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Opportunity Cost for Free Allocations of Emissions Permits: An Experimental Analysis

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Abstract An important feature of emissions trading is how emissions permits are allocated. The choice between an auction and free allocation should not influence firms' production choices nor consumer prices according to economic theory. However, many parties expect the method of allocation to affect product prices. This paper describes an experimental investigation into price determination under a cap-and-trade program with different allocation methods. Participants initially display diverse pricing strategies. However, given a simple economic setting in which earnings depend on behavior, we find that subjects learn to consider the opportunity cost of permits and overall behavior moves toward the economic prediction.

Keywords Auction · Emissions allowances · Grandfathering

JEL Classification C91 · D44

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1 Introduction

A cap-and-trade program sets a limit on the available number of emissions permits (often termed emissions allowances). An important objective is to alter relative prices throughout the economy by including the social cost of pollution in product prices. At the same time, higher retail prices for goods such as electricity may be politically controversial, particularly if price effects are regressive. To many observers, a solution would be to distribute permits to polluting entities for free, rather than through an auction, so that their direct costs are less affected by the regulatory program, resulting in a smaller change in retail prices.

However, economic theory indicates that retail prices will increase, reflecting the economic value of permits whether polluting entities received them for free or not, because economic costs include the *opportunity cost* of using a permit that otherwise could be sold in the permit market.

In the public dialogue, free allocation is frequently put forward as a means of reducing the downstream price effects of the EU Emissions Trading System (EU ETS). For example, one energy company official said if permits "are auctioned that will only lead to 100 per cent of the carbon price being priced into the electricity price, and thus increase it."[1] Governmental authorities have raised similar arguments. For instance, the German Federal Cartel Office (Bundeskartellamt) stated in a "warning letter" [2] to RWE[3] that their industrial electricity prices were abusive; the company had passed on more than 25 percent of the value of its CO_2 emission permits within its electricity prices. More recently, the Belgian energy market regulator CREG stated that the country's authorities must act to prevent utilities from making windfall profits by passing on the cost of CO_2 emission permits to consumers.[4] CREG referred to estimates that electricity producers in the Belgian market generated about 1.2 billion euros in profits between 2005 and 2007 by charging clients for CO_2 emissions permits they had received for free. In sum, the intuition that only direct costs should be included in product prices seems deeply ingrained. Thus, the fundamental question of what price effects different allocation mechanisms may yield is an empirical one.

Previous studies on price effects of emissions trading include econometric time series performed by Bunn and Fezzi (2007) in the UK electricity market and Fell (2009) in the Nordic market. Both find electricity prices respond to a change in the price of emissions permits, suggesting that consumers pay for a significant portion of the value of emissions permits, even when the industry has received them for free. However, the studies are ambiguous about how much pass-through occurs. Ambiguity stems from the heterogeneity of technologies, emissions rates and marginal costs. In most wholesale electricity markets (except where power purchase agreements are in place), each producer receives the same price equal to the bid of the last generator, *i.e.* the one with the highest marginal cost. Thus, to calculate the amount of pass-through requires information about what technology is on the margin at any given point in time (Sijm et al. 2006).

In public discussion the issue is driven by concerns of perceptions of fairness, compensation, and potential windfall profits. Hence, an additional source of ambiguity is pass-through for infra-marginal facilities, which may have emissions rates greater or less than for the

[1] *Carbon Market Europe, Point Carbon*, October 14, 2005, 6.

[2] December 20, 2006: www.bundeskartellamt.de/wEnglisch/News/Archiv/ArchivNews2006/2006_12_20.php

[3] RWE is one of the largest electricity producers in Germany. In the EU ETS all entities have received a major share of their permits for free.

[4] Reuters, January 21 2009.

marginal facility. Complete pass-through for the marginal facility may lead to an industry-wide rate that is greater or less than 100 percent of total permit value.

This paper examines the behavior of firms through the use of experiments in a laboratory setting. A large experimental literature examines aspects of emissions trading, but few address the effects of allocation on efficiency. Plott (1983) conducted experiments where tradable licenses were required for economic activity. Even when licenses were distributed initially for free, the price of production reflected their opportunity cost and the licenses were used in an approximately efficient manner. However, unlike actual permit markets, the licenses were not distributed in proportion to their ultimate use. Consequently, producers had to engage extensively in the secondary market for licenses, and this likely contributed to the recognition of the market-driven opportunity costs. In our experiment, when permits were distributed for free, subjects had sufficient permits to cover production, perhaps making it more difficult for subjects to recognize their opportunity cost.

More recently, Buckley et al. (2008) find emissions trading to be more efficient than tradable performance standards, as theory predicts. Most relevant, Goeree et al. (2009) find that free allocation may even lead to slightly higher permit prices than an auction, if high users are given high allocations. They conjecture that behavioral aversion to trading (such as the endowment effect) is reinforced by strategic tendency for high users to retain too many permits, which can result in lower product output. They do not address opportunity cost, production, pricing decisions directly. Bunn and Fezzi (2007) show that a mix of free allocation and a one-sided auction (with no secondary market) can lead to an inefficient auction price because allowance holdings affect bidding behavior when allowances cannot be sold back into the market.

2 Procedures

Participants acted as producers, with capacity to produce up to three units of a product in each of ten rounds. Each production unit required one unit of fuel and one permit. Fuel costs were \$1, \$3, and \$5 for production units 1, 2, and 3, respectively, representing increasing marginal costs. In some treatments three permits were received for free, and in other treatments permits had to be purchased. There was a single market price of \$4 for permits. Subjects automatically received the market price for any unused permits; thus their opportunity cost was independent of the production decision.

Subjects were informed of the randomly determined product price each round. Two different random seeds were used. The incentives were straightforward; subjects should produce a unit as long as it was more profitable than not producing.

An alternative treatment investigated the effect of information about a subject's performance relative to others. After each round, subjects were told their profits. In some treatments, subjects were informed how their profits ranked relative to the other subjects in the room. Subjects knew they all faced the same prices and costs, so any differences in profits were attributable to production decisions.

We ran 8 treatments in total: with and without relative information and with and without free allocation, with two random seeds. Twelve subjects were recruited for each session among students at the University of Virginia. Earnings in experimental dollars were converted to real currency for payment at the end of the experiment.[5]

[5] Additional details are reported in Wråke et al. (2008).

3 Experiment Results

A production decision that failed to maximize profits is characterized as an error. For example, a decision to produce when marginal cost (including the opportunity cost of a permit) was above the market price, or not to produce when marginal cost was below market price. Since subjects made a decision pertaining to each of their three production units, they could make up to three errors in each round. Figure 1 depicts the proportion of erroneous production decisions made by the 12 participants in each of the 10 rounds (averaged over seeds). In the first round there are about twice as many errors made in treatments with free allocation than without, but this effect diminishes over time.

Result 1 Subjects improve their payoff over multiple rounds of the experiment. Greater improvement occurs among participants that receive emissions permits for free.

A central question is whether learning is facilitated by having to pay for permits and/or by information about one's performance relative to others. We examine behavior in the first three rounds compared to the last three rounds using individual participants as observations. If there were a learning effect, we would expect to see a positive difference between the numbers of errors in early compared to late rounds. Table 1 reports the Wilcoxon matched-pairs signed rank test for all four treatment combinations.

The number of observations with a positive difference in errors between early and late rounds ($W+$) dominates those with negative difference ($W-$), consistent with learning. The difference is statistically significant for all treatment types.

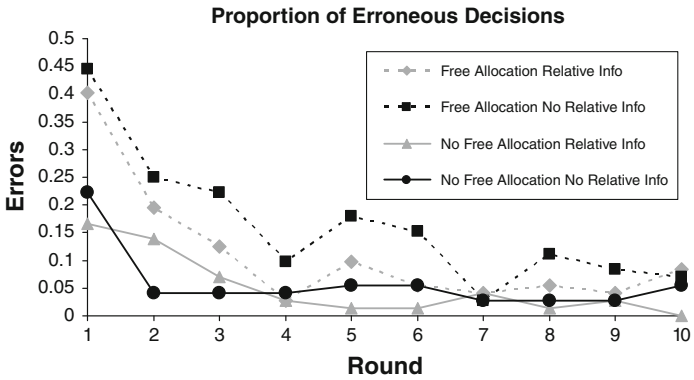

Fig. 1 Proportion of erroneous decisions by treatment type

Table 1 Learning effects

	$W+$	$W-$	*p-value*	*n*
Free allocation, no relative info	186	4	0.0000267***	19
Free allocation, relative info	137.5	15.5	0.00209***	17
No free allocation, relative info	78	0	0.0004883***	12
No free allocation, no relative info	70.5	7.5	0.009272***	12

Results from a Wilcoxon matched-pairs signed rank test. * significant at 10% level, ** significant at 5% level and *** significant at 1% level

Table 2 Treatment effects

	Rounds 1–5		Rounds 6–10	
	W	*p-value*	*W*	*p-value*
Effect of free allocation	1,840	$p <= .000354$***	2,243	$p <= .5358$
Effect of relative information	2,271.5	$p <= .6816$	2,178	$p <= .2733$

Results from Wilcoxon rank sum test. * significant on the 10% level, ** significant on 5% level and *** significant on 1% level

Result 2 Subjects more easily identify the payoff-maximizing production strategy when they receive no free allocation, especially in the early rounds.

To formally test whether treatments invoke different behavior we perform the non-parametric Wilcoxon rank sum test. We use individual participants as observations, and errors summed over rounds 1–5 and rounds 6–10 as a measure of performance. Table 2 reports the test of a null hypothesis that treatment effects do not matter.

We find a statistically significant difference between treatments with and without free allocation for rounds 1–5, but not rounds 6–10. The difference in the early rounds suggests that the profit-maximizing strategy may be more comprehensible when the cost of an emissions permit is a direct cost rather than an opportunity cost. The lack of a difference in the last 5 rounds suggests that subjects in free allocation treatments learn to incorporate the opportunity cost.

Result 3 Information about relative performance does not speed the transition toward payoff-maximizing decisions.

Table 2 shows no significant difference when subjects were given or not given information about their relative performance. This result holds in early and late rounds of the experiments, and whether permits were received for free or not.[6]

4 Conclusion

This paper reports on experimental methods to investigate how the initial distribution of emissions permits affects behavior in a simple decision task motivated by cap-and-trade policies. The experimental approach applied in this paper allows us to study the pass-through decision directly. Our findings confirm that the concept of opportunity cost is intuitively difficult. Participants initially exhibit a range of behavior; however, we find learning to be a central process for understanding firm behavior and market performance. Participants initially make decisions that are closer to economic theory when they have to purchase permits than when they receive them for free. Over time participants make decisions that are closer to profit maximizing levels in treatments both with and without free allocations.

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[6] This provision of relative information does have an effect in a more complex bidding environment, where it plays a role in accelerating learning under free allocation but not otherwise (Wråke et al. 2008).

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