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The effect of transaction costs in CO2 markets

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Summary

The Continuous Double Auction (CDA) is used in the CO2 emissions permits. High market efficiency (close to 100%) is the most robust results in a typical CDA experiment, where transactions and submissions are costless. However, in real world trading, there are monetary costs on transactions. In this paper we study the sensitivity of CDA performance to the imposition of monetary costs on the market using an artificial agent-based model approach. We find that the monetary costs reduce market efficiency according to both the theory and previous Experimental Economics results. Moreover, our model provides new behavioural explanations of these effects that have practical value in the design and analysis of CO2 permits markets

Keywords: Continuous Double Auction. Artificial Economics. Behavioural microeconomics. CO2 market.

1. Introduction

Even the common citizen is aware of the difference between value and price. However, she is not so much aware of the fact that the market measures and transforms valuable goods, services or rights into prices. John Stuart Mill demonstrated an early insight into the value of the natural world (Mill, 1848): "*Air, for example, though the most absolute of necessaries, bears no price in the market, because it can be obtained gratuitously: to accumulate a stock of it would yield no profit or advantage to any one; and the laws of its production and distribution are the subject of a very different study from Political Economy. It is possible to imagine circumstances in which air would be a part of wealth. If it became customary to sojourn long in places where the air does not naturally penetrate, as in diving-bells sunk in the sea, a supply of air artificially furnished would, like water conveyed into houses, bear a price: and if from any revolution in nature the atmosphere became too scanty for the consumption, or could be monopolized, air might acquire a very high marketable value. In such a case, the possession of it, beyond his own wants, would be, to its owner, wealth; and the general wealth of mankind might at first sight appear to be increased, by what would be so great a calamity to them. The error would lie in not considering, that however rich the possessor of air might become at the expense of the rest of the community, all persons else would be poorer by all that they were compelled to pay for what they had before obtained without payment.*"

However, the first air pollution trading market took another century and a half to set up, in 1990. It was introduced by the EPA in the USA and it was applied to the SO2 emissions of electric utilities. Although, the environmental target was achieved, no wonder the EPA´s auction was a failure because of its quite particular exchange rules. However, it was a very instructing experience for the CO2 emission market design. The causes of the SO2 EPA market failure was explained using agent based model analysis by Posada et al (2008). This

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failure led to a new design of the CO2 emissions permits markets as a Continuous Double Auction (CDA).

The CDA is a double sided auction where buyers and sellers announce and accept bids and asks at any time. The information is held separately by many market participants (in the form of privately known reservation values and marginal costs).

The analytical game approach has been unable to explain its properties. However, the Experimental Economics approach has established that fast price convergence and high allocative market efficiency (closed to 100%) are two of the most robust results in CDA markets. Smith (1962) first demonstrated these properties, and subsequent researches have replicated them under alternative environment `s conditions. The results are of theoretical and practical relevance because CDA is used in the real-world trading of equities, CO2 emissions permits, derivatives, policy analysis like the Tobin's tax, etc

There are three dimensions that are essential in the design of any market experiment following Smith (1982): the institution (I) (the exchange rules, the way the contracts are closed, and the information network), the environment (E) (agent endowments and values, resources, knowledge) and the agents' behavior (A).

A major limitation of Experimental Economics is the lack of control for the human participant's behavior and experimental replication under alternative IxE settings. Why don't we take a step further and experiment with soft agents that could allow us to control the experiment to engineer the trading institution? If the human traders are replaced by software agents, the modeller can control the agent strategies by specifying the decision rules. When human-subjects are substituted by artificial-agents, the agents' behavior (A) dimension of our experiments can be controlled.

In the last decade the microeconomics of CDA markets as been extensively studied with artificial-agents. The results show that there is high market efficiency even if the artificial agents are zero intelligent (Gode and Sunder, 1993; Licalzi and Pellizari, 2008a; Licalzi and Pellizari, 2008b). Price convergence and individual surplus depend on the agents' learning and strategy (Posada et al, 2006; Gjerstad, 2007, Posada and López, 2008) explaining the paradox that a perfect market does not preclude intensive agents competition.

However, transactions and submissions are costless in all these CDA experiments. In this paper we study the sensitivity of CDA performance to the imposition of a monetary cost on the market. Transaction costs are relevant because they are an important feature of these markets, where costs of making offers exist as broker's commissions, travel costs of reaching markets, costs of writing contracts and search costs of locating and identifying trading partners. Since the early paper by Smith and Williams (1990) little attention has been paid to the transaction cost effects on the microeconomics of CDA markets. Our paper is related to the EE work by. Noussier et al (1998) to study the imposition of a monetary cost in CDA markets.

The purpose of this paper is to study CDA market performance when monetary costs are imposed on submissions to buy or to sell as in Noussier's work, and furthermore when they are imposed on transactions. We replicate and extend the results obtained in Experimental Economics and provide additional explanations of the monetary costs effects in the CDA market.

The structure of this paper is the following. In Section 2 we describe the performance of an emission trading market and the microeconomic agent-based model. In Section 3 we calibrate the model and describe the experiments. In Section 4 we analyze the market efficiency when monetary costs are imposed to either submissions (to buy and to sell) or transactions and these results are compared to a CDA market with no-monetary costs. Finally, in Section 5 we report the main conclusions of the paper.

2. The CO2 market performance

The fact that trade is both a converter of value into prices and a social and individual profit generator has to be remembered every now and then even by prestigious economic newspapers as *The Economist*. It is perhaps opportune to call the reader's attention to the fact that trade can generate wealth even with no physical inputs, but just rights, and to introduce with a simple example, another relevant fact: that social efficiency can be achieved for a wide range of the prices to settle the exchange.

Table 1 shows the data and cost of a clean air policy. There are two power plants with different cleaning air pollution marginal costs, per CO2 ton and producing 4 tons each. They are allowed 2 ton of CO2 permits each and both should clean up the other 2 tons. No trade is allowed. The regulator goal is to limit total air pollution to 4 Tn. In this case the cleaning social cost of the 4 CO2 Tns is: (300=100+200) + (900=300+600) = 1200 €

Table 1. Data and cost of a clean air policy

Marginal costs of cleaning a unit of SO2 emissions Tn	**Plant A**	**Plant B**
First unit	100 €	300 €
Second unit	200 €	600 €
Third unit	300 €	900 €
Fourth unit	400 €	1200 €

An alternative proposal of a wiser regulator will keep the number of permits for each plant but it will allow trading of the permits. Then, the less efficient plant B could make a contract with the other plant: "*please, clean a third unit for me and I will pay you for it*". The total amount of CO2 will be kept in four, but the social cost will be: (100+200+300) of plant A and 300 of Plant B. The total social cost is 900 € and a social gain (generated wealth) is 1200- 900= 300 €. No goods are traded, just rights.

What about the agreed price of the traded permit? It just does not matter for the social gain: the wrongly named Coase Theorem. But, of course, the total social efficiency depends on the market design and the resulting price depends on the type of trading agents. Even more, for a given market's design the involved transaction costs have an effect on both: total social cost and emissions permits prices. In what follows we provide evidence of these effects using an artificial agent based CDA simulation model.

In what follows we describe our model in terms of the essential dimensions of any market experiment following Smith (1982): the institution (the exchange rules, the way the contracts are closed, and the information network), the environment (agent endowments and values, resources, knowledge) and the agent behaviour.

2.1. The institution

The institution is a CDA. Any trader can submit or accept an offer to buy or to sell at any time during the trading period. There are several variations of the double auction exchange rules to simplify its implementation. LiCalzi and Pellizari (2008a) pointed out that the simplifications of the CDA rules matter. We consider that in the market there are selling and buying books and the spread reduction rule is applied. Traders randomly place offers on the books. Orders are immediately executed at the outstanding price if they are marketable. Otherwise, they are recorded on the books and remain valid until either the end of the trading session (that is, without re-sampling) or the agent improves its offer (to buy or to sell).

2.2. The environment

A tradable permits market for air pollution control is constructed as follows. Tradable permits are issued to firms (more exactly, to facilities of relevant industrial sectors) by each country's National Allocation Plan. These emission allowances are denominated in units of a specific pollutant (for example in tons of CO_2). At the end of period, facilities must own sufficient permits to cover their emissions. This implies that each facility must hold at least as many valid credits as emissions during the compliance period. A penalty is levied if a facility does not deliver a sufficient amount of allowances on time. The payment of a fine does not remove the obligation to achieve compliance, which means that undelivered permits have to be handed in

In our agent-based model, traders (firms) exchange single units of tradable permits. Each trader is either a seller (clean firm) or a buyer (pollutant firm). It is endowed with a finite number of units (emission allowances) and a private valuation for each unit (marginal reduction cost of pollution).

The environment is stationary (the competitive equilibrium price is the same in every period) in order to study, ceteris paribus, the price convergence performance. Each agent has fifteen units to trade and their valuations are those reported in Noussair et al (1998) in order to reproduce this experimental work (that is, 4 sellers and 4 buyers and a monetary cost on submissions to buy or to sell, TC1). Demand and supply are an approximation of $D(x)=1535-30x$ and $S(x)=35+30x$, respectively. Competitive equilibrium exits at any market price of between 780 and 790 and a quantity of 25 transacted. The consumer surplus is 9125 and the producer surplus is 9125.

In order to extrapolate the environment to a market populated by 12 sellers and 12 buyers, we consider an approximation of the following demand and supply $D(x)=1535-10x$ and $S(x)=35+10x$, respectively (which have been built by adding three equal demands and supplies, respectively). Competitive equilibrium exits at any market price of between 780 and 790 and a quantity of 75 transacted. The consumer surplus is 27375 and the producer surplus is 27375 (on the left of Figure 1).

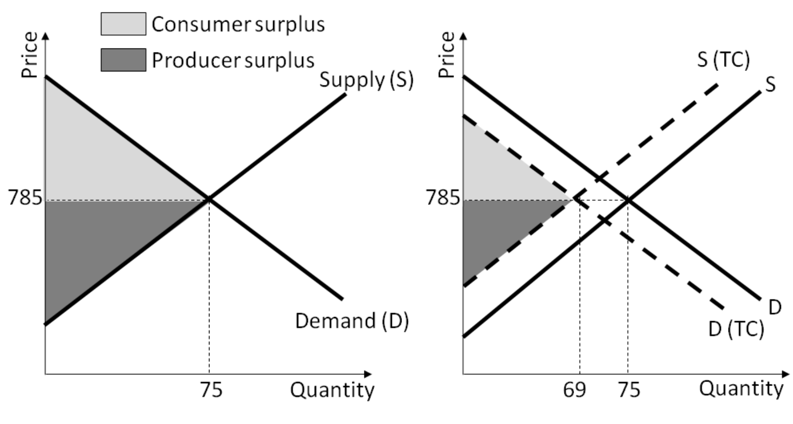

Figure 1. Environment without monetary cost (left) and with monetary cost on transactions (right)

The monetary cost is of 50 units. We consider three alternative cases: when the monetary cost is imposed only on submissions to buy or to sell (TC1), when the monetary cost is imposed on transactions (TC2), and when there is no monetary cost (TC0). When a monetary cost is imposed, there is a loss of surplus, which reduces the allocative market efficiency.

This surplus loss can be calculated theoretically when the monetary cost is imposed on transactions (TC2). Competitive equilibrium exits at any market price of between 780 and 790 and a quantity of 69 transacted. The consumer surplus is 23805, the producer surplus is 23805, and the total monetary cost is 3450. Therefore, the ratio of market efficiencies is 0,932 (on the right of Figure 1).

However, the surplus loss cannot be calculated theoretically when the monetary cost is imposed on submissions (TC1) that is why we turn to Experimental Economics research.

2.3. The agent behaviour

In CDA markets traders face three non-trivial decisions: How much should they bid or ask? When should they place a bid or an ask? And when should they accept an outstanding order? Bidding strategies corresponds to particular answers for these decisions. LiCalzi and Pellizari (2008) pointed out that learning greatly improves the expected value of the allocative effiency in CDA without the resampling assumption. Therefore, we consider GD and K bidding strategies which are related to the two financial investor's behaviours: passive (who submit market orders) and active (who accept the orders submitted).

2.3.1 Passive investors

Passive investors face the two first decisions. They learn to decide on how much should they bid or ask, and they submit their orders 25 times the percentage. The GD bidding strategy (Gjerstad and Dickhaut 1998) is the most sophisticated learning designed for CDA in order to submit the best order. Each agent chooses the offer that maximizes his expected surplus, defined as the product of the gain from trade and the probability for an offer to be accepted. GD agents modify this probability using the history. The history memory is the only parameter of this bidding strategy (see Table 2).

Table 2. GD parameter

Parameter	**Value**
Memory	8

2.3.2. Active investor

Active investors face only the last decision. They can use either the GD bidding strategy (Gjerstad and Dickhaut 1998) or the K bidding strategy.

When an active investor use the GD bidding strategy, they accept an outstanding offer to sell if it is less than its calculated offer to buy (submitted or not) and they accept an outstanding offer to buy if it is greater than its calculated offer to sell (submitted or not). The market performance is excellent in terms of price convergence and efficiency when all traders in the market use a GD bidding strategy.

Kaplan (K) is the simplest learning designed for CDA. It was the winner in the tournament of Santa Fe Institute in 1993 (Rust et al. 1993). The basic idea behind the Kaplan strategy is: "wait in the background and let others negotiate. When an order is interesting, accept it". K agents are parasitic on the intelligent agents to trade and to obtain profit. The market performance is poor in terms of price convergence and efficiency when most of the traders in the market use a K bidding strategy. However, its performance in terms of individual agents' profits is excellent. If all traders in the market are K agents no trade will take place. The K parameters are detailed in Table 3.

Table 3. K parameters

Parameter	**Value**
Minimum profit	[0.01 , 0.03]
Time out	[0.05 , 0.15]
Ratio orders	[0.0125 , 0.0375]

3. The simulations

Each run consists of a sequence of ten consecutive trading periods, each one lasting 100 time steps. We have analyzed the following twenty four scenarios (see Table 4) that accommodate a symmetric environment with:

Table 4. Scenarios of simulation

	4 sellers x 4 buyers			**12 sellers x 12 buyers**		
Traders	**TC0**	**TC1**	**TC2**	**TC0**	**TC1**	**TC2**
100% GD -0%K	E11	E12	E13	E11	E12	E13
75% GD -25%K (buyers)	E21	E21	E21	E21	E21	E21
62,5% GD -37,5%K (buyers)	E31	E31	E31	E31	E31	E31
50% GD -50%K (buyers)	E41	E41	E41	E41	E41	E41

Different number of agents competing in the market (4 sellers and 4 buyers; 12 sellers and 12 buyers).

Two kinds of learning agents (GD and K) with four alternative market populations: 100%GD-0%K, 75%GD-25%K (buyers), 62,5%GD-37,5%K (buyers), and 50%GD-50%K (buyers).

Two sources of monetary costs: on submissions to buy or to sell, TC1, (per offer excise tax), and on each transaction, TC2, in order to compare the results with a no-monetary cost case, TC0.

E11, E21, E31, and E41 scenarios are the benchmarking scenarios, which allow us to compare Experimental and Artificial Economics results. They provide new explanations to those in the human based experiments.

4. Main results

We analyzed CDA market efficiency performance. Our results confirm both expected theoretical effects and experimental results, and they provide new behavioral explanations of market dynamics.

As market efficiency is not a univocally concept defined in the economic literature, we make some comments about it. We deal with market efficiency as understood in conventional microeconomics, and following the experimental economics research on market dynamics. We define allocative market efficiency as the total profit actually earned by all the traders divided by the maximum total profit that could have been earned by all the traders (i.e., the sum of producer and consumer surplus) (Smith 1962).

A comparison of the graphics of Figure 2 shows that introducing monetary costs reduce allocative market efficiency in all the scenarios. Our results confirm expected theoretical: the lowest efficiency in all scenarios is achieved when a monetary cost is imposed on each transaction (TC2). Our results also confirm experimental results: the efficiency is lower when a monetary cost is imposed on submissions (TC1) than when there is not monetary cost (TC0). Moreover, we obtain as well a measure of the relative effects of TC1 versus TC2, relevant information when designing real CDA institutions.

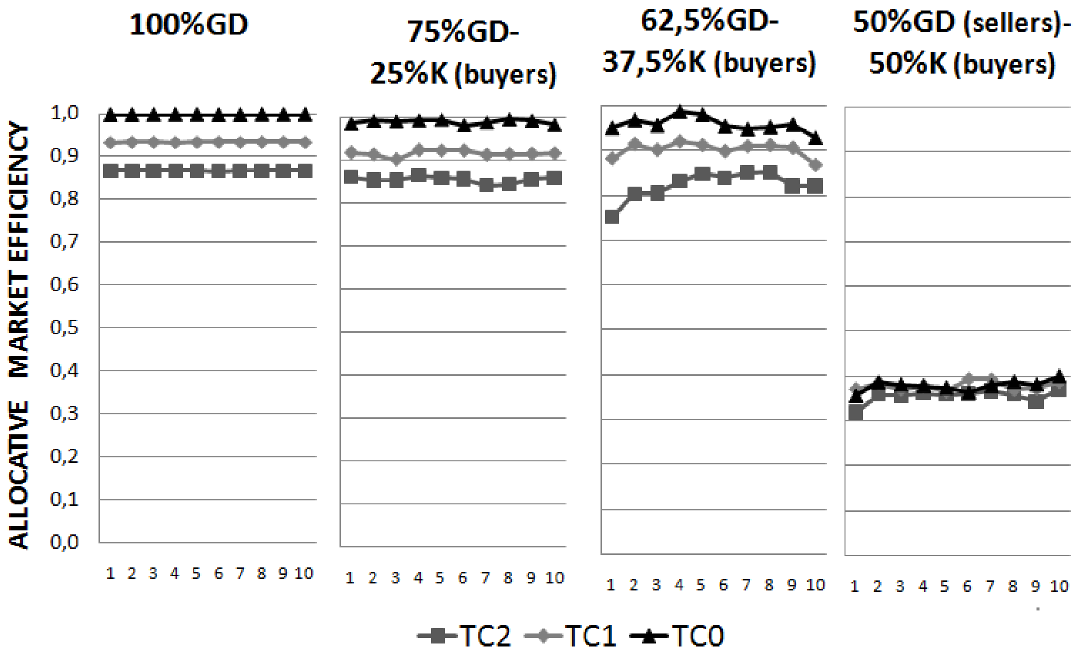

Figure 2. Average efficiency per period of a market with 12 sellers x 12 buyers

However, the efficiency loss not only depends on the source of the transaction cost but it also depends on the agents' learning. The efficiency decreases as the percentage of K agents increases in the market. There is a wide gap when this percentage goes from 37,5% to 50%.

The sample averages per run efficiency are reported in Table 5 and the sample standard deviations per run are reported in Table 6. As it can be seen, market efficiency depends of the type of traders if we take in consideration transaction costs.

Table 5. 12sellers x 12 buyers: market efficiency average

Traders	TC0	TC1	TC2
100% GD -0%K	0,9993	0,9337	0,8672
75% GD -25%K (buyers)	0,9894	0,9153	0,006411
62,5% GD -37,5%K (buyers)	0,9587	0,9027	0,8223
50% GD -50%K (buyers)	0,3791	0,3784	0,3560

Table 6. 12sellers x 12 buyers: Standard deviation

Traders	TC0	TC1	TC2
100% GD -0%K	0,000212	0,000191	0,000226
75% GD -25%K (buyers)	0,00365	0,0064112	0,00496
62,5% GD -37,5%K (buyers)	0,0131	0,01198048	0,0151
50% GD -50%K (buyers)	0,00719	0,00561	0,00454

Our results provide new behavioral explanations due to the agents' behavior can be control in Artificial Economics. The extreme case is when only sellers submit offers to the markets due to all buyers are K agents (that is in E41, E42, E43, E44, E45 and E46 scenarios). Our explanation relies on agents' learning skills.

5. Conclusions

Experimental Economics (EE) allows a deep analysis of microeconomic markets and inspires new empirical bases for testing theories, institutional design and, behavioral explanations of market dynamics.

As pointed out more then 150 year ago, by Mill (1848), by creating a market, in this case for CO2 permits rights, we can reveal the value of clean air, and assign a price to this good. The CDA experiments with artificial agents have widened the scope and provided a thinner resolution and alternative explanations of price dynamics and social and individual efficiency for a wide range of AxExI microeconomic settings. When one adds realistic assumptions to the pure CDA, such as transaction costs and emotional agents, AE can be very useful to inspire explanations of the observed behavior. Our Artificial Economics model confirms and extends previous works on a CDA with transaction costs and provides new behavioral explanations of the price dynamics.

Posada et al (2006) first demonstrated that, if the market is populated by K agents, and more clearly if they are on one side of the market (making bids or asks), price convergence is not achieved. This result is even stronger when, as it the case in our experiment, there are transaction costs which are imposed on the communications. The consequence for market policy design is that if monetary costs are imposed, it should be on the transactions, because communication costs reinforce the parasitic feature of the K agents.

We have assumed a symmetric environment (E) to replicate the Noussier et al (1998) experimental work, but a relevant extension could be (as in the CDA with no transaction costs) the study of the CDA price dynamics with asymmetric environments and endogenous changes in the bidding strategies.

As we show, Artificial Economics models are a necessary companion of Experimental Economic models. With artificial agents the experimental results' robustness can be checked against alternative controlled agents' behavior with reliability and at low cost, providing detailed explanations of the limitation and scope of EE results

A final conclusion is in order. Up to now Economic Theory has been fed by Econometric and Mathematical models from historical real data and more recently Experimental Economics with humans has been welcome as the "second way" to the making of Economics. As these and related papers show the time has come for a ***"third way***": Artificial Economics (Experiments with soft agents) to be accepted as an endogenous generator of Economic Theory and as an innovative teaching tool.

References

Gjerstad, S.; Dickhaut, J. (1998) Price Formation In Double Auctions. Games and Economic Behaviour, Vol. 22, pp. 1-29.

Gjerstad, S. (2007). The Competitive Market Paradox. Journal of Economic Dynamics and Control, Vol. 31, pp. 1753-1780

Gode, D.; Sunder S. (1993). Allocative Efficiency of Market with Zero-Intelligent Traders: Market as a Partial Substitute for Individual Rationality. Journal of Political Economy, Vol. 101, pp. 119-137.

LiCalzi, M.; Pellizzari, P. (2008a). Simple Market Protocols for Efficient Risk Sharing". Journal of Economic Dynamics and Control 31, pp. 3568-3590

LiCalzi, M.; Pellizzari, P. (2008b). Zero-Intelligence Trading without Resampling. Lecture Notes in Economics and Mathematical Systems, Vol. 614, pp. 3-14.

Mill, J.S. (1848). The Principles of Political Economy with some of their applications to social philosophy.

Noussair, C.; Robin, S.; Ruffieux, B. (1998). The Effect of Transaction Costs on Double Auction Markets. Journal of Economic behaviour & Organization, Vol. 36, pp. 221-233.

Posada, M.; Hernández, C.; López-Paredes, A. (2006). Learning in a Continuous Double Auction Market. Lecture Notes in Economics and Mathematical Systems, Vol. 564, pp. 41-51.

Posada, M.; Hernández, C.; López-Paredes, A. (2008) Emissions Permits Auctions: An Agent Based Model Analysis. *Social Simulation: Technologies, Advances and New Discoveries.* Edmonds, Hernanez and Troitzsch Edit. IGI Global Pub.

Posada, M.; Lopez-Paredes, A. (2008). 'How to Choose the Bidding Strategy in Continuous Double Auctions: Imitation Versus Take-The-Best Heuristics'. Journal of Artificial Societies and Social Simulation 11(1)6 <http://jasss.soc.surrey.ac.uk/11/1/6.html>.

Rust, J.; Miller, J.; Palmer, R. (1993). Behaviour of Trading Automata in Computerized Double Auctions. In: Friedman and Rust (eds.), The Double Auction Markets: Institutions, Theories And Evidence. Addison-Wesley.

Smith, V.L. (1962). An Experimental Study of Competitive Market Behavior in Journal of Political Economy, Vol. 70, pp. 111-137.

Smith, V.L. (1982). Microeconomic Systems as an Experimental Science. American Economic Review, Vol. 72, pp. 923–955.

Smith, V.L., Williams, A. (1990). The Boundaries of Competitive Price Theory: Convergence, Expectation and Transaction Costs. In Green and Kagel eds. Advances in behavioral economics, Vol. 2, pp. 3-35.