

An Experimental Analysis of Modifications to the Centralized Milk Quota Exchange System in Quebec

Maurice Doyon,¹ Virginie Simard,² Kent D. Messer,³ Lota D. Tamini⁴ and Harry M. Kaiser⁵

¹Professor, Department of Agricultural Economics and Consumer Science, 4310-F, Pavillon Paul-Comtois, Laval University, Quebec, Quebec G1K 7P4 (corresponding author: phone: 418-656-2131, ext: 4546; fax: 418-656-7821; e-mail: Maurice.doyon@eac.ulaval.ca).

²Analyst at La Financière Agricole, 1026 chemin St-Joseph, St-Nicolas, Quebec G7A 2A3 (phone: 418-831-8445; e-mail: simardvirginie@hotmail.com).

³Assistant Professor, Food & Resource Economics, 266 Townsead Hall, University of Delaware, Newark, DE 19716 (phone: 302-831-1316; e-mail: messer@udel.edu).

⁴Senior Researcher, Institut de Recherché et de Développement en Agroenvironnement (IRDA), 2700, rue Einstein Québec, Québec, G1P 3W8 (phone: 418-646-7826; e-mail: lota-d.tamini@irda.qc.ca).

⁵Professor, Cornell University, Department of Applied Economics and Management, 350 Warren Hall, Ithaca, NY 14850 (phone: 607-255-1598; e-mail: hmk2@Cornell.edu).

Using experimental economics, this paper tests the potential impacts of modifying the centralized quota exchange system in Quebec with the intent of decreasing the quota price while minimizing negative impacts on auction effectiveness. Two separate treatments are applied to a uniform price auction similar to that employed in Quebec. The first treatment is an exclusion (5% or 15%) of the highest buyer bids and seller offers. The second is a tax (2% or 10%) on all units offered for sale that remain unsold. Various combinations of the two treatments are also tested. The results suggest that exclusion of the highest bids and offers can decrease the price of the quota and that a 15% exclusion rate is more effective than a 5% rate. The tax alone has little impact on quota price. The combination of the two treatments generates a more marked reduction in both the number of exchanges and the price of the quota than when the tax or the exclusion is applied individually. However, the combination of treatments results in a greater loss of economic efficiency. In all cases, relatively small market price reductions are realized at the expense of substantial losses in economic efficiency.

La présente étude teste de manière expérimentale la capacité d'une modification au système centralisé de vente du quota à faire diminuer le prix du quota laitier au Québec tout en minimisant les impacts négatifs des changements sur l'efficacité de l'enchère. Cette modification consiste à appliquer deux traitements sur l'enchère de prix uniforme où s'échange le quota. Le premier traitement consiste en une exclusion (5% ou 15%) des mises les plus élevées des acheteurs et des vendeurs. Le second traitement est une taxe (2% ou 10%) appliquée aux unités que les vendeurs mettent en marché et ne réussissent pas à vendre. Différentes combinaisons de ces deux traitements sont également testées. Les données générées permettent de conclure que le mécanisme d'exclusion des mises les plus élevées permet de faire diminuer le prix du quota, l'exclusion de 15% étant plus efficace que celle de 5%. Pour sa part, la taxe seule a peu d'impact sur le prix du quota tandis que la combinaison des deux traitements entraîne une diminution du nombre de transactions et du prix du quota plus marquée que lorsque les traitements de taxe et d'exclusion sont appliqués individuellement. Cela a comme corollaire d'entraîner une perte

d'efficacité économique plus importante. Dans tous les cas, des baisses de prix de marché relativement modestes sont réalisées au coût d'importantes pertes d'efficacité économique.

INTRODUCTION

Since 1971, Canadian dairy producers have had to possess an allotment or “quota” to legally market their milk. Although the quantity of quota is determined nationally, each province supervises how quota is allocated and traded provincially. Initially, in Quebec, buyers and sellers traded quota on an informal basis. By the end of the 1970s, however, the informal system had been replaced by a centrally administered exchange. The central exchange was structured as an English-type auction in which quota was sold to the highest bidder. A uniform price auction system was suggested as a replacement in 1984 and was implemented one year later. At present, the exchange operates on a monthly basis and is the only means by which quota can be bought or sold as a separate asset in the province (Fédération des producteurs de lait du Québec (FPLQ) 2006a). In a typical dairy quota auction, sellers are less numerous than buyers and total demand is larger than total supply. However, sellers usually offer larger quantities of quota than demanded by buyers since the sellers are often retiring from milk production altogether or are reducing the size of an operation because of health or financial problems. In contrast, buyers are frequently interested in extra quota due to expansion plans or productivity gains.

In a uniform price auction, the seller always obtains a price equal to or higher than his offer price and the buyer tenders a price equal to or lower than her bid. All units traded are exchanged at the same price (Davis and Holt 1992; Ausubel and Cramton 2002). In Quebec, potential buyers and sellers of milk quota reveal the quantity of quota they wish to exchange and their exchange price through closed bids submitted to the central exchange by phone or fax prior to the auction. The central exchange organizes potential sellers' offers in cumulative, ascending order while bids by potential buyers are organized in cumulative, descending order. The equilibrium price occurs at the point where the cumulative quantity of quota offered for sale approximates the cumulative quantity of quota demanded.¹ Successful sellers and buyers receive/pay the equilibrium price for each unit. Table 1 shows how this process was used to determine the equilibrium price of \$32,500 per kg of butterfat (BF)/day for 1,193.60 kgBF/day of quota for Quebec in June 2006.

Between March 1999 and July 2006, quota prices in Quebec rose a dramatic 43%, from \$22,000 per kgBF/day to \$31,500 per kgBF/day (FPLQ 2006b). High quota prices are a concern for stakeholders in the Quebec dairy industry because they negatively affect producer incomes and because large sums of money become capitalized into a nonproductive asset (Belzile 2003). These and other problems have spawned a vast literature on the consequences of high quota prices for the efficiency and competitiveness of the dairy sector (Boots et al 1997; Alvarez et al 2006).

Uniform price auctions are efficient since they ensure that buyers with the highest subjective valuations for goods obtain those goods and, in exchange, sellers receive returns that approximate the totality of this value (Ausubel and Cramton 2002; Krishna 2002).² However, an efficient auction does not prevent high prices or speculative bubbles (Chatterjea and Jarrow 1998). The latter reflects, *ex post*, inaccurate asset valuation by

Table 1. Bid and offer distribution per price strata (in \$ per kg of BF/day) in Quebec, June 2006

Sellers			Buyers			
Number	Quantity in kgBF/day	Cumulative	Prices in kgBF/day	Number	Quantity in kgBF/day	Cumulative
3	14.00		≤29,000	24	112.00	
23	414.00	428.00	>29,000 ≤30,805	59	215.50	
51	650.90	1,078.90	>30,805 ≤32,101	59	203.00	
1	5.00	1,083.90	>32,101 <32,500	20	42.70	
6	99.70	1,183.60	32,500	20	61.80	1,193.60
11	115.10		>32,500 ≤33,000	53	146.00	1,131.80
4	98.40		>33,000 <34,000	101	363.70	985.80
5	68.10		≥34,000 <35,000	85	306.20	622.10
3	28.30		≥35,000	72	315.90	

Source: FPLQ (2006b).

a sufficient number of market participants and is not sustainable in the long run. Nevertheless, motivated by the belief, true or false, that quota prices were above their “real” value, a committee formed by the FPLQ proposed modifications to the centralized quota exchange. The goal of the committee’s modifications was to create downward pressure on price for an otherwise economically efficient market. The modifications included exclusion of the highest bids and offers from calculation of the equilibrium price, imposition of a tax on sellers, and combinations of the exclusion and tax rules (Comité sur le Quota 2003). The committee’s hypothesis was that eliminating the highest bids at purchase would reduce bid amounts in general as potential highest bidders would risk having their bids excluded from the market. For potential sellers, the implication was similar. By asking a high price for their quota, potential sellers would risk being involuntarily excluded. The second aspect of the committee’s proposal was to impose a tax on individuals who offer quota for sale but fail to sell it. According to the committee, the tax would lower the quota price offered by sellers.

This study uses experimental economics to examine the likely consequences of implementing the recommendations put forth by the Committee on the Quota. In particular, it assesses whether there is a combination of exclusion rates and tax rates that reduces quota prices while minimizing negative impacts on the economic efficiency of the auction. Various auction types and structures have been evaluated using experimental economics (Smith 1991; Davis and Holt 1992; Sade et al 2005). Much of the earlier research focused on the market for bonds issued by the U. S. government and for electricity, each of which uses uniform price auctions. Studying the agri-food sector, Lusk et al (2001) and Dickinson and Bailey (2002) auctioned real goods in their experiments on food products. Menkhous et al (1999) used experimental economics in the context of supply and demand in a short-term market in which participants did not have any exchangeable goods. Messer et al (2005) and Messer et al (2007) used a uniform price auction to study various voluntary funding mechanisms for generic advertising. Closer to the present subject, Doyon (2001) tested the consequences of a deregulation of the U.S. milk industry by eliminating federal milk marketing orders.

This paper is organized as follows: The next section surveys the literature on uniform price auctions to guide development of the experimental framework presented in section three. This is followed by a discussion of the propositions to be tested in the experiment, the results of which are discussed thereafter. Finally, the last section offers concluding remarks on this research.

LITERATURE SURVEY OF UNIFORM PRICE AUCTIONS

In uniform price auctions with multiple units of a good, theory suggests that, after the first unit, potential buyers will bid less than their subjective valuations for the next unit. The rationale for this strategy is that all potential buyers and sellers in a uniform price auction influence the equilibrium price. Potential buyers place bids below their subjective valuations to reduce the equilibrium price and thus secure a larger benefit. This phenomenon, known as “fall in the demand,” has been widely documented because it involves a reduction in allocative effectiveness and in income (List and Lucking-Reilly 2000; Kagel and Levin 2001; Ausubel and Cramton 2002; Krishna 2002; Milgrom 2004).

Engelbrecht-Wiggans et al (2006) demonstrated that the fall in demand subsides with an increase in the number of potential buyers. They showed that a large number of potential buyers reduces, but does not completely remove, the ability of each to influence price individually. Bogetoft et al (2002) argue that double auctions are generally stable. The results of several empirical studies confirmed Bogetoft et al's (2002) assertion, even in situations with few participants. This outcome is consistent when there is no auction manipulation or collusion and the objective is to maximize profits. However, according to McAdams (2002), the existence of a link between marginal and infra-marginal units is one of the reasons for the presence of many types of equilibria—some being undesirable—in uniform price auctions.

Any intervention aimed at modifying the outcome of a uniform price auction like the one used in the Quebec quota market is likely to reduce the *efficiency* of that auction. The economic research problem addressed in this paper is delineation of the effects of alternative interventions aimed at reducing the price while minimizing negative impacts on auction efficiency. The next section describes the structure of the economic experiment to test the effect of such changes on the Quebec quota exchange.

EXPERIMENTAL DESIGN AND ITS RELATION TO THE QUOTA MARKET IN QUEBEC

The two modifications (treatments) tested are exclusion of the highest bids from buyers and offers from sellers and a tax on units offered by sellers but not successfully sold. Three variations are tested for both treatments and are presented in Table 2. The three levels of exclusion are 0%, 5%, and 15%, while the three levels of tax are 0%, 2%, and 10%. Therefore, nine combinations of treatments are tested. Both 0% options together form the base scenario for comparison.

In each experiment, 11 groups (cohorts) of nine subjects were recruited. Each cohort was composed of four sellers and five buyers. The relative number of buyers and sellers reflected the Quebec quota market (Belzile 2003; FPLQ 2006b) and is consistent with pretest results aimed at optimizing market liquidity while minimizing the number of participants. Individuals were assigned the role of buyer or seller at random by drawing a

Table 2. Experimental design, cohorts by number (1–11), and order (1–5)*

		Exclusion rate					
		0%		5%		15%	
		Treatment 1		Treatment 2		Treatment 3	
	0%	C _{01,1}	C _{07,1}	C _{01,2}	C _{07,4}	C _{02,2}	C _{08,5}
		C _{02,1}	C _{08,1}			C _{03,4}	
		C _{03,1}	C _{09,1}				C _{11,3}
		C _{04,1}	C _{10,1}	C _{04,3}			
		C _{05,1}	C _{11,1}			C _{05,3}	
		C _{06,1}		C _{06,5}			
		Treatment 4		Treatment 5		Treatment 6	
Tax rates	2%	C _{01,5}				C _{01,3}	C _{07,5}
		C _{02,3}	C _{08,4}	C _{02,5}			
		C _{03,2}		C _{03,3}	C _{09,4}		C _{09,3}
				C _{04,2}	C _{10,2}		C _{10,5}
				C _{05,4}		C _{05,2}	C _{11,2}
						C _{06,4}	
		Treatment 7		Treatment 8		Treatment 9	
	10%		C _{07,3}		C _{07,2}	C _{01,4}	
				C _{02,4}	C _{08,3}		C _{08,2}
				C _{03,5}	C _{09,2}		C _{09,5}
		C _{04,4}			C _{10,3}	C _{04,5}	C _{10,4}
		C _{05,5}					C _{11,4}
		C _{06,2}				C _{06,3}	

*Where the first two digits are the cohort number and the third digit is the treatment order.

bingo ball upon entering the computer lab. Each participant was given five units of quota and instructed either to sell or buy during each period. Production costs (marginal costs) were assigned to each seller's unit and subjective values (marginal benefits) associated with each unit were assigned to buyers. Sellers (buyers) had to make an offer (bid) for each unit in a given period (one treatment generally implied 16 periods). Because a uniform price auction was used, those units for which the offer (bid) was below (above) or equal to the resulting market price were sold (bought). The only variant was that each participant dealt with multiple units in one trading period but all of the units were sold or bought at a uniform market price, as described for the auction in Table 1.

The complexity of simulations was such that a cohort could react in a different way if participants encountered a particular treatment in a different sequence of treatments (Forsythe and Lundholm 1990). This experimental design made it possible to control for the differences between cohorts, which was important since participants possessed varying levels of intelligence, motivation and familiarity with the experimental environment and processes (Kagel and Roth 1995). The design also made it possible to control for the effect of the particular order of treatments.

Each cohort participated in five treatments, as illustrated in Table 2.³ For example, cohort 3 (03 in Table 2) started in Treatment 1 with the 0% tax and 0% exclusion, moved

to Treatment 4 with the 2% tax and 0% exclusion, followed by Treatment 5 (2%, 5%) and then Treatment 3 (0%, 15%) and finished with Treatment 8 (10%, 5%). Each cohort started with Treatment 1 (0%, 0%) as a base scenario. This base scenario created a common period of training and allowed participants to familiarize themselves with the experiment.

Regarding parallelism to the Quebec dairy quota market, in reality a milk producer can be a buyer or a seller of quota. However, at some specific time this producer will be either a seller or a buyer. This situation corresponds to the design of the experiment since participants were either buyers or sellers but not both.⁴ Demand and supply curves were obtained from the valuations and costs of each of the five units held by the buyers and sellers in the experiment. The development of these curves rested on a descriptive analysis of actual quota exchanges in Quebec during the last five years (Doyon et al 2006). Each point on the supply and demand curves was attributed to sellers and buyers. The design gave each seller low- and high-cost units and each buyer high- and low-value units. In reality, buyers have different subjective valuations of dairy quotas. Within the framework of this study, the various prices received by buyers reflected these differences. Thus a high valuation reflected a situation for a producer who, for reasons such as greater efficiency or positive outlook, is willing to buy quota at a higher price. Potential sellers in the centralized quota exchange also want different selling prices (FPLQ 2006b). In the simulation, potential sellers were faced with a cost. A sale that occurred at a price higher than this cost created a benefit to the seller. Thus, in the simulation a potential seller with a low cost was prepared to sell at a low price. The presence of intermediate and high costs in the simulation reflected the diversity of subjective valuations and opportunity costs that exist in the real market.⁵

As illustrated by Figure 1, equilibrium occurred at 5,500 francs with an equilibrium tunnel for quantity of 15 and 16 units exchanged. The “franc” was the term used to define the experimental monetary denomination during experiments. The “franc” was used in place of “dollar” to avoid any anchoring effect⁶ and to allow a greater flexibility in adjusting the remuneration of the individuals who participated in the experiment. The surpluses of the sellers and buyers were calculated to be 7,100 francs and 4,500 francs, respectively. Subjects were paid \$45 U.S., on average, for participating in the experiment, which lasted less than two hours in the laboratory.

For each period, valuations, prices, and costs characterize and guide the actions of buyers and sellers. Throughout the experiment, each participant retained his/her given characteristics and role of buyer or seller. The stability of the experimental environment benefited the statistical analyses but did not necessarily reflect the reality encountered by Quebec dairy producers. In the medium and long term, such stability would likely give rise to an underestimation of the price changes.

PROPOSITIONS

In conjunction with the main goal of the Quota Committee, this section formulates propositions regarding the impact of the modifications to the centralized quota exchange on equilibrium price. Two additional propositions regarding the tax on unsold units and the exclusion of units with the highest prices are formulated in terms of their impact on the number of units exchanged and market efficiency.

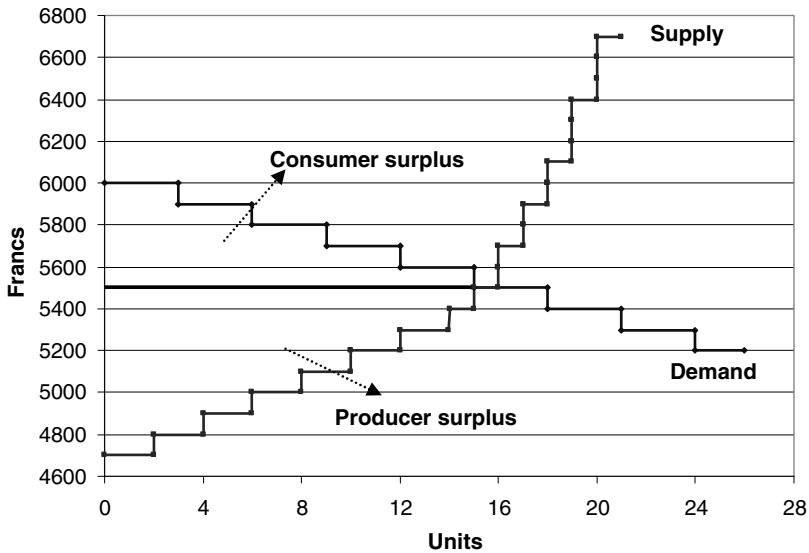


Figure 1. Demand and supply curves

Imposing a Tax on Unsuccessful Sales

The tax applies only to sellers who fail to sell and therefore should have little impact on selling strategy. Once the equilibrium price and quantity can be estimated, after the first few periods, the optimal selling strategy should be to only offer units for sale that are likely to be included in market sales. Units for which the cost is higher than a recently observed equilibrium price should not be offered since they would likely be taxed. Sellers should offer units at a price equal to the cost, except for those units for which cost exceeds the expected equilibrium price (which sellers should not offer for sale). This treatment should influence the strategy of sellers but not the equilibrium price outcome. In theory, this treatment does not affect the equilibrium price-quantity combination. However, this outcome is conditional on the availability of information about equilibrium price and quantity so sellers could withdraw from the market a number of units, that is, the number of units that would be naturally excluded from the market.⁷

Proposition 1: *The treatment for the tax on units offered for sale but not sold will preserve the equilibrium price of the quota at a level equivalent to the initial price of the base scenario.*

Proposition 2: *The treatment for the tax on units offered for sale but not sold will preserve the number of transactions at a level equivalent to the base scenario.*

Economic efficiency should remain stable between the base scenario and the treatments composed of a tax of 2% or 10% since the price and the number of transactions should stay the same. This translates into Proposition 3.

Proposition 3: *The treatment for the tax on units offered for sale but not sold will preserve economic efficiency at a level equivalent to the base scenario.*

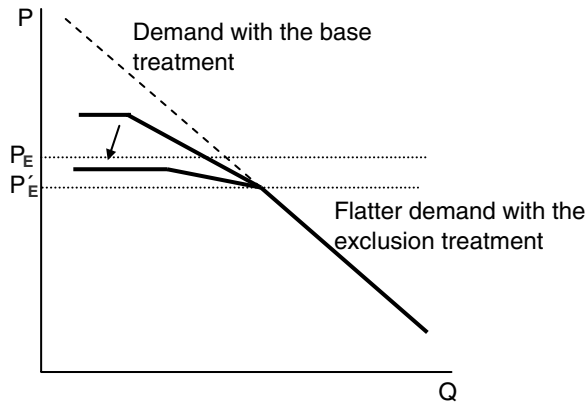


Figure 2. Demand curves with an exclusion of 5% or 15% of buyers' highest bids

Exclusion of the Units with the Highest Prices (Buyers and Sellers)

Recall that only a fraction of the units available in the market are exchanged in equilibrium. A percentage of the units offered for sale remains unsold and is thus excluded from exchange. Theoretically, any level of exclusion lower than this percentage should not affect a seller's strategy. Since, at equilibrium, 30% of the units are naturally excluded from the market (Figure 1), an exclusion of 5% or 15% should not have any impact on the strategy of sellers.

The situation is different for buyers. Their dominant strategy is to place a bid for the first unit at a price equal to their valuation. With exclusion, this approach no longer applies since the highest prices are withdrawn from the market. Figure 2 illustrates how different levels of exclusion kink the demand curve. Effective demand occurs along and inside a fork located under the level of exclusion and above the equilibrium price. More specifically, it is optimal to bid just above the equilibrium price of the present period. However, this price is unknown and therefore must be estimated using both the equilibrium price in the previous period and the history of the transactions (i.e., the price trend). This treatment thus makes the strategy of the buyers more complex. The demand curve derived from their behavior has three different segments. Units with the highest prices are excluded from the market, which means that the demand curve is flat at a certain price level for the first few units. In the next segment, offers to purchase have some probability of being excluded according to whether the bid price is close to the equilibrium price. This demand segment is less inelastic than the initial segment of the demand curve. Finally, buyers whose unit values are close to the equilibrium price do not have to modify their behavior for this unit. Since the excluded units will be replaced by units demanded at a lower price, the cumulative quantities offered and demanded will meet at a lower price and quantity than the initial theoretical equilibrium produced by a uniform price auction. Thus, if the level of exclusion is sufficiently high, this treatment should create pressure for a lower price.

Proposition 4: *The treatment for exclusion of the highest offers and the highest bids will decrease quota prices relative to the base scenario.*

It is expected that there will be fewer transactions during the treatments consisting of an exclusion compared to the base scenario. Since a percentage of the highest bids will be excluded, this will prevent exchanges that otherwise would have occurred.

Proposition 5: *The treatment for exclusion of the highest offers and the highest bids will decrease the number of exchanges compared to the base scenario.*

Since exclusion will reduce the price and the number of exchanges in equilibrium, it is possible that maximum economic efficiency will not be realized.

Proposition 6: *The treatment for exclusion of the highest offers and highest bids will result in a lower level of economic efficiency.*

Combinations of Various Levels of Tax and Exclusion

Treatments involving both the tax and exclusion combine the behavior of sellers during a treatment with the tax and of buyers during a treatment with exclusion. The combination of treatments reflects the effects of ensuing interactions. For sellers, the effect of interaction between exclusion and tax is important. Indeed, regardless of the number of units offered, a certain percentage will be excluded and, as a result, the excluded units will be taxed. In subsequent offers, therefore, the taxed sellers are likely to reduce the quantities they offer for sale, which will reduce the number of transactions. The units that are eliminated first are those that have the highest marginal cost. Buyers will try to place bids that are less than the exclusion price but more than the equilibrium price. Sellers' behavior should also complicate the buyers' decision-making.

It is difficult to predict the impact of the interaction of the two treatments on price. Indeed, sellers should offer some high-cost units, exposing them to tax and exclusion, to ensure that the lowest cost units are sold, maximizing their profits. This strategy is profitable up to the point at which the costs associated with the tax and exclusion equal profits from the sale of units at a low marginal cost. In fact, to maximize sellers' net total income, they should coordinate with each other so that the number of taxed units is the same as the number of excluded units. If they succeed, there should be only a marginal resulting effect on prices and quantities. If this rather complex strategy is not applied by sellers, the number of units exchanged would fall, as would prices (a reduction in the marginal cost of units offered for sale combined with the flattened top of the demand curve, as illustrated in Figure 2).

Proposition 7: *The treatment consisting of a tax on the units offered for sale but not sold and exclusion of the highest offers and the highest bids will decrease the quota price compared to the base scenario and the treatments without interactions.*

Proposition 8: *The treatment made up of a tax on the units offered for sale but not sold and exclusion of the highest offers and the highest bids will decrease the number of exchanges compared to the base scenario and the treatments without interactions.*

The predicted drop in price and in the number of units exchanged in the treatments combining a given level of tax and exclusion leads to a foreseeable reduction in economic efficiency that will be observed after subsequent treatments.

Proposition 9: *The treatment made up of a tax on the units offered for sale but not sold and of exclusion of the highest offers and the highest bids will result in a lower level of economic efficiency than the base scenario and the treatments without interactions.*

ANALYSIS OF THE RESULTS

Descriptive Analysis of the Results

Average prices based on data from the second half of the periods during the experiment are shown in Table 3. The analysis focuses on the last half of the periods (eight periods for all treatments and five for the base) of each cohort for each treatment.⁸ Using these final periods minimizes errors from potential learning effects. The base treatment (Treatment 1: 0% exclusion and 0% tax), with an average price of 5,479 francs and 14 units exchanged, is close to the theoretical equilibrium of 5,500 francs and 15 units exchanged. The differences between theoretical and observed data can be explained by players' errors and slight market distortion. To take into account and to control for this *imperfect world*, the results from the other treatments are compared to the base treatment.

Table 3 indicates that the tax by itself has little or no impact on price, quantities traded, and efficiency. In contrast, the exclusion policy reduces price but is also detrimental to the number of units traded and to efficiency. The strongest impacts are found when exclusion and the tax are combined (Treatments 5, 6, 8, and 9), which implies that there is an interaction effect between the two treatments. Treatment 9 with the 15% exclusion and 10% tax generates the lowest level of economic efficiency (50%) with an average of six units traded compared with 14 for the baseline (Treatment 1).

Statistical Analysis of the Results

As previously discussed, for the purpose of the statistical analysis, only the results from the first eight cohorts are preserved in order to maintain the same number of observations for each treatment.⁹ Moreover, the analysis focuses on the last half of the eight periods for each cohort per treatment. Since each cohort participated in five treatments, the statistical analysis in this section is based on 320 observations.

The results are analyzed using the *mixed* SAS procedure. The procedure involves estimating a linear model that simultaneously associates fixed and random effects. In the present analysis, the cohorts are the random effect while the levels of the tax and the exclusion, and the periods are the fixed effects. This procedure is a generalization of the GLM procedure that considers linear models with fixed effects only. The use of this model in our analysis could be defined as an "advanced ANOVA approach" as described by Yu et al (2004) and is used for hypothesis testing.¹⁰ This model can be written as $y_{ijk} = \mu + \alpha_i + d_{ij} + \tau_k + (\alpha\tau)_{ik} + e_{ijk}$. The parameters for the fixed effects are the average μ , the fixed effect of treatment i denoted by α_i , the fixed effect of the time period k denoted as τ_k , and the fixed interaction term between treatment i and period k denoted as $(\alpha\tau)_{ik}$. The random effects are represented by the random effect between cohorts denoted by d_{ij} and the error term e_{ijk} . The *mixed* SAS procedure estimates the model using the methods of maximum likelihood and generalized least squares (Littell et al 1998). According to Littell et al (1998), one of the major aspects of repeated measurements is the type of correlation between various measurements of the same treatment. Ignoring this result can lead to erroneous statistical conclusions.

Table 3. Average prices, number of exchanges, and economic efficiencies for the second half of the periods by treatment

Treatment	Exclusion rate	Tax rate	Observations	Price of the second half of periods		Number of exchanges during the second half of the periods	Efficiency for the second half of the periods compared to treatment 1	Efficiency for the second half of the periods
				Average price	Difference compared to treatment 1			
Treatment 1	0%	0%	275	5,479	-	13.9	-	86%
Treatment 2	5%	0%	256	5,441	-0.69%	13.3	92%	79%
Treatment 3	15%	0%	320	5,307	-3.14%	12.0	82%	70%
Treatment 4	0%	2%	256	5,512	0.60%	13.8	100%	86%
Treatment 5	5%	2%	384	5,334	-2.65%	10.1	75%	64%
Treatment 6	15%	2%	448	5,208	-4.95%	7.1	56%	48%
Treatment 7	0%	10%	256	5,480	0.02%	13.8	99%	85%
Treatment 8	5%	10%	384	5,305	-3.18%	9.4	71%	60%
Treatment 9	15%	10%	448	5,205	-5.00%	6.1	50%	43%

The covariance between the answers to time k and l of treatment i on cohort j is $\text{cov}(y_{ijk}, y_{ijl}) = \text{cov}(d_{ij} + e_{ijk}, d_{ij} + e_{ijl}) = \text{var}(d_{ij}) + \text{cov}(e_{ijk}, e_{ijl}) = \sigma_d^2 + \text{cov}(e_{ijk}, e_{ijl})$. The structure of the variance-covariance must be imposed when the model is estimated (Littell et al 1998). Several shapes for the variance-covariance matrix were tested: symmetric, autoregressive of order 1, and unstructured. In this study, the correlation matrix was characterized as an autoregressive type of order 1. Analyses of variance were conducted to determine the interactions between pairs of treatments to compare the various levels of exclusion rate and tax rate between them.

Impact of Treatments on Prices

Panel A of Table 4 shows that exclusion has a significant impact on price. The null hypothesis of equality between the equilibrium price of this treatment and that of the base scenario is rejected. This result is consistent with the descriptive analysis of the preceding section. After the first period for a treatment of a 5% or 15% exclusion, price decreases relative to the base scenario. This supports Proposition 4 (the effect of exclusion on price). Moreover, there is a significant interaction between exclusion and time that is reflected by the equilibrium price decreasing over successive periods.

The tax does not have a significant impact on the equilibrium price relative to the base scenario. This supports Proposition 1. The interaction between the tax and the exclusion is not statistically significant. Thus, we reject Proposition 7—that treatment interaction results in a decrease in prices compared to the base scenario and the treatments without interaction. This does not mean that the combination of tax and exclusion has no impact on the price, but rather that the interaction of the two treatments is not significantly different than the sum of the two treatments. It is the same for the combination of tax and the period and of tax, period, and exclusion.

The analysis of variance (not shown) used to compare the effects of the various levels of treatment and the period indicates that the three levels of exclusion have differentiated and statistically significant impacts on prices. The treatment with 15% exclusion is most effective in decreasing the price of the quota. In contrast, the impact of different levels of tax does not vary significantly with each other or from the base scenario.

Impact of Treatments on the Number of Exchanges

Panel B of Table 4 shows that exclusion has a significant effect on the number of exchanges. There does not appear to be an interactive effect between exclusion and the periods, which supports Proposition 5. Proposition 5 stipulated that a treatment consisting of an exclusion of the highest offers and bids will decrease the number of exchanges relative to the base scenario.

The tax also has an effect on the number of exchanges regardless of whether the time period is considered, which refutes Proposition 2. However, analysis of the individual results shows that the impact of the tax on the number of exchanges is a product of the difficulty sellers have in predicting the number of exchanges in equilibrium. Sellers make forecasting errors. Indeed, certain participants withdrew units from the market because they feared being taxed when those units normally would have been sold. This led to a chain reaction—some other participants were then taxed for units that they otherwise would not have been. Consequently, these players chose not to offer any more units for sale, which gradually reduced the number of exchanges. The association of the tax and

Table 4. Mixed model for prices, the number of exchanges, and economic efficiency^d

	D.F.	D.F.E.	F-value	Prob > F
Panel A: Prices				
Exclusion	2	241	21.08	< 0.0001 ^{a,c}
Tax	2	241	1.57	0.2095
Exclusion × tax	4	241	1.03	0.3932
Period	7	241	4.26	0.0002 ^{a,c}
Exclusion × period	14	241	2.34	0.0048 ^{a,c}
Tax × period	14	241	1.05	0.4001
Exclusion × tax × period	28	241	0.94	0.5636
Panel B: Number of exchanges				
Exclusion	2	241	18.27	< 0.0001 ^{a,c}
Tax	2	241	7.39	0.0008 ^{a,c}
Exclusion × tax	4	241	2.19	0.0711 ^{b,c}
Period	7	241	1.92	0.0677 ^{b,c}
Exclusion × period	14	241	1.26	0.2308
Tax × period	14	241	1.75	0.0466 ^{a,c}
Exclusion × tax × period	28	241	1.02	0.4399
Panel C: Economic efficiency				
Exclusion	2	241	24.06	< 0.0001 ^{a,c}
Tax	2	241	5.02	0.0073 ^{a,c}
Exclusion × tax	4	241	1.83	0.1233
Period	7	241	1.83	0.0828 ^{b,c}
Exclusion × period	14	241	1.02	0.4352
Tax × period	14	241	1.85	0.0332 ^{a,c}
Exclusion × tax × period	28	241	1.12	0.3153

Notes: D.F. = degrees of freedom; D.F.E. = degrees of freedom for error.

^aSignificant at the 95% level of confidence.

^bSignificant at the 90% level of confidence.

^cNegative impact on the variable.

^dThe analysis is realized using 320 observations.

exclusion amplified the impact of participants' errors in the experiment. The difference in the number of exchanges was significant at the 10% level, as indicated by the exclusion tax interaction shown in Panel B of Table 4.

These results support the first part of Proposition 8 in which the combination of tax and exclusion leads to a decrease in the number of exchanges. In addition, the proposition stipulates that the observed decrease should be larger than for treatments without a combination of tax and exclusion. Student's *t*-tests performed on the averages confirm the impact of the interactive effect. The average number of exchanges in each combination of treatments was statistically different (with the threshold of 5%) from any treatment of tax or exclusion taken individually, that is, without a combination of treatments.

Using analysis of variance, the three levels of exclusion were compared while taking the period into account. The effect of the passage of time on the number of exchanges during treatments of exclusion at 5% and 15% was statistically different from that of the base scenario. Similarly, there was a significant difference (at the 10% level) between treatments of 5% and 15% exclusion. Statistically significant differences between treatments for all levels of the tax were also found.

Impacts of Treatments on Economic Efficiency

Panel C of Table 4 shows how the various treatments of tax and exclusion affect economic efficiency. These results support Proposition 6—that exclusion would reduce prices and the numbers of transactions and thus have an impact on economic efficiency. The tax does not have an effect on the price but it does affect the number of transactions, which explains why it also impacts economic efficiency. The corollary is rejection of Proposition 3. The interaction between treatments of exclusion and tax does not have statistically significant impacts on efficiency at the 90% confidence level, which refutes Proposition 9. This last result may appear surprising since the descriptive analysis (Table 3) seems to indicate an

Table 5. Result summary (revisions below to match statement of propositions in the body)

Propositions	Result
P1 The treatment for the tax on units offered for sale but not sold will preserve the equilibrium price of the quota at a level equivalent to the initial price of the base scenario.	Accepted
P2 The treatment for the tax on units offered for sale but not sold will preserve the number of transactions at a level equivalent to the base scenario.	Not accepted
P3 The treatment for the tax on units offered for sale but not sold will preserve the economic efficiency at a level equivalent to the base scenario.	Not accepted
P4 The treatment for exclusion of the highest offers and the highest bids will decrease quota prices relative to the base scenario.	Accepted
P5 The treatment for exclusion of the highest offers and the highest bids will decrease the number of exchanges compared to the base scenario.	Accepted
P6 The treatment for exclusion of the highest offers and highest bids will result in a lower level of economic efficiency.	Accepted
P7 The treatment consisting of a tax on the units offered for sale but not sold and exclusion of the highest offers and the highest bids will decrease the quota price compared to the base scenario and the treatments without interactions.	Not accepted
P8 The treatment made up of a tax on the units offered for sale but not sold and exclusion of the highest offers and the highest bids will decrease the number of exchanges compared to the base scenario and the treatments without interactions.	Accepted
P9 The treatment made up of a tax on the units offered for sale but not sold and of exclusion of the highest offers and the highest bids will result in a lower level of economic efficiency than the base scenario and the treatments without interactions.	Accepted*

*When all cohorts are being used in the calculation.

interactive effect. Moreover, the significant interactive effect on quantity (Table 4, Panel B) could give the impression that an impact on the economic efficiency would be observed. A limitation of the requirement of using an equal number cohorts by treatment in the mixed model is that the data from the 10 cohorts are not used, whereas the threshold of rejection of Proposition 9 is just reached (p -value 0.1233), as shown in Panel C of Table 4. Consequently, additional statistical tests were calculated using all cohorts that participated in interactive treatments. The results of that analysis indicate that treatments that combine tax and exclusion have an economic efficiency that is statistically smaller than treatments taken individually. Thus, when all cohorts are considered, Proposition 9 is supported.

The three levels of exclusion were compared by taking into account the period effect. Relative to the base scenario, treatments of exclusion of 5% and 15% had a significant impact on economic efficiency. However, the difference between the effect of a 5% and a 15% exclusion was not significant. Taxes of 2% and 10% had a significant impact on economic efficiency compared to the base scenario. There was no significant difference between the two levels of tax, however.

Table 5 summarizes the nine propositions discussed earlier in light of this discussion of the statistical analysis.

CONCLUSIONS

Uniform price auctions are an effective means to ensure that buyers with the highest subjective valuations for goods obtain these goods and, in exchange, that sellers receive returns that approximate the totality of this value. However, a committee formed by dairy producers in Quebec proposed modifications to the centrally administered quota exchange based on the presumption that quota prices in Quebec were too high. To reduce quota prices, the committee suggested that the highest bids to buy and offers to sell be excluded from the uniform pricing scheme and that a tax be imposed on sellers who offered but failed to sell quota. In a laboratory setting, this study tested the impacts of the committee's proposal on price reduction while looking for treatments that minimized negative impacts on the efficiency of the market. The results indicate that a tax on the units offered but not sold does not reduce the price of quota compared to a base scenario (in which there is neither a tax nor exclusion). On the other hand, the tax reduces the number of exchanges and the economic efficiency of the auction. Exclusion of the highest bids from buyers and offers from sellers does decrease the quota price and also decreases the number of exchanges and economic efficiency. The treatment of 15% exclusion has a greater reduction effect on quota price than does the 5% exclusion. However, the difference in the impact on economic efficiency between the 15% and 5% exclusion is not statistically significant. Finally, the treatments that combine various levels of tax and exclusion do not have statistically significant interactive effects on the price level. However, there is a negative effect on the number of units exchanged and on economic efficiency. Although the treatment of 15% exclusion generated the largest ratio of quota price reduction to loss of economic efficiency, in all cases relatively small market price reductions were realized at the expense of important losses of economic efficiency.

It is important to note that the experimental design used in this study created a stable environment in which to test the various treatments. Each participant was either

a seller or a buyer and had the same costs or values throughout the experiment. In reality, an individual can at times be a buyer and at other times be a seller. Similarly, costs and valuations can change over time. However, the nature of these controlled experiments reflects a short-term horizon and thus it was reasonable to treat participants as short-term buyers or sellers with time-independent valuations and costs, especially since, in the real quota market, sellers tend to be leaving the market entirely due to retirement or significant changes in their health or financial situation. Moreover, the ranking of the impacts of various treatments is not cardinal but ordinal. The analysis suggests that prices would fall if the recommendations of the committee on the quota were implemented but it is not clear by how much. Indeed, the price decrease from an exclusion of 15% in the experiment cannot be used to calculate the reduction in the price of the quota that would occur in reality starting, for example, from a price of \$31,500/kg of BF per day. These are the two principal limits of this research.

The working hypothesis of this paper was that the effect of the starting value for quota reflects the perceptions of the producers and that these perceptions are stable in the short term. Since the price of quota has increased consistently since the program's inception in 1971, producers may anticipate that the quota price will continue to climb. Producers may therefore have an incentive to pay high prices now rather than higher prices in the future and to delay when they need to sell. On the other hand, the possibility of increased market liberalization could foreshadow the demise of the supply management system. Therefore, it would be interesting to integrate a speculative component with probabilities of decreases or increases in the quota price into the experiments. This could be the objective of future research.

NOTES

¹When supply and demand are not perfectly equal, the FPLQ uses a reserve that enables it to buy or sell small quantities of quota to fill the difference (FPLQ 2006a).

²Economic efficiency is defined in terms of the percentage of total surplus (buyer and seller surpluses) being captured. The higher the percentage captured, the higher the efficiency. This definition of efficiency will be used throughout the paper.

³Initially, all treatments except the base were tested by four cohorts. However, treatments with potential interaction effects (from initial results) were further tested, such that some treatments were tested by six or even seven cohorts. Lengthy pretesting revealed that 10 periods (repetitions) were sufficient to reach equilibrium or saturation for the base treatment. However, subsequent treatments, which were more complex, such as those involving both exclusions and taxes, consisted of 16 periods. In order to verify if more trading would affect the results, one cohort (cohort 11) was assigned 25 periods by treatment and no differences were found in trading patterns for 25 periods compared with 16 periods. As explained in the result section, these extra trading periods were not used in the statistical analysis for data consistency.

⁴In the present case, buyers and sellers have multiple units to trade at various prices at the same time, which is possible but rarely observed in the real world. The difference between reality and simulation theoretically could have an impact on the effectiveness of the auction simulation. According to theory, our simulations could overestimate the loss of market efficiency as participants may adopt a strategic behavior in simulation in the presence of multiple units (Ausubel and Cramton 2002; Krishna 2002) whereas such behavior is rarely seen in actual fact. However, this possibility is not a significant problem for this study as the objective is to compare treatments starting from the same experimental base, that is, the treatment consisting of neither the tax nor the exclusion. As only the

variation from the base scenario is of interest, this should only minimally impact the accuracy of the subsequent statistical analyses.

⁵It seems that the price of quota as of the summer of 2006 was above its fundamental value so the opportunity cost to continue to sell milk is not a constraint (milk prices are above marginal production costs). Thus, there is a risk of underestimating the extent of the price decrease. This is particularly true for a medium-term horizon in which events could quickly bring the quota price back to its fundamental value or even reduce its fundamental value. The structure of the experiment was not designed to capture these effects and therefore could underestimate the potential decrease in quota prices. A maintained assumption of this study is the confidence of dairy producers toward the longevity of the supply management system and the constancy of current methods of financing quota purchase.

⁶The anchoring effect is manifest when the participants are influenced by the value of their units or their profit and they then try to transpose these in real-world situations.

⁷This situation is the outcome of a stable experimental environment. In the contrary case, the direct effect of implementing a tax on the unsold units would be to increase the asking price of sellers of quota and to reduce the number of exchanges, all things being equal.

⁸For cohort 11, which has 25 periods, periods 9 through 16 were used for the analysis.

⁹The data of the excluded cohorts are similar to those of the cohorts in their respective treatments.

¹⁰Traditionally, ANOVA tests, such as ANOVA with repeated measures, are used for this type of analysis in the literature. However, as indicated by Littell et al (1998) for repeated treatment, variance homogeneity is not insured, which could affect the quality of results of hypothesis tests. In such case, it is more appropriate to use “linear mixed-effect models.” The hypotheses to be tested with the “linear mixed-effect models” are the same as the one that would be tested using an ANOVA type analysis.

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