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Imputing Dairy Producers' Quota Discount Rate Using the Individual Export Milk Program in Quebec[1]

Maurice Doyon
Associate Professor, Department of Agricultural Economics and Consumer Studies, Laval University

Catherine Brodeur
Graduate research assistant, Department of Agricultural Economics and Consumer Studies, Laval University

Jean-Philippe Gervais
Canada Research Chair in Agri-industries and International Trade, Department of Agricultural Economics and Consumer Studies, Laval University

The Issue

Trade liberalization scenarios are often evaluated using sophisticated programming models that rely on a number of assumptions related to demand and supply parameters. One challenge researchers often encounter in the calibration of dairy trade liberalization models is to identify the supply response of producers under production quotas. The existence of production quotas in the Canadian dairy industry implies departures from standard marginal cost pricing. Under traditional net present value models, an assumption about the discount factors attached to production quotas must be made to infer the supply response of Canadian dairy producers following a change in the economic environment (e.g., import tariffs). The Individual Export Milk (IEM) program in Quebec generated an opportunity to estimate dairy producers' discount factors for production quotas conditional on different assumptions about structural parameters such as producers' risk preferences and cost efficiency.

Implications and Conclusions

Different assumptions about production quotas' discount rates are used in different trade policy simulation models (e.g., Cox et al., 1999, and Meilke, Sarker and Le Roy, 1998). Meilke, Sarker and Le Roy use a discount rate of 20 percent and state that it is "… in the mid-range of discount rates estimated by … economists." As they note, estimates of discount rates in the literature vary wildly. The current article estimates that annual discount rates range from approximately 8 percent to 12.5 percent in May 2001 and May 2002. These estimates are conditional on the producers' degree of risk aversion, producers' cost efficiency and the non-stochastic return on the export market. The estimates of the discount rate are relatively greater than the commercial risk-free interest rate on government bonds or returns on other risk-free assets sometimes used to discount quota values; however, they are also smaller than previously computed discount rates (e.g., Chen and Meilke, 1998).

Background

A ruling of the WTO Dispute Settlement Body in October 1999 forced the Canadian dairy industry to reform dairy export mechanisms in the fall of 2000. An electronic marketplace for exports of dairy products, known as the Individual Export Milk (IEM) program, was implemented in Quebec (and in other provinces). Under this program, export milk was sold directly to processors without the intervention of the national supply management system. The IEM program was subsequently successfully challenged by New Zealand and the United States, and the program ceased to exist in early 2003. The current analysis seizes the opportunity created by the existence of the IEM programs to produce iso-utility lines that determine threshold values for the discount rate conditional on risk preferences, cost efficiency and a given export price.

The Economic Model

A portfolio model is built to derive optimal purchases of export contracts and domestic production quotas by dairy producers. Let α and $1-\alpha$ represent the shares of milk allocated to the domestic and export markets respectively under the existence of the IEM program. Assuming that output of dairy producers is pre-determined and that variable costs are constant, the per-unit profit function is

$$\tilde{\pi} = \left(\tilde{p}^d - r\delta\tilde{p}^q\right)\alpha + p^x\left(1-\alpha\right) - c\,, \qquad (1)$$

where $\tilde{p}^d$, p^x and $\tilde{p}^q$ represent the domestic price of milk, the export price of a contract offered to a producer and the auction equilibrium price of production quotas, respectively. The symbol ~ denotes randomness in a variable, *c* is the constant average variable cost of production, *r* represents the annual discount rate and the parameter δ is the factor that converts kg of butterfat per day into hectolitre of milk produced in a year $(\delta \equiv 3.6/365)$.[2] Therefore $r\delta\tilde{p}^q$ is the opportunity cost of holding production quotas in a period.

The current analysis differs from that of Turvey, Weersink and Martin (2003) in a fundamental way: the timing of decisions and the assumptions about what is known to producers when they make their decisions are different. It is assumed that the equilibrium quota value on the auction market is the relevant short-term random variable from the producers' perspective, rather than the export price. Quebec dairy producers were aware of the most profitable export contract available before making irreversible delivery allocation decisions with respect to the export and domestic markets. Given that the output level is predetermined in our model, the risk faced by producers stems from the uncertain opportunity cost of one period of time of not owning the quota. Producers that do not enter into a binding agreement to sell on the export market through the IEM program at the beginning of a period must either sell their output in the within-quota domestic market, if they possess a corresponding quantity of quotas, or sell in the over-quota market at world prices.[3]

Numerical simulations are used to solve the optimal ratio of quota purchases (or sales) over total output for Quebec dairy producers under the IEM program. As Tomek and Peterson (2001) point out, three empirical issues need to be addressed before proceeding with the simulations. First, the relevant parameters of the probability distribution of the random variables must be estimated. The second and third steps must specify the objective function of producers and explain the simulation algorithm. There are two random variables in the model from the producers' perspective: i) the equilibrium price of the production quota and ii) the domestic price of raw milk. Suppose that the conditional distribution of these variables can be modelled as

$$\tilde{p}_t^q = \lambda_0 + \lambda_1 \bar{p}_t^x + \lambda_2 \sigma_{p_t^x}^2 + \lambda_3 WTO_t + \varepsilon_{1t} \text{ and} \quad (2)$$

$$\tilde{p}_t^d = \beta_1 Target_t + \varepsilon_{2t}, \quad (3)$$

where ε_{1t} is a random error term distributed normally, $\bar{p}_t^x$ represents the average price of all export contracts offered to producers at time t, WTO_t is a dummy variable which equals zero for the period preceding December 2001 and one onward, and $\sigma_{p_t^x}^2$ is the negative semi-variance of all export contracts offered to producers at time t defined as $\sum_{f=1}^{F} k_f w_f \left(p_f^x - \bar{p}^x\right)^2 \big/ W$. The variable w_f is the volume of the export contract, k_f is an index function taking the value of one if $p_f^x \le \bar{p}^x$ and zero otherwise, and F and W are respectively the total quantity of contracts available and the total volume of export contracts. In equation (3), ε_{2t} is a random error term distributed normally and the variable $Target$ is the target price of the Canadian Dairy Commission based on cost of production estimates.

The Quebec domestic farm milk price is an average price based on a reference hectolitre with 3.6 percent of butterfat, 3.2 percent of protein and 5.7 percent of other

Table 1 OLS estimates for the prediction equations

Quota equilibrium price		Domestic price	
Variables	**Estimates**	**Variables**	**Estimates**
Constant, λ_0	349.35 (13.10)	Target price, β_1	0.95 (0.01)
Average export price, λ_1	-2.98 (0.44)		
Negative semi-variance, λ_2	3.70 (2.15)		
WTO dummy, λ_3	18.73 (5.14)		

Note: The numbers between parentheses are the standard errors associated with each coefficient.

solids. The IEM program was administered by an independent agency, and export prices for each contract settled between producers and processors are publicly available. The independent variables of the forecast model were selected to balance the necessity for producers to form their subjective distribution of prices using all information available and the desire to keep the model parsimonious in terms of the number of parameters to estimate. The Breusch-Pagan Lagrange multiplier test for the null hypothesis of a diagonal variance-covariance matrix of residuals produces a statistic of 0.05 (p-value of 0.83). Thus, there are no efficiency gains related to estimating the forecast equations jointly. OLS estimates for each equation are reported in table 1, along with their standard errors between parentheses. All independent variables are statistically different from zero at the 90 percent confidence level and have the expected algebraic sign. The statistical fit of each equation is good, as the adjusted R^2 measures in (2) and (3) are 0.90 and 0.89 respectively.

Simulation

The final task involves specifying the objective function the producer optimizes. Suppose that the utility function of the producer is of the constant relative risk aversion (CRRA) type:

$$U(\pi) = \begin{cases} \ln \pi \text{ if } \gamma = 1 \\ \dfrac{\pi^{1-\gamma}}{1-\gamma} \text{ if } \gamma \neq 1 \end{cases}, \tag{4}$$

where γ is the Arrow-Pratt relative risk aversion parameter. This is a convenient way to approximate producers' risk preferences, and it has the advantage of not assuming that risk preferences are independent from initial wealth level. The CRRA assumption implies that absolute risk aversion is decreasing in wealth. The empirical strategy is as follows.

Two random shocks are drawn from a univariate normal distribution $N\left(0,\sigma_i^2\right)$ using the variance of the estimated residuals in (2) and (3). The random quota price and domestic price are computed using the random forecast errors in the prediction model in (2) - (3), conditional on a set of predetermined variables. This procedure is repeated 50,000 times to compute that many realizations of the random profit function defined in (1).

A non-linear optimization algorithm is used to maximize expected utility of profit over the choice variable α in (1). Solving the optimization problem requires calibrating the annual discount rate (r), the risk aversion parameter (γ) and the marginal cost (c). The empirical strategy is thus to build a grid search over the potential values of the annual discount rate for given values of γ and c such that producers will choose to sell production exclusively on the domestic market $(\alpha = 1)$. This is achieved by averaging out the utility realizations of the 50,000 random draws and optimizing over the variable α. That optimization procedure is repeated ten times and the average optimal proportion is used to determine the iso-utility lines relating the price of export contracts and the discount factor of production quotas. The grid search procedure is assumed successful when the optimization procedure yields a value within 0.01 of the desired level $(\alpha = 1)$.

Results

Two different optimization scenarios were computed. The first one relates to export milk deliveries occurring in May 2001, and the second relates to May 2002, a period of higher quota price. Estimates of marginal costs are not readily available, but average variable costs have been estimated for the province of Quebec in Levallois and Perrier (2001). They report that average variable costs range from \$16.30 per hl to \$25.05 per hl depending on various factors that are farm-specific. Based on these estimates, the portfolio model solves the optimization routine for three different levels of marginal costs: \$16, \$20 and \$24 per hl.

Simulations for May 2001

Figure 1 illustrates various iso-utility lines for a producer with an average variable cost of \$20 per hectolitre, according to his/her coefficient of relative risk aversion. The horizontal axis lists the different prices of export contracts available in May 2001. The iso-utility lines plot the maximum value of the quota discount rate for which the producer would not be willing to participate in the export market. For example, a producer with marginal variable costs of 20\$ per hl and a coefficient of relative risk aversion of two will not participate in the commercial export milk program if his/her discount rate is lower than 8.7 percent, given that the most profitable export contract available is priced at \$35.09 per hl (figure 1). If that producer accepts to supply milk for export at \$35.09 per hl, it implies that he/she discounts the production quota at a higher rate than 8.7 percent. The same producer will accept an export contract priced at \$29.03 per hl if his/her discount rate of the quota is greater than 10.9 percent on an annual basis. The positive slope of the iso-

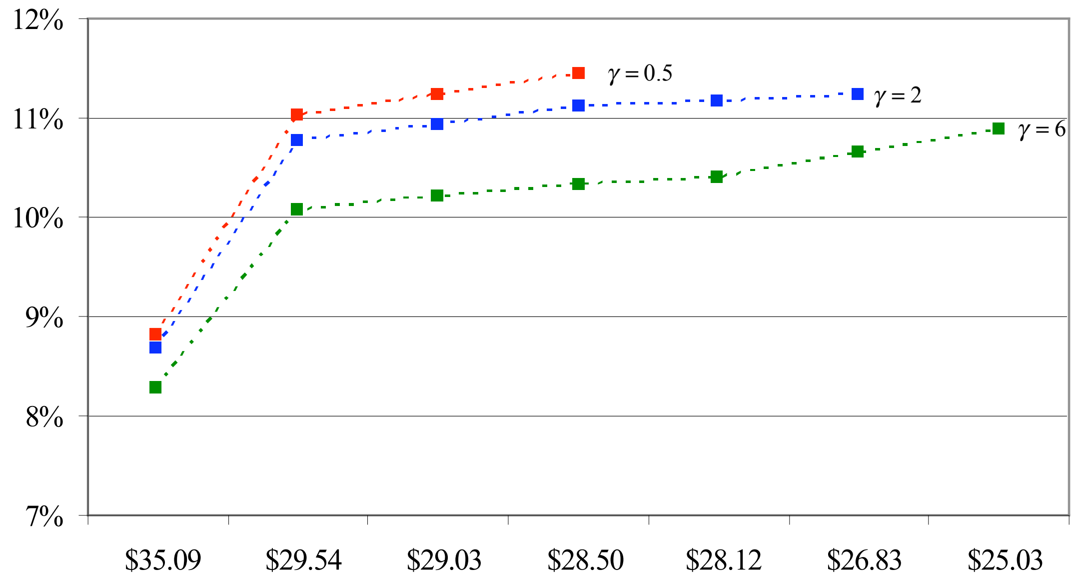

Figure 1 Maximum discount rate of production quotas that entails no participation in the IEM program for deliveries in May 2001 when average variable costs are $20 per hl.

utility line has an intuitive justification.[4] The maximum discount rate of the quota must be inversely proportional to export prices to guarantee that a producer will not participate in the commercial export milk program. Thus, the iso-utility lines generated by the model yield discount rates for dairy trade models that are a function of cost efficiency and degrees of risk aversion.

Consider next the case in which producers have risk preferences that yield a CRRA coefficient of 0.5. In terms of risk aversion, the current hypothetical producer is less risk averse than when $\gamma = 2$, and thus willing to pay a lesser amount to avoid the risks associated with dairy quota transactions. If the producer is offered an export contract of $35.09 per hl, the maximum value of the discount rate is higher (8.8 percent) than when the producer is less risk averse, *ceteris paribus*. The smaller degree of risk aversion implies that a producer will not dislike variability in the domestic price of milk and the price of the production quota for domestic deliveries as much as another producer with a larger relative risk aversion coefficient. Thus, participation in the IEM program will necessitate a higher discount rate. The differences between the maximum values of discount rates given export prices are not especially large or important when comparing values for γ of 0.5 and 2. These differences tend to be heightened when a producer possesses a high coefficient of relative risk aversion $(\gamma = 6)$.

Note that an estimate of the maximum discount rate is not available when a producer is offered an export contract worth less than $28.50 per hl and $\gamma = 0.5$. This is explained by the fact that the expected utility function becomes linear in the decision variable as γ tends to zero. Moreover, the net return on the risk-free asset, defined as the difference

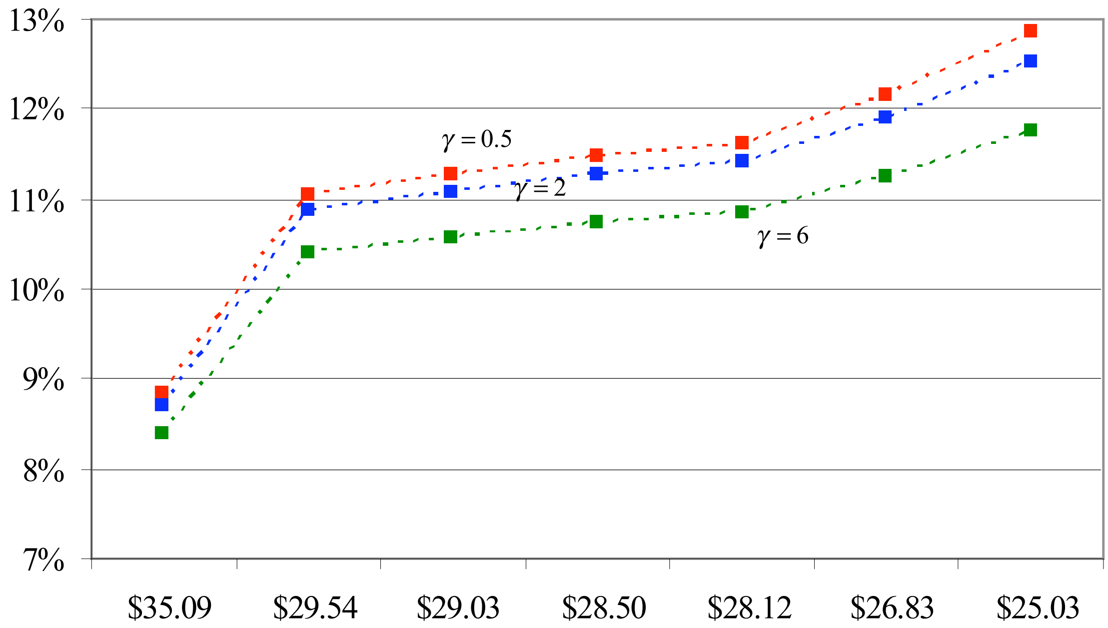

Figure 2 Maximum discount rate of production quotas that entails no participation in the IEM program for deliveries in May 2001 when average variable costs are $16 per hl.

between the export contract and the average variable cost, is decreasing with the export price. The latter two observations imply that the grid search algorithm is sensible to the choice of parameters and that it can be unstable. This remark becomes particularly relevant in instances in which the most profitable contract available is priced below the average variable cost. Under this condition, the optimization problem is degenerate since the net return of the risk-free asset is negative.

Figure 2 illustrates the impact of producers' efficiency on the maximum discount rates. Consider a hypothetical producer that produces milk at a constant average variable cost of $16 per hl. A decrease in average variable costs in the model has the same interpretation as a positive change in the initial wealth of the producer. In the current portfolio allocation model, production is fixed and the difference between the domestic price and marginal cost does not explain the valuation of production quotas by producers. Although costs do not directly explain quota values holding production fixed, they have a significant wealth effect with respect to the allocation of milk deliveries by producers.[5] Constant relative risk preferences imply decreasing absolute risk aversion. In other words, as wealth increases, a producer will become less risk averse. The maximum annual discount rate of a producer that entails no participation in the individual export milk program ranges from 8.4 percent to 8.8 percent depending on the producer's preferences towards risk, given that the most profitable export contract is $35.09 per hl. If the most

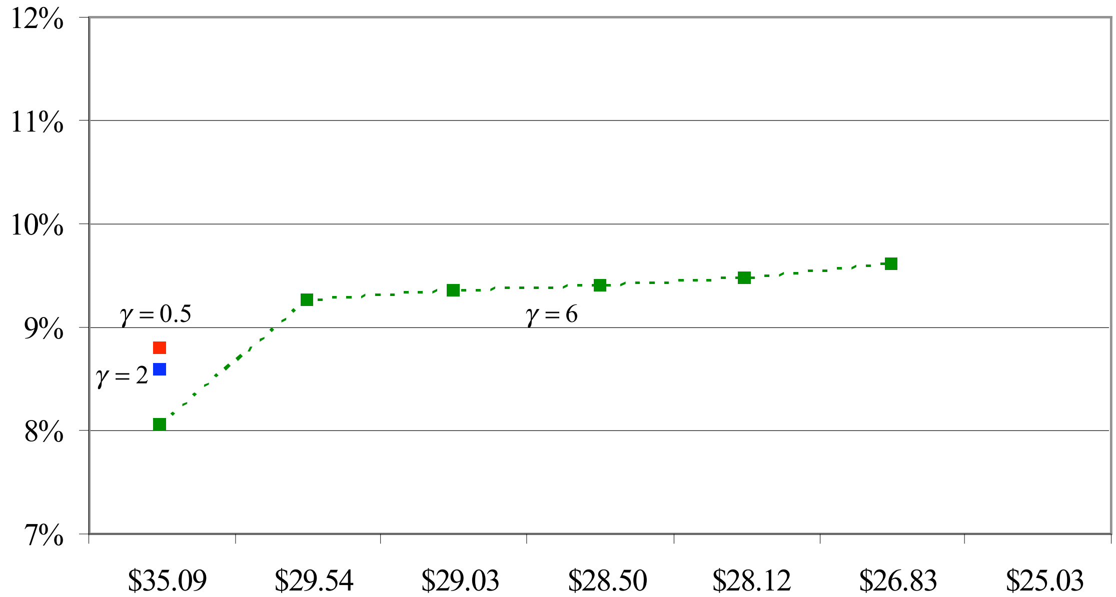

Figure 3 Maximum discount rate of production quotas that entails no participation in the IEM program for deliveries in May 2001 when average variable costs are $24 per hl.

profitable export contract is $28.12 per hl, the maximum annual discount rate ranges from 10.9 percent to 11.6 percent at an efficiency level of $16 per hl.

Figure 3 illustrates the trade-off between the discount rate of producers and export prices if average variable costs are $24 per hl. Convergence of the grid search algorithm fails when the second most profitable export contract in May 2001 is below $35.09 and risk aversion is not high ($\gamma = 0.5$ or 2). However, the maximum discount rate that entails no participation in the IEM program ranges from 8.1 percent to 9.6 percent when producer risk preferences entail a relative risk aversion coefficient of 6.

Simulations for May 2002

The second period used in the simulation of the portfolio model relates to export decisions contracted in March 2002, a period of higher quota price, for deliveries occurring in May 2002. The volume of contracts offered to producers during that month was much lower than a year earlier (9.1 million hl), but all contracts were accepted by producers.

Given the lower export prices for that period, the numerical model can only yield valuable answers if the export price is sufficiently larger than the producers' average variable cost and/or the risk aversion coefficient is high. Figure 4 illustrates the maximum discount rate of producers that does not entail participation in the IEM for the four different export contract prices and risk aversion coefficients of 0.5, 2 and 6. A producer who is strongly risk averse $(\gamma = 6)$ and produces at a constant marginal cost of $16 per hl will not accept an export contract valued at $32 unless he/she discounts the production quota at a rate of more than 9.3 percent. If the value of the export contract is lowered to

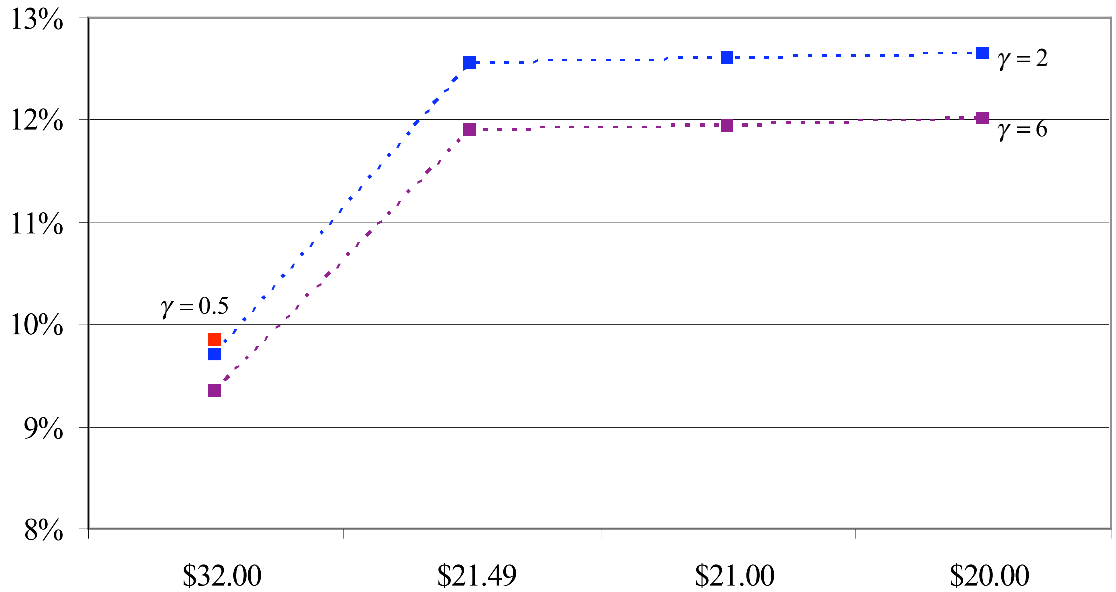

Figure 4 Maximum discount rate of production quotas that entails no participation in the IEM program for deliveries in May 2002 when average variable costs are $16 per hl.

$20, the decision rule is not to participate in the IEM unless the discounting factor is higher than 12 percent. The numerical model generally fails to explain the actual marketing decisions of high-cost-of-production dairy producers in May 2002. A marginal cost of production of $20 or more makes the return of the risk-free asset in the model (the export market) insignificant; thus no sensible discount rate can explain participation in the IEM under these assumptions.

Summary

The main objective of this article is to estimate Quebec dairy producers' quota discount rates conditional on some structural parameters related to risk preferences and technology. Results show that maximum annual discount rates that entail no participation in the export market range from approximately 8 percent to 12.5 percent in the months of May 2001 and 2002. The precise estimate depends on a number of factors, such as the producers' degree of risk aversion, producers' cost efficiency and the non-stochastic return on the export market. These figures are relatively greater than the commercial risk-free interest rate on government bonds or returns on other risk-free assets sometimes used to discount quota values. Conversely, they are smaller than previously computed discount rates (e.g., Chen and Meilke, 1998).

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Endnotes

[1] We wish to thank Robert Romain, for providing valuable comments at the early stage of this research, as well as an anonymous reviewer. The standard disclaimer about remaining errors applies.

[2] Note that fixed costs in (1) are normalized to zero. This assumption is convenient for two reasons. First, given that output share is the relevant decision variable from the producers' perspective, fixed costs have impacts in the analysis that cannot be distinguished from initial wealth impacts in the current stochastic environment. It would be difficult to pinpoint with confidence the fixed costs level that would fairly represent a large proportion of Quebec dairy producers. Second, the per-unit nature of the profit function would also require running simulations that are a function of the scale of production of various dairy farms.

[3] Note that total output of a dairy producer is determined by the size of the dairy cow herd; thus monthly hectolitres of milk produced are constant. The analysis is thus confined to a short-run perspective.

[4] No attention must be devoted to the non-linear shape of the iso-line, given that prices of the export contracts are irregularly spaced on the horizontal axis.

[5] Using comparative static tools on the first-order condition of the maximization problem defined in (1), it can be shown that the share of production quota held by producers is increasing (decreasing) in marginal costs when absolute risk aversion decreases (increases) with wealth.