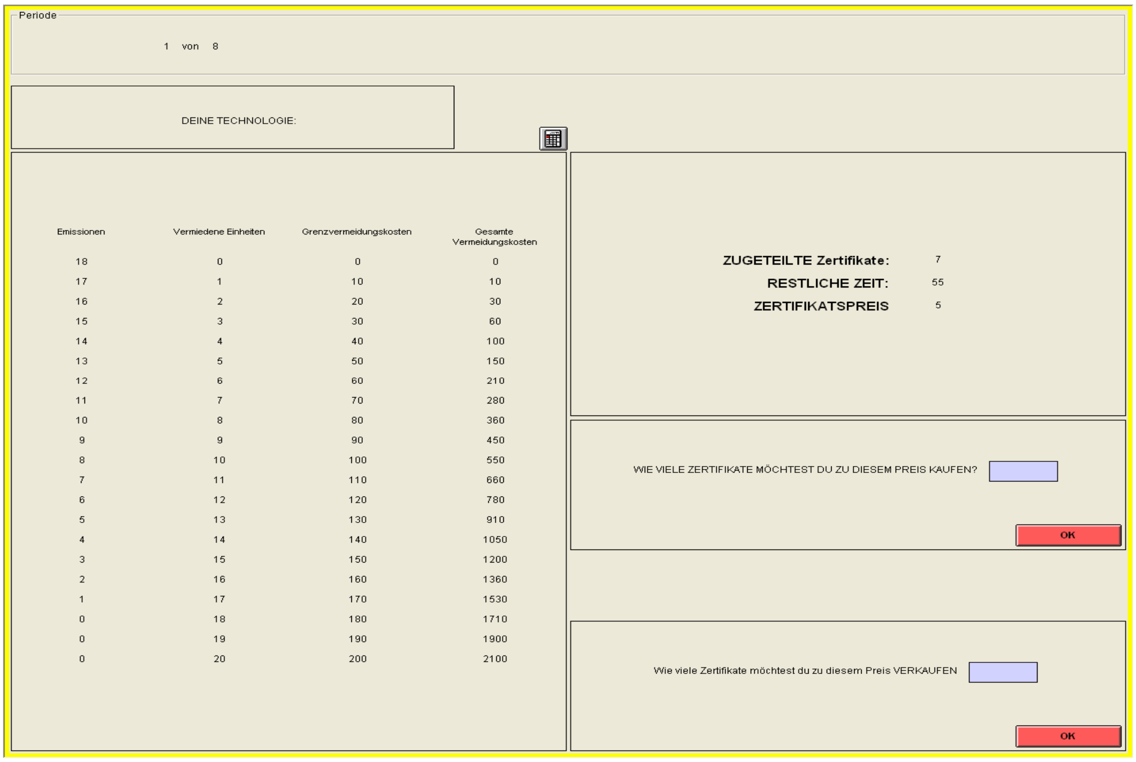
Angebotener Verkaufspreis
60
50
40

Transaktionspreis

Angebotener Kaufpreis

Angebotener Kaufpreis:

Figure 9: *The 'auction' screen in the SGDA and MGDA treatments*


Periode

1 von 8

DEINE TECHNOLOGIE:

Emissionen	Vermiedene Einheiten	Grenzvermeidungskosten	Gesamte Vermeidungskosten
18	0	0	0
17	1	10	10
16	2	20	30
15	3	30	60
14	4	40	100
13	5	50	150
12	6	60	210
11	7	70	280
10	8	80	360
9	9	90	450
8	10	100	550
7	11	110	660
6	12	120	780
5	13	130	910
4	14	140	1050
3	15	150	1200
2	16	160	1360
1	17	170	1530
0	18	180	1710
0	19	190	1900
0	20	200	2100

ZUGETEILTE Zertifikate: 7

RESTLICHE ZEIT: 55

ZERTIFIKATSPREIS 5

WIE VIELE ZERTIFIKATE MÖCHTEST DU ZU DIESEM PREIS KAUFEN?

Wie viele Zertifikate möchtest du zu diesem Preis VERKAUFEN

Figure 10: *The ‘auction’ screen in the SGAC treatment*