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Asymmetric Information and International Tradable Quota Treaties
An experimental evaluation

Abstract:
This paper reports an experimental test of international quota trading on a market characterised by several dominant traders. Asymmetric information regarding quota demand and supply imply true market-clearing prices which differ from an expected competitive quota price. However, in the experiment the expected price level emerges as a focal point on which the bulk of quota trade contracts are keyed. Thus, incomplete price discovery obtains.

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1. Introduction

The objective of international environmental agreements is to improve upon the non-cooperative outcome with regard to specific environmental problems (see, for instance, Barrett (1998)). An important category of such agreements is comprised of international climate treaties which stipulate aggregate greenhouse gas emissions targets below the non-cooperative business-as-usual scenario. Theory suggests that such targets may be implemented efficiently by means of a tradable quota system where the aggregate quota corresponds to the treaty's emissions target. The rationale is that quota trading equalises marginal abatement costs across the agreement's parties regardless of the initial quota allocation. By implication, a cost-effective allocation of emissions obtains (IPCC (1996)).

Although the theoretical aspects of international tradable quota agreements have been thoroughly examined, in practice there are still few real-life examples of such treaties and international quota trading[1]. Recently, however, a number of papers have tried to investigate the empirical properties of international tradable quota treaties using experimental tests (see, e.g., Bohm (1997) and Bohm and Carlén (1999)). The market structure in these tests are characterised by traders who are approximately equal with regard to market shares. Asymmetric information is incorporated into the experimental designs in that each trader knows the technical marginal abatement costs of all the participants, but only his own true social marginal abatement cost. A mark-up distinguishes the latter cost concept from the former. Nevertheless, the main finding is that quota trade appears to be efficient and to occur at prices that converge to the competitive market-clearing price level.

Moreover, Carlén (1998) shows that, when there is negligible asymmetric information regarding traders' marginal abatement costs, efficient trading and convergence to the competitive price occur even within a market structure characterised by strong asymmetry, to wit, a dominant buyer of quotas interacting with several "small" sellers.

This paper seeks to complement the mentioned experimental research on international quota trading. The reported experiment investigates the behaviour of several dominant traders on an international tradable quota market characterised by, first, common knowledge of an expected market-clearing

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[1] The two most prominent tradable quota treaties are, first, the Kyoto Protocol to the UN 1992 Framework Convention on Climate Change. This treaty facilitates trading in emissions quotas, but is as of yet not ratified. Second, the Montreal Protocol to the 1985 Vienna Convention for the Protection of the Ozone Layer allows for trading in (production) quotas of certain ozone depleting substances. However, information on international trade in these quotas is commercially sensitive, and difficult to acquire (Hagem and Holtsmark (1998)).

quota price and, second, considerable asymmetric information regarding the treaty's parties' underlying marginal abatement costs, the implication of which is that the true market-clearing quota price is deemed uncertain. The main objective of the paper is to investigate the paths of quota prices, and in particular the extent to which these prices are influenced by the expected quota price or converge to the actual and divergent market-clearing level. The behaviour of dominant traders warrants particular attention given their potential for market power, i.e., their ability to determine the terms of trade of the majority of the feasible quota trades.

Experimental economics generally follow the convention of reporting raw data only and usually conduct analyses of these using graphical methods as well as non-parametric statistics (see Camerer (1995)). In this paper the style of data analysis is expanded to also include the results from post-experimental debriefings of the experiment's participants. By combining these two modes of data analysis the ambition is to achieve a more comprehensive understanding of both the conducted experiment and, by implication, possible empirical properties of international tradable quota treaties.

The remainder of the paper is organised as follows. Following the introduction, section 2 provides a set of experimental conjectures to be discussed. Section 3 describes the experimental design, whereas section 4 reports the experimental data. Concluding remarks are presented in the last section.

2. Experimental conjectures

Negotiations on an international tradable quota treaty most likely are two-dimensional in the following sense. First, the bargaining parties need to agree upon an aggregate emissions target. Second, the negotiators have to identify an acceptable initial allocation of emissions quotas. It is reasonable to assume that the bargaining parties will need to evaluate both different aggregate emissions targets as well as various initial quota distributions in terms of the implied net costs. These costs are comprised of aggregate abatement costs plus revenue from quota exports minus purchases of quotas.

A prerequisite for calculating the relevant abatement costs is an estimate of the bargaining parties' marginal abatement cost functions. Also, in equilibrium, the parties' marginal costs are assumed to become equalised and similar to the market-clearing quota price. Thus, the estimation of predicted revenue from net quota exports is a straightforward matter.

Each bargaining party's domestic marginal abatement costs can be assumed to be reasonably well known. In addition, as a result of efforts by international organisations and due to national communications, the marginal abatement costs of all the bargaining parties may be considered approximately common knowledge (confer Bohm (1998)). Hence, if the negotiations result in a ratified tradable quota treaty, shared information concerning the parties' marginal abatement cost functions will facilitate a prediction of the market-clearing quota price as well as the equilibrium distribution of abatement and quota trade amongst the parties.

However, a common perception of the parties' marginal abatement costs need not be certain. An additional complication is that a tradable quota treaty may specify a relatively long commitment period during which the parties' marginal abatement costs can shift and vary, and not necessarily in a way that is transparent to all the treaty's parties. Equivalently, even though all parties to the treaty have information about expected prices and trading volumes, it may be that they have correct information about their own marginal abatement cost only. In this asymmetric information case the real market-clearing quota price as well as the equilibrium distribution of quota trades may diverge from their expected levels.

The question arises as to how asymmetric information regarding marginal abatement costs affects the parties' behaviour on the tradable quota market. One possibility is that the shifts in the parties' true marginal abatement costs are considered inherently unpredictable, and that the market is unsuccessful in revealing the traders' marginal abatement costs. Traders may instead adhere to a "rule of thumb" by continuing to key quota trade contracts on the expected price. An expected price level is nonbinding, but such prior expectations may come to play an important role in co-ordinating the parties' market behaviour in the sense of exerting a systematic influence on the terms of trade of contracts that are agreed on the market for tradable quotas (also confer Crawford (1990)). However, in the case where the expected price differs from the market-clearing level, this will imply incomplete price discovery in the quota market which could foster inefficiencies.

Another possibility is that market behaviour will respond efficiently to altered and updated private information on marginal abatement costs. The likelihood of this depends in part upon the institutional framework adopted to govern quota trading. One likely candidate is an international stock exchange for tradable emissions quotas (Sandor et al. (1994)). Such a market can be modelled experimentally as a double auction, i.e., a multilateral bargaining process in which messages consist of offers to buy (bids) and offers to sell (asks) quotas. A quota trade is triggered by an acceptance of (parts of) the

current best bid or ask. A multitude of experimental evidence indicates that the double auction provides incentives for traders to achieve a successful price discovery, through which the traders' demand and supply are revealed (see, e.g., Friedman (1993) and Plott et al. (1997)). Importantly, it is highly probable that these empirical properties of the chosen trading institution is deemed common knowledge amongst the parties to a tradable quota treaty.

To sum up, prior to the commencement of quota trading, it can be assumed that the parties to the treaty have common prior expectations as to the market-clearing quota price as well as the equilibrium distribution of emissions abatement and quota trades. The relevant empirical issue is how asymmetric information, caused by non-transparent shifts in the parties' marginal abatement costs during the commitment period, affects the traders' behaviour on the market.

Thus, this experiment seeks to discuss the following conjectures:

1. *Focal point conjecture*:

The expected quota price exert a persistent influence on the tradable quota market even when the true market-clearing price differs from the expected level. This results in incomplete price discovery since the market does not achieve a complete relevation of the parties' private marginal abatement costs.

When quota trade contracts are keyed on or in the vicinity of the focal price, the traders' realised trade gains are going to vary monotonically with the changes in marginal abatement costs: A net quota importer (buyer) benefits from a vertically negative shift, and vice versa in the case of a net quota exporter (seller).

2. *Complete price discovery conjecture*:

The prices in the tradable quota market consistently converge successfully to the market-clearing price despite asymmetric information on marginal abatement costs and common knowledge of expected quota price.

Due to the sheer size of large traders' expected quota trades, they will be influential in determining the terms of trade for the bulk of the contracts. Support for either conjecture consequently depends to a large extent upon the ask (bid) strategies adopted by the dominant sellers (buyers) of tradable quotas.

3. Experimental design and parameters

The reported experiment's design was inspired by the Kyoto protocol[2]. This international environmental treaty specifies emissions quotas for the industrialised countries and moreover allows these targets to be implemented via international quota trade. The period 2008-2012 has been designated as the Kyoto protocol's commitment period. Accordingly, the experiment mimicked quota trade amongst the parties to the protocol over the course of 5 trading periods. The trading periods were separate in the sense that the experiment did not allow any intertemporal carryover across trading periods. Equivalently, banking or borrowing of tradable emissions quotas was disregarded.

Market environment

The emissions numbers depicted in Table 1 refer to emissions of the 6 greenhouse gases covered by the Kyoto protocol. In line with the objective of the protocol, the reproduced Kyoto emissions quotas in column (2) add up to an aggregate emissions level which is 5.2 percent lower than the 1990 level.

The treaty's parties' periodical emissions reduction commitments equal the difference between the hypothetical business-as-usual (BAU) scenario and the Kyoto emissions quota. Each party's emissions reduction commitment was identical across the 5 experimental trading periods.

Table 1. Periodical emissions reductions commitments, Mton CO_2-equivalents

	BAU emissions	Kyoto emissions quota	Emissions reduction commitment
	(1)	(2)	(3) = (1) - (2)
USA	6820	5340	1480
Canada	660	530	130
Japan	1370	1130	240
Russia[3]	2820	2980	0 (-160)
EU	3900	3580	320
Eastern Europe	2030	1970	60
Australia/New Zealand	580	550	30
Sum	18170	16080	2260 (2100)

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[2] See http://www.unfccc.de/index.html

[3] Russia's BAU in the commitment period is lower than its Kyoto emissions quota. The difference - 160 Mton CO_2-equivalents - is usually referred to as "hot air".

Emissions reductions may be implemented by means of a combination of domestic abatement and net purchase of emissions quotas. In the experiment no restrictions on the extent of allowable quota trade applied. Provided with information about the parties' marginal abatement cost, it is possible to calculate how each party's optimally implements its committed emissions reductions[4]. The results of these calculations are presented in Table 2, and pertained to each of the 5 trading periods.

Table 2. Periodical net quota trade, Mton CO_2-equivalents

	Emissions reduction commitment	Domestic abatement	**Periodical net quota import**
	(1)	(2)	**(3) = (1) - (2)**
USA	1480	780	**700**
Canada	130	60	**70**
Japan	240	180	**60**
Russia	0 (-160)	310	**-470**
EU	320	440	**-120**
Eastern Europe	60	240	**-180**
Australia/New Zealand	30	90	**-60**
Sum	2260 (2100)	2100	**0**

The table shows that, in equilibrium, Russia, EU, Eastern Europe and Australia/New Zealand in each trading period export 830 Mton of emissions reductions to USA, Canada, and Japan. In this experimental design USA represents 84 percent of the periodical net demand for emissions reductions, whereas Russia and Eastern Europe make up 57 and 22 percent respectively of the aggregate supply of emissions reductions in each of the 5 trading periods. Expressed in terms of Herfindahl indices, the market concentration on the demand (supply) side is 0.72 (0.39)[5].

Thus, according to Table 2, the marginal abatement cost functions of the quota exporters (importers) can be interpreted as periodical demand for (supply of) quotas. This is graphically depicted in Figure 1, in which the competitive market-clearing quota price - US\$ 12.58 per ton - and the competitive trading volume - 830 Mton - result from the intersection of the aggregate quota demand and the

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[4] The marginal abatement costs and BAU-scenarios incorporated in the experimental design have been estimated by CICERO - Centre for International Climate and Environmental Research at the University of Oslo. For a thorough documentation, see Hagem and Holtsmark (1998).

[5] The Herfindahl index was calculated as: $H = \sum_i s_i^2$, where s_i is the market share of the i-th buyer (seller) in equilibrium.

aggregate quota supply curve. Note that the dominant seller countries - Eastern Europe and Russia - are able to offer in total 360 Mton of emissions reduction at zero marginal cost. Alternately, USA's quota demand is represented by the horizontal lines in the market demand curve.
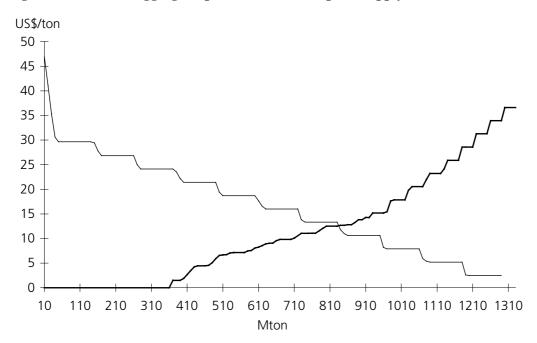
Figure 1. Periodical aggregate quota demand and quota supply

In the experiment, the periodical aggregate quota demand and quota supply depicted in Figure 1 were adopted as the expected quota demand and supply. By implication, the expected market-clearing quota price and aggregate trading volume were specified as 12.58 US$/ton and 830 Mton respectively. These expectations pertained to the 5 experimental trading periods as a whole.

Uncertain marginal abatement costs were incorporated into the experimental design by means of vertical shifts of these costs between each of the 5 trading periods. The shifts were accomplished by adding or subtracting to each of the parties' marginal abatement cost curves that constitute the expected market demand and supply. Thus, the relative location of each party on the market supply and demand arrays did not change. Table 3 shows both the direction and the magnitude of the implemented shifts relative to the expected marginal abatement cost curves, as well as the implied periodical competitive market-clearing quota price.

Table 3. Amount added to expected demand and supply

Period	1	2	3	4	5
Amount added	0	-0.63	+0.63	+1.26	-1.26
Periodical, market-clearing price	12.58	11.95	13.21	13.84	11.32

Hence, in period 1 there was no difference between the real and the expected quota demand and quota supply. In period 2 the real curves were shifted vertically downwards in the magnitude of 0.63 US$/ton, the implication of which was an underlying periodical market-clearing quota price equal to 11.95 US$/ton.

In general, the incorporation of uncertainty in this experiment resulted in the periodical competitive quota price varying in the magnitude of ± 10 percent compared with the expected level of 12.58 US$/ton. A theoretical market-clearing trading volume of 830 Mton was constant across the 5 trading periods.

Trading institution

Trading occurred on the multiple-unit double auction trading software developed by the Experimental Science Laboratory at the University of Arizona, Tucson[6]. The traders' roles were pre-determined as either buyers or sellers.

Buyers (sellers) were free to post bids (asks) at any time, but the market would accept bids (ask) specifying higher (lower) prices only. A bid (ask) consists of a price-quantity pair. Quantities were expressed in units of 10 Mton. The current bids and asks as well as a queue of below market bids (and above market asks) - analogue to the specialist's order book - were shown to all traders. These might accept (parts of) the market ask or bid at all times before the end of the trading period. In the event of a trader proposing a bid (ask) implying negative profit, he was warned by the programme and given an opportunity to alter the message. This served to minimise the extent of typographical errors.

On each buyer's (seller's) computer screen there was a record sheet updating the his profit across trading periods as well as the marginal abatement cost functions which constituted periodical quota demand (supply). Each of the 5 trading periods lasted 8 minutes.

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[6] Confer http://www.econlab.arizona.edu

Information

Six days prior to the experiment taking place, subjects were given background information concerning the Kyoto protocol and the double auction trading institution. Also, the information on the parties' expected demand and supply curves, expected competitive quota price as well as the distribution of expected net quota imports were handed out. It was stressed that the expected information pertained to the 5 trading periods as a whole. Subjects were informed that "small" deviations from the expected information could occur between each trading period affecting at least 1 of the 7 participants. This information was read out to the participants prior to the experimental session[7]. In between trading periods each buyer (seller) received private and updated information on his real demand (supply) curve only.

Two experimental test sessions were run before the main experiment. The first test was intended to make the subjects familiar with trading on computerised double auction market. The second test had a design that mimicked the main experiment in terms of the participants' market shares.

Subjects

The experiment was conducted at Statistics Norway, Oslo. Subjects were economists at Statistics Norway's Research Department. None had any previous experience with economic experiments, but the subjects representing USA, Russia, and Eastern Europe all had game theoretical backgrounds.

Payoffs were scaled so as to imply equal expected payoffs to the subjects: If all trades in each of the 5 trading periods were conducted at the periodical competitive prices, each participant would have earned 500 NOK ($\approx$ 60 Euro). The average actual payoff to subjects was 489 NOK, with max and min values equal to 554 NOK and 401 NOK. Including the oral presentation of the experimental instructions, the test sessions and the main experiment lasted a little less than three hours.

4. Experimental results

The results are reported in three subsections. The first and second focus on the observed periodical quota price paths as well as the underlying bid and ask strategies adopted by the large traders. Data on the dominant traders' gains from trade are presented in the third section. For the sake of brevity, data

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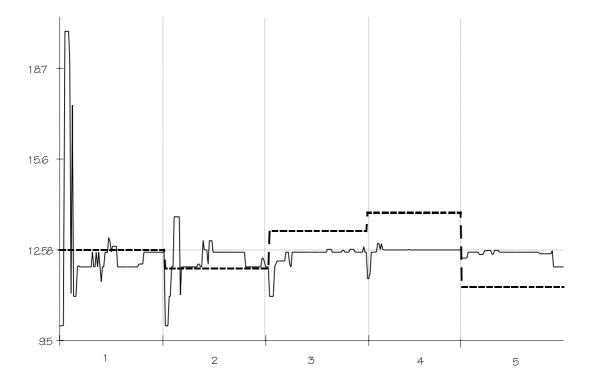[7] The experimental instructions are available from the author upon request.

on the residual 'small' traders are excluded from the presentation. The full results are available on request from the author.

Prices, trading volume, and efficiency

Figure 2 contains the time series of quota prices observed in the experiment. The vertical lines demarcate the different trading periods, whereas the horizontal dotted lines indicate the competitive market-clearing price for each period as presented in Table 3.

The visual impression from this figure is that prices fluctuate more in the first trading period as compared with the subsequent four periods. However, towards the end of this period prices seem to converge to the periodical competitive price level, a pattern which is consistent with what is commonly observed in double auction experiments. A similar pattern is observable in period 2, although the price variance now has decreased relative to the first period.

Figure 2. Time series of quota prices

An eyeballing of the figure gives the impression that the contract prices in the experiment do not converge successfully to the periodical competitive prices in the last three periods of trading. In fact,

it appears that the experimental quota prices in periods 3 -5 exhibit a tendency to track the expected price level.

This impression is strengthened by an examination of the coefficients of convergence relative to both the expected price level and the periodical market-clearing price. The coefficient of convergence is a measure of price behaviour that captures both price variability and the deviation of prices relative to a specified price level, to wit, the expected quota price and the periodical market-clearing price level. The most common measure, α, is unbounded from above and increases with price volatility and with deviations of the mean price from the expected/periodical market-clearing price level[8].

As can be seen in Table 4, the values of the coefficients of convergence coincide in period 1 insofar as the periodical competitive price equals the expected price. However, over time prices are seen to deviate significantly less from the expected price level as compared with convergence to the periodical market-clearing price.

Table 4. Coefficients of convergence

Period	1	2	3	4	5
Convergence to competitive price	2.01	0.72	0.90	1.31	1.12
Convergence to expected price	2.01	0.75	0.40	0.19	0.22

As depicted in Table 5, the inability of quota prices to converge to the periodical market-clearing levels results in market volumes below the competitive level (830 Mton) in periods 3 - 5. However, the untraded units are associated with small potential trade gains. Therefore, trade yields an approximately complete exhaustion of the available exchange surplus despite the incomplete price discovery in the last three periods. The average efficiency across all trading periods is 99.6 percent.

Table 5. Market trading volume and efficiency

Period	1	2	3	4	5
Market volume	840	830	780	750	820
Efficiency	99.9%	99.8%	99.5%	99.1%	99.7%

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[8] The coefficient of convergence - α - is derived by taking the square root of $\alpha^2 = s^2 + (m - \bar{p})^2$, where s^2 denotes the variance of the periodical prices, m the associated mean and $\bar{p}$ signifies the considered target of the convergence process (see Davis and Holt (1993)).

Observation 1: Price discovery is successful in the first two trading periods, but the price paths in the last three give support to the focal point conjecture: Quota prices track the expected quota price, and incomplete periodical price discovery obtains.

Bargaining strategies; bids and asks

The prices in the experiment originate from the traders' acceptance of bids and asks. Thus, a closer examination of these bids and asks will tend to reveal in more detail how asymmetric information interfere with the bargaining process and the resulting quota prices.

Figure 3 depicts the large traders' periodical median bid (ask) as well as the observed periodical median quota price. A visual impression is that the median price is to a large extent determined by USA's bidding behaviour in the first 4 trading periods. Over time the asks of Eastern Europe and Russia tend to move downwards to the expected price level of 12.58.
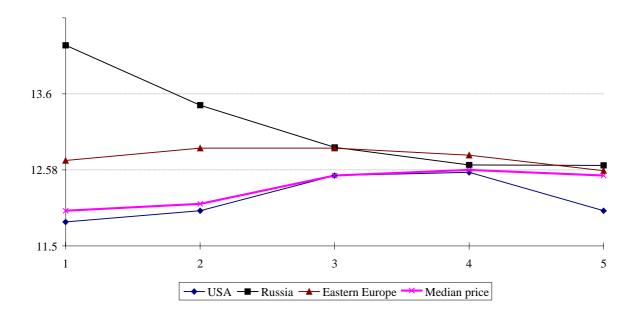
Figure 3. Periodical median bids, asks, and quota prices

Following the experimental session, brief interviews were conducted to acquire additional data concerning the large trader's bargaining strategies. According to the subject representing USA,

> "In the first period, at least initially, quotas were being bought and sold at relatively high prices. Eventually these prices converged to more or less the expected level. Personally, I didn't understand why anyone would want to engage in trading at prices which diverged from the expected level.

After some time I decided to let the market know who was "in charge". This I tried to signal by means of specifying large quantities in my bids. By doing so I was able to convey information about the size of my demand, and hoped that this would - eventually - enable me to set the norm for 'acceptable' prices in the market.

However, smaller buyers sometimes placed bids that only marginally improved upon mine and thus became the standing market bids, but upon completing their trades my bids again become the going bids.

I observed that I was able to use my bids to establish a kind of norm in the market. In retrospect it is possible that I should have used the first trading period more actively and there tried to signal or establish lower prices.

In summary, the main impression is that the subject representing USA bid aggressively and was capable of establishing the expected price level as a kind of focal point for the double action bargaining process. This view is corroborating by the subject acting on behalf of Eastern Europe:

"Initially I tried to fetch as high prices as possible, and at least try to define a range of prices, preferably above the expected level, as 'reasonable'. Nonetheless, it rapidly become apparent that this was unfeasible and henceforth I specified ask prices in the vicinity of the expected level.

All along I knew that I was at best a "medium-sized" trader, but in the beginning I operated with relatively small quantities in my asks. Gradually I felt that I had to increase the stated quantities in order to be "noticeable" in the market. But I believe that large bids influenced the trading process considerably in that it seemed that many sellers eventually accepted these bids to buy and the associated terms."

This described pattern is consistent with an examination of the extent to which bids or asks lead to the observed prices. Table 6 contains summary statistics on the number of placed bids and asks in each of the 5 trading periods that were accepted and led to contracts.

On average, buyers, of which USA is the predominant, determine the prices of the majority of conducted trades. However, in line with Figure 3, sellers are relatively more successful in the last trading period.

Table 6. Number of successful bids and asks

Period	1	2	3	4	5
Successful asks	10	7	5	2	8
Successful bids	25	22	22	23	14
% successful bids	71%	76%	81%	92%	64%

Turning to the issue of asymmetric information, it appears that the dominant traders regarded the shifts in the demand and supply curves as genuinely unpredictable, and tended to concentrate upon the expected price level as a convenient "rule of thumb" when figuring out a best response to the uncertain shifts.

The USA commented that

> "As for the updated private information, my bidding strategy was by and large unaffected by this. The rationale for this was that I had no information about the other traders' demand/supply curves and vice versa. Thus, I considered 12.58 US$/ton to be the best approximation to the underlying equilibrium price."

By the same token, the subject representing Russia stated that

> "My initial asks in every trading period specified high prices. This was essentially an attempt to signal to the market that I had incurred higher costs, and hence was aiming for similarly higher quota prices.
>
> It seemed natural to be to stick to rules of thumb, regardless of the new cost information I received before each round. Since I was unable to know what kind of shifts the other traders had experienced, my expectation of which price I could get as the game progressed did not change with the new information. By implication, I sought not to sell any quotas below 12 US$/ton."

Similarly, the subject acting on behalf of Eastern Europe came to the conclusion as follows:

> "The updating of my private information didn't affect me much. First I had a vague theory that my curve had shifted but not the others'. However, when I experienced that my own supply curve shifted between every trading period, I figured something similar might be occurring to the other traders as well. In so far as I had no clear perception as to the direction of these shifts, I stuck to specifying asks within the "established" range. Also, in the "heat of the moment" and since the clock was ticking this was both a convenient and a practical manner in which to behave."

Observation 2: The dominant traders, and particularly the USA, adopted bargaining strategies that appears to have been importantly influenced by prior expectations of the quota price level. The updating of the traders' private information did not significantly alter the traders' behaviour. Taken together, this sheds light on the observed incomplete price discovery in the last trading periods.

Trade gains

A buyer's (seller's) trade gains determined by the aggregate difference between his demand (supply) curve and the contracted quota prices. The periodical aggregate potential trade gains is affected by the shifts in aggregate demand and supply that occur between the trading periods. This is accounted for in Table 7, which depicts each of the large traders realised trade gains as a percentage of their potential periodical trade gain. The latter is calculated under the assumption that all trades are conducted at the periodical competitive market-clearing price.

In the case of USA, its realised trade gains varies between 111% and 87% of the periodical competitive equilibrium. Approximately the same variance applies to Russia, whereas Eastern Europe experiences a slightly greater fluctuation.

Table 7. Trade gains in percentage of periodical competitive equilibrium

Period	1	2	3	4	5
USA	104%	96%	107%	111%	87%
Russia	99%	105%	93%	88%	112%
Eastern Europe	90%	103%	91%	85%	116%

Noticeably, periods 2 and 5 are characterised by negative shifts in the traders' demand and supply curves, whereas positive shifts occur in trading periods 3 and 4 (confer Table 3). In as much as quota prices were found to track the expected price level 12.58, the implemented shifts in quota demand and supply imply buyers' realised trade gains overshooting 100 percent periods 3 and 4, and undershooting the competitive outcome in periods 2 and 5. These consideration also apply to sellers, except that the directional effects are reversed. This monotonic correlation between shifts in demand/supply curves and realised trade gains is highly significant for each of the large traders[9].

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[9] In each case the Spearman rank correlation coefficient obtains the value 1 ($p = 0.0083$; $n = 5$) (see Conover (1980)).

Observation 3. A large buyer country benefits from an unexpected negative shift in aggregate quota demand and supply. Large sellers are able to extract larger trade gains than the competitive benchmark in the case of an unexpected positive shift in aggregate quota demand and supply. This is consistent with the focal point conjecture.

5. Concluding remarks

The reported experiment investigated international quota trading within a market structure comprised of both a dominant buyer as well as two large seller countries who traded quotas over the course of five trading periods. In between these periods, shifts in all traders' quota demand and supply curves were accomplished, the implications of which was a periodical competitive market-clearing price that varied ± 10 percent relative to the expected level. These shifts were noncommon knowledge amongst the participants, who were provided with updated information on their private quota demand and supply curves only.

The main result is that the expected price emerged as a <u>focal point</u> on which bids, asks, and quota prices are keyed despite the existence of asymmetric information regarding the underlying quota demand and supply. In the experiment, this pattern became increasingly transparent over the course of the trading periods, and implied incomplete price discovery in as much as the true periodical market-clearing prices differed from the expected level. Thus, the traders' realised trade gains is to a large extent determined by the direction and magnitude of the underlying shifts. A buyer country benefits from a positive vertical shift in the quota demand and supply, and vice versa with regard to a seller country. Importantly, these results were markedly influenced by the bargaining strategy carried out by the dominant buyer in this experiment.

This conclusion is based upon one experiment and one specific paramterisation of asymmetric information only. Consequently, it should at best be interpreted as an indication of likely behaviour in an international tradable quota market characterised by uncertain periodical market-clearing quota prices and dominant traders. Further research is needed in order to establish the degree and kind of asymmetric information that would alter the obtained results.

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