

Explaining Variations in the Price of Dairy Quota: Flow Returns, Liquidity, Quota Characteristics, and Policy Risk

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An econometric model based on the net present value model is used to examine factors that drive the variation of California dairy quota values over a 29-year period. The results suggest the price of quota is based on expected returns, variations in quota owner liquidity, and the risk of policy default. The dominant influence on the variation of the quota price was the historical variation in monthly flow of net benefits from owning quota. This analysis confirms that the rate of return to quota rises in periods of policy uncertainty.

Key words: adaptive expectations, capitalization of policy, dairy policy, policy risk, quota

Introduction

The expected value of policy benefits is capitalized into the asset prices of inelastically supplied resources. This basic principle is well accepted, but the capitalization rate has been particularly hard to measure for assets created by agricultural policies for several reasons: policies are complex and change over time, non-policy factors typically affect the value of farm assets associated with policy, and sufficient market data measuring farm asset prices are often not available.

Understanding how policy benefits are capitalized into agricultural assets is vital to assessing how policy affects welfare. Land has received most of the attention in the literature about capitalization into farm assets (Alston, 1986; Lence and Miller, 1999). For example, researchers have determined that part of the capital value of some farm policy benefits is included in farmland values (Duffy et al., 1994; Clark, Klein, and Thompson, 1993; and Seagraves, 1969, among others). However, because farmland markets are complex with multiple influences, researchers have found it difficult to measure the contribution of farm policy to farmland prices.

Other farm assets are actually created by farm policy itself. Unlike land and other capital assets such as animals, tractors, etc., policy-created assets exist solely at the will of the government. Another distinguishing feature of policy-created assets is that these assets seem to exhibit relatively high rates of return relative to alternative investments (e.g., Barichello and Chen, 1996; Chen and Meilke, 1998; Johnson, 1991; Lerner and Stanbury, 1985; Moschini and Meilke, 1988; Organization for Economic Cooperation and Development, 1996; Sumner, 1988; Sumner and Alston, 1984).

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This analysis uses monthly data from a unique market for a farm policy-created asset to describe how program characteristics and policy events affect asset prices over a 29-year study period, 1970–1998. The rate of return to ownership of California dairy quota, about 27% per annum (the ratio of the sum of flow revenue earned plus capital gains relative to the quota price), has been substantially higher than the rate of return for stock market indices of 8.4% (return of the NYSE/AMEX/NASDAQ value-weighted market index) (Sumner and Wilson, 2000b).

Our data allow us to observe quota asset prices directly and to examine the influence of policy more directly and over a longer period than has been possible in previous studies. An econometric model based on simple net present value ideas is used to examine factors that drive the variation of quota values over time. Our results suggest the price of quota is based on expected returns, variations in quota owner liquidity, and the risk of policy default.

Literature on Quota Returns

Several studies have examined the movement of quota prices conceptually and empirically (e.g., Alston, 1992; Arcus, 1978; Barichello, 1996; Hubbard, 1992; Johnson, 1991; Seagraves, 1969; Veeman and Dong, 1995). In his 1969 study of flue-cured tobacco acreage allotments, Seagraves used data on farmland prices and found that the ratio of the estimated value of the flow return to the asset value of tobacco allotment fell over the 20 years of the data set. Seagraves interpreted the decline as increased confidence in the allotment program—a decline in the risk of policy default.

Veeman and Dong (1995) used a first-order adaptive expectations model to estimate parameters of the variables potentially affecting the deflated price of fluid milk quota in Ontario for the period August 1984 through July 1993. They included a dummy variable representing the period of hearings by the Canadian Parliament's Committee on Agriculture. The hearings concerned an adverse GATT ruling about Canadian dairy policy. The coefficient on the dummy variable was negative and statistically significant.

Barichello and Chen (1996) estimated sets of regression models to explain the price of quota in Ontario, Quebec, and Alberta. They defined a dummy variable for the periods of trade negotiations. In most cases, the dummy variable for default risk was negative and statistically significant.

The work reported here builds on the literature cited above, investigating the case of California dairy quota. We have an advantage of much cleaner and richer data than previous studies because it was not necessary to derive the average quota prices and the monthly flow return for quota. Thus, we are able to avoid some of the empirical problems faced by previous researchers.

The Basic Operation of the Milk Price and Quota Program in California

The principal features of the California milk marketing order system are (a) classified pricing, which sets minimum prices paid based on the end-use of the milk; (b) price pooling, under which farmers are paid a weighted average of the prices paid for milk by end-use; and (c) the pool quota program, which determines the pool price paid to each farmer based on the amount of quota the farmer owns relative to the amount of milk

marketed. The specifics of the policy have changed from time to time, but these features have remained.

The law requires that the Director of the California Department of Food and Agriculture (CDFA) issues Stabilization and Marketing Plans for Market Milk. While the law provides a framework for the pooling policies, the substance of the law is in the pooling plans (*Calif. Food & Agr. Code*, 1998, § 62700–62731).

Milk Price Policy Overview

California establishes five distinct minimum price classes based on milk end-use. Minimum prices for each end-use class of milk are set as follows: Class 1 (C_1) applies to milk or cream sold for fluid use (it is generally the highest-priced class); Class 2 (C_2) applies to milk used for sour cream, yogurt, and cottage cheese; Class 3 (C_3) applies to milk used for the manufacture of frozen dairy products; Class 4a (C_{4a}) applies to milk used for butter, milk solids, and dry milk; and Class 4b (C_{4b}) applies to milk used for hard cheeses (*Calif. Food & Agr. Code*, 1998, § 61932–61935). The total quantity of milk demanded (or total consumption, C) is the sum of milk used in each class:

$$(1) \quad C = C_1 + C_2 + C_3 + C_{4a} + C_{4b}.$$

The price for each class actually received by farmers is the maximum of either the market clearing price or the minimum class price. Producers also may receive premiums over the minimum price directly from distributors. Such payments are outside of the pool. Premiums reflect quality factors such as higher fat content. Assume the minimum prices paid into the pool are P_1, P_2, P_3, P_{4a} , and P_{4b} . The current method for determining prices P_1, P_2, P_3, P_{4a} , and P_{4b} relies on formulae which relate the prices of milk in each class to state and national market prices and other data. The CDFA has changed the formulae periodically.

The CDFA uses formulae and public hearings to establish minimum prices for each milk class. As with federal orders, the California order calculates blend prices based on marketwide use of milk by class. Unlike federal orders, where all producers in an order receive the same blend price (subject to quality and transportation cost differentials), the monthly blend price received by California producers depends on the quantity of quota the producer holds relative to the total quantity of milk the producer markets during the month.

Pool Revenue

Aggregate milk production may be written as $M = \sum_i M_i$, where M_i is the production of producer i . Let total production equal total consumption ($C = M$). Pool revenue (R) to producers can be calculated as follows:¹

$$(2) \quad R = P_1 C_1 + P_2 C_2 + P_3 C_3 + P_{4a} C_{4a} + P_{4b} (M - C_1 - C_2 - C_3 - C_{4a}).$$

¹ Because multiple components (snf and fat for each class and the fluid carrier for Class 1) are the basis of the minimum prices based on formulae, the CDFA actually pools revenue across 11 prices and end-use demands.

The quota program has no direct role in setting milk prices by end-use or in allocating milk among classes. The quota program applies to the dispersal of pool revenue. Quota ownership varies across farms, and the revenue of an individual farm depends on the amount of quota the farm owns.

Quota Milk Prices Prior to 1994

Before 1994, the price of quota milk (P_q) was the weighted average of the prices of higher-priced end-use classes of milk. The price of overbase or non-quota milk (P_n) was the weighted average of the prices of lower-priced end-use classes of milk. Therefore, the flow return to quota ownership was $f = P_q - P_n$, where f is the quota flow return.

The cut-off point determining the share of the intermediate classes used in calculating P_q or P_n depended on the aggregate quantity of quota relative to the quantity of milk sold in that month. In addition, the class weights varied monthly, depending on milk sales. Milk prices P_q and P_n each varied because the underlying class prices and weights varied. In sum, the flow return, f , the return to quota, varied because of variation in (a) milk sales by class, (b) amount of quota, and (c) class prices.

Quota Milk Prices After 1994

Since 1994, state law has fixed the flow return per unit of quota. Under the system, the first step in dispersing pool revenue to quota owners is to allocate daily \$0.195 per pound of solids not fat (snf) for each pound of quota owned. No assignment is made for fat. This dispersal is also defined as \$1.70 per hundredweight of milk quota daily (8.7 pounds snf per hundredweight milk times \$0.195 per pound snf). For the aggregate quota quantity Q (in hundredweight of milk), the total revenue assigned to all quota is \$1.70 Q , and the quota revenue for an individual is \$1.70 Q_i , where Q_i varies from zero (for about 20% of producers) up to total milk output (for less than 5% of producers in any month). The CDFR disperses the rest of the milk pool revenue (R_n),

$$(3) \quad R_n = R - 1.70Q,$$

according to milk production. The average per unit pool price paid for milk is $P_n = R_n/M$, where P_n is the non-quota or overbase milk price. Therefore, each producer receives a portion of the pool revenue depending on the total milk marketing of the producer (M_i). The quota milk price (P_q) is the sum of the \$1.70 dispersal and the overbase price, i.e., $P_q = \$1.70 + P_n$ per hundredweight milk. Total revenue for producer i (R_i) is simply equal to

$$(4) \quad R_i = P_n M_i + 1.70Q_i.$$

Sumner and Wolf (1996) showed that under these conditions quota did not affect marginal production decisions.

Quota Market Regulations

Quota can be bought or sold, but it cannot be rented. Several rules limit full liquidity. Once purchased, a producer cannot sell quota for two years, except in cases of hardship

(fire, flood, and storms, for example). A producer cannot buy back quota for two years after selling quota. Further, a producer who receives “new” quota from the CDFA or purchases quota from a hardship case cannot sell quota for five years. The provisions of the quota program do not state a minimum quantity of milk a producer must supply or a maximum a producer may produce or supply. The State of California cannot use the pooling plan (thus the quota) to limit the amount of milk a farmer can market (*Calif. Food & Agr. Code*, 1998, § 62721).

The CDFA has allocated new quota intermittently following a formula, which has changed occasionally. Generally, the CDFA has created new quota in proportion to the increase in the quantity of Class 1 use. In 1978, the State broke from this basic policy by creating new quota without consideration of Class 1 sales (Boynton, 1996). Given flat, Class 1 milk sales in California, the last dispersal of new quota was in 1992.

Economic Considerations in Specifying the Model for Quota Prices

A net present value model of expected flow returns is used to specify the price of quota. That is, *Quota Price_t* at time t is the sum of expected (at time t) flow return to quota $E_t[f_{t+n}]$ from $t+n$, where $n = 0$, until the end of the time horizon, $t+N$, divided by a discount factor which depends on an expected discount rate that varies over time, $E_t[r_{t+n}]$:

$$(5) \quad \text{Quota Price}_t = \sum_{n=0}^N \frac{E_t[f_{t+n}]}{(1 + E_t[r_{t+n}])^n}.$$

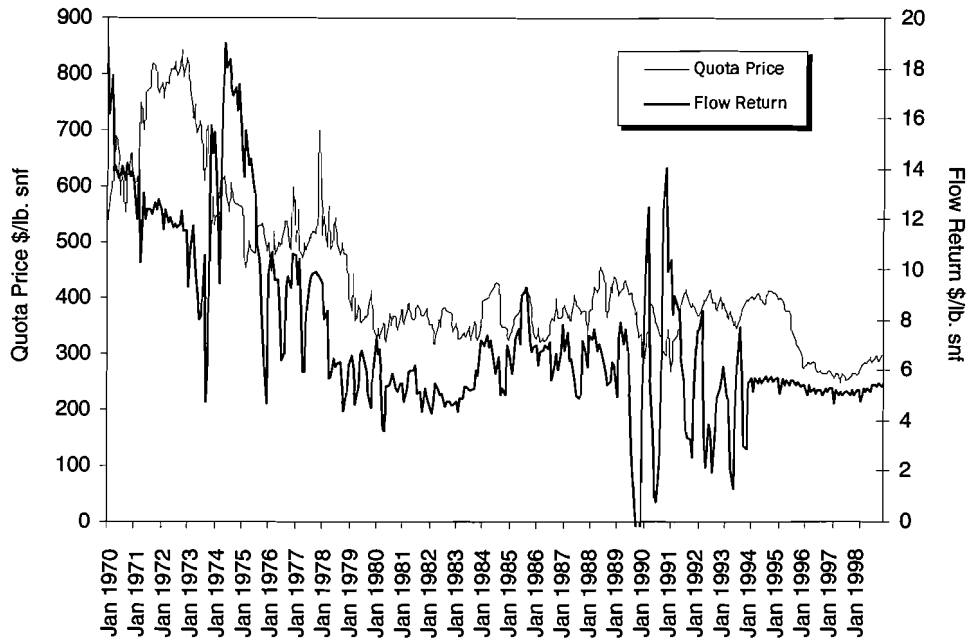
If one assumes the expected flow return and the expected discount rate are fixed over an infinite time horizon, then the model simplifies to the following:

$$(6) \quad \text{Quota Price}_t = \frac{E_t[f]}{E_t[r]}.$$

Therefore, in the simplified model, the price of quota is simply a function of the expected flow return and the expected discount rate of the quota.

Variables Affecting the Price of Quota

We divide the variables affecting the price of quota into four categories. Specifically, (a) the expected return associated with quota investments is related to current and past observations of flow return; (b) units of California milk quota have specific characteristics that vary and affect the current and expected flow return; (c) the expected discount rate applicable to quota investment in any period is a function of credit availability or liquidity in the dairy industry; and (d) policy events also can affect (i) the expected discount rate, (ii) the time horizon, or (iii) the size of the expected flow return, $E_t[f_{t+n}]$. As detailed in the discussion below, the model specification provides a framework for understanding the influence of these categories of independent variables on *Quota Price*.



Notes: Figure 1 data are from various issues of the *California Dairy Information Bulletin* (CDFA, Dairy Marketing and Milk Pooling Branch) and other State documents; the price deflator is from annual issues of *Agricultural Prices: Annual Summary* (USDA, National Agricultural Statistics Service). In October 1989, *Flow Return* fell to -0.299 \$/lb. snf; in November 1989, *Flow Return* fell to -3.195 \$/lb. snf.

Figure 1. Quota Price—the deflated average monthly price of California dairy quota; and Flow Return—the deflated monthly per unit net return of owning California dairy quota (1970–1998)

- Data on the *Flow Return* represent the monthly cash receipts from owning quota (see figure 1). The *Flow Return* is the deflated, monthly difference between the hundredweight quota and overbase milk prices. To capture the returns to the multiple components of milk (described below) and make the return a monthly return, we divided by 8.7 to adjust to dollars per snf prices for compatibility with the price of quota, and then multiplied by the number of days in the month. The net present value model states that the price of quota is a function of expected flow return, but expectations of the *Flow Return* are not observable. We use an adaptive expectations (AE) model to incorporate expectations into the econometric model. *Flow Return* is hypothesized to have a positive effect on the quota price.
- A measure of cash flow, *Liquidity*, affects the market for quota to the extent that credit constraints or an upward-sloping supply of capital affects dairy producers. In times of financial stress for dairy farms, the supply of quota on the market will rise and the demand for quota will fall, causing a fall in the price of quota.² *Liquidity* is the deflated, monthly difference between the hundredweight overbase milk price and the statewide, weighted cost of production, divided by 8.7. Notice, *Liquidity* does not reflect expectations about future dairy profits; rather, *Liquidity* reflects the effects of

² Some quota brokers and dairy farm accountants have argued that quota is the most liquid asset a California dairy producer owns. Therefore, in times of financial difficulty, quota is often the first asset sold.

short-run credit and liquidity constraints on quota price as well as the legal restriction that only California dairy producers may hold quota. Thus, the effect of *Liquidity* on the price of quota is hypothesized to be positive.

- Each unit of quota traded is not homogeneous because of the multiple components (snf and fat) and the historical allocation. Quota is traded in units of solids not fat (snf). The CDFA allocated to each pound of quota snf specific amounts of quota fat, base snf, and base fat. To understand this allocation, one needs to recognize the historical allocations. Initially, the State gave quota in accordance to the quantity of Class 1 (fluid milk) contracts a producer possessed. However, a producer typically produced more milk than his/her Class 1 contract, so base was allocated to cover historical production beyond quota. Any milk produced beyond base is called overbase milk. The quota and base snf and fat distribution was founded on the farms' historical production of fats and snf (Sumner and Wilson, 2000a). The composition of quota (in terms of fat and snf) affects the income generated from a unit of quota. Thus, the quota fat to quota snf ratio (*Fat/snf*) affects the expected future flow return, and consequently the price of quota in snf units. The monthly return to owning quota fat (*Quota Fat Milk Price less Overbase Fat Milk Price* in dollars per pound of fat) has usually been positive, but it was more than occasionally negative in the first two decades of the program's history. The mean flow return to quota fat was slightly positive but smaller than the return to snf; therefore, it is hypothesized that *Fat/snf* affects quota asset price negatively. Finally, ownership of base has two effects on the return to quota. First, for many years, the CDFA set a price premium for base milk relative to non-quota or overbase milk. Second, a higher ratio of base-to-quota increases the eligibility of producers to receive new quota; thus, *Base/Quota* is expected to have a positive effect on the price of quota.
- We interviewed dairy producers (and others related to the California dairy industry) about the policy shifts or proposed policy shifts that affected their expectations of the future. No consensus developed on any individual policy events (Wilson, 1999). However, we selected five (out of at least 139) policy events that represent the most significant changes in federal or state dairy policies which might have affected expectations about the future of the quota program. Those policy events are used as the basis for five dummy variables. The variables reflect potential changes in expectations about the future flow return from the quota program. Start and end dates of policy events are difficult to determine because the timing of information dispersals and expectation formation are not known. Start and end dates are selected corresponding to the actual start and end dates (if such dates exist) of the policies. Implicitly, we assume the effect of policy uncertainty is not permanent because the end occurs before the end of the data set.³ In cases where the dates are not clearly defined, we define a priori the time we believe incorporates the entire effect of the policy change. The policy event variables capture direct and indirect effects of the policies on the value of quota. We also model producers' expectations of the policy events. An adaptive expectations model is used that covers all of the variables, thereby capturing some of the producer expectations of changes of policies. The five variables reflecting policy events are dummy variables and are defined as follows:

³ We thank an anonymous reviewer for this comment.

Rising Price Support. This variable equals one for the months January 1974 through December 1981, and zero otherwise. During this period, the U.S. Department of Agriculture made frequent nominal adjustments to the federal price support for manufactured milk products. No other period since the creation of the quota program had such rapid changes (either positive or negative). These changes suggested uncertainty in federal policy, which left California producers uncertain of their relatively new quota program. Thus, the shift in policy would have had a negative impact on the quota price, and we hypothesize a negative coefficient on *Rising Price Support*.

Equalization Shock. In July 1978, the California Legislature passed a law equalizing all producers. Specifically, the California Legislature gave, without regard to Class 1 sales, quota to producers so that each producer had 95% of production base covered by quota. Under the Gonsalves Act of 1967, equalization was to occur through growth in Class 1 sales. The fact that new legislation was required might have made producers apprehensive about the possibility of additional unknown changes (Wilson, 1999). Therefore, *Equalization Shock*—which equals one for July 1978 through December 1980, and zero otherwise—is expected to have a negative coefficient.

Equalization Period. The equalization legislation was a fundamental shift in California dairy policy. The legislative action reflected that equality among producers would not be achieved through natural growth in milk consumption. For years to come, the quota program would have producers who benefitted differently from the program because of their quota ownership; thus, the change created the potential for political strife among dairy producers. Also, the change reduced the flow return per unit of quota relative to the past. Additional quota in the system meant lower per unit returns by raising the ratio of quota-to-milk sales. The variable *Equalization Period* equals one beginning July 1978 through December 1998, and zero otherwise. We believe the effect persisted until the end of the data period because the fundamental policy concern and differential quota ownership were never fully corrected. Thus, the coefficient on *Equalization Period* is hypothesized to be negative.

Dairy Termination. After several years of financial stress, the federal government paid producers to leave the dairy industry under the Dairy Termination Program, in effect from April 1986 through September 1987. The period of this policy event was selected as an explanatory variable because it provides a clear beginning and ending of a policy reflecting a fundamental change in the approach of USDA to dairy policy. The *Dairy Termination* variable equals one for the months April 1986 through September 1987, and zero otherwise. During the 18-month period of the Dairy Termination Program, more dairy producers sold quota than in any other comparable period. We expect the program lowered the quota price because of the additional volume of quota on the market from producers leaving the industry. For these reasons, the coefficient on *Dairy Termination* is predicted to be negative.

Fixed Differential. In 1994, after several months of erratic flow returns, the California Legislature fixed the flow return to quota by fixing the differential between quota milk and overbase milk. *Fixed Differential* equals one from January 1994 (the beginning of the policy) through December 1998 (the end of the data set), and zero otherwise. Producers stated in interviews they believed this event signaled other policy changes. Some in the industry have argued that fixing the differential made

the differential more transparent, and therefore easier to reduce in the future. Fixing the differential held monthly returns to quota fixed, while milk total revenue varied even more. A negative coefficient is hypothesized.

Description of Data

The data used for the statistical analysis consisted of 348 monthly observations from January 1970 through December 1998 (CDFA, Milk Pooling Branch). Although data were available for the initial months August 1969 through December 1969, these observations were omitted because these months represented the introductory period of the market. During the introductory period, the monthly price of quota was extremely volatile, with price swings of more than 100%.

All of the quota prices were deflated by the *Index of Prices Paid by Farmers, Items Used for Production* (1992 = 100). This index was used because it reflects the value of other assets besides quota that producers purchase or invest. After deflating, each series was checked for unit roots and none were found. (All time-series analyses of the data are available from the authors upon request.) For each series, the means and standard deviations are presented in table 1.

Model Specification for Expectations and Functional Form

The dependent variable *Quota Price* is the deflated average price of the quota transactions made during the month. The *Quota Price* was deflated by the *Index of Prices Paid by Farmers, Items Used for Production*. As reported in table 1, the mean for *Quota Price* was \$436.55 (in 1992 dollars per pound of snf quota), with a standard deviation of \$138.78. Figure 1 shows the *Quota Price* rose initially, then fell below its initial level in 1975, and fell again in 1978. *Quota Price* was fairly constant after 1978, until it fell again in 1995.

From discussions with dairy producers, we knew they valued quota by examining quota prices during recent months, but the producers did not agree on the number of previous months used in their valuation (see Wilson, 1999). Therefore, time-series analysis was used to describe *Quota Price*. Using an autoregressive time-series model, it was determined that, on average, lags of two months contained the information needed to identify the current *Quota Price*.

The model, as suggested earlier, is built on expectations of the flow return and other variables, specifically policy shifts. To incorporate expectations into the model, we used the adaptive expectations model. Recognizing the two-month lag process of the dependent variable, the second-order adaptive expectations [AE(2)] model was selected. This lag structure is consistent with the responses from producers and the time-series model. Additionally, the AE(2) model provides a more complex expectation mechanism relative to the AE(1) model, and the AE(2) model nests the AE(1) model. In the AE(2) model, the expectations variable is written as follows:

$$(7) \quad x_t^* = \frac{(1 - \lambda_1)(1 - \lambda_2)}{(1 - (\lambda_1 + \lambda_2)L + \lambda_1\lambda_2L^2)} x_t,$$

Table 1. Descriptive Statistics of Regression Variables

Variable	Mean	Standard Deviation	Variable	Mean	Standard Deviation
	<--- 1992 \$/lb. snf --->			<----- Ratio ----->	
<i>Quota Price</i>	436.55	138.78	<i>Fat / snf</i>	0.41	0.012
<i>Flow Return</i>	7.45	3.59	<i>Base / Quota</i>	1.04	0.110
<i>Liquidity</i>	0.10	0.13			

where λ_i ($i = 1$ and 2) is the AE(2) parameter, L is the lag operator, and x_t is the observed value from which producers form expectations.⁴

Imposing the autoregressive form of a linear regression on the AE(2) model generates an order two autoregressive error process AR(2), expressed as follows:

$$(8) \quad y_t = (1 - (\lambda_1 + \lambda_2) + \lambda_1\lambda_2)\alpha + \beta(1 - \lambda_1)(1 - \lambda_2)x_t + (\lambda_1 + \lambda_2)y_{t-1} - (\lambda_1\lambda_2)y_{t-2} + v_t,$$

where $v_t = \varepsilon_t - (\lambda_1 + \lambda_2)\varepsilon_{t-1} + (\lambda_1\lambda_2)\varepsilon_{t-2}$.

In the AE(2) model, if the error term ε_t has autoregressive terms and if the parameters of those autoregressive terms are equal to the coefficients on the moving average error terms, then the autoregressive and moving average terms cancel, leaving white noise. In this case,

$$(9) \quad \varepsilon_t = \rho_1\varepsilon_{t-1} + \rho_2\varepsilon_{t-2} + u_t,$$

where $\rho_1 = (\lambda_1 + \lambda_2)$, and $\rho_2 = -(\lambda_1\lambda_2)$, so that

$$(10) \quad y_t = (1 - (\lambda_1 + \lambda_2) + \lambda_1\lambda_2)\alpha + \beta(1 - \lambda_1)(1 - \lambda_2)x_t + (\lambda_1 + \lambda_2)y_{t-1} - (\lambda_1\lambda_2)y_{t-2} + u_t,$$

where $u_t \sim N(0, \sigma_{u_t}^2)$. This result also holds in the case where the equality of the rhos is approximate. If the error term in equation (9) did not have an autoregressive process which at least approximately cancelled out the moving average component, estimation of equation (10) without the moving average components would generate a serially correlated error term. Assuming equality of the autoregressive terms, we then tested for serial correlation of the first, second, and third orders with the Breusch-Godfrey test. The null hypothesis of no serial correlation could not be rejected, providing support for the equality of the autoregressive terms. Under these conditions, estimating equation (10) as an OLS model generates best linear unbiased estimates, which are also asymptotically efficient.

To simplify exposition, equations (8) and (10) above included only one explanatory variable. In the empirical model here, several explanatory variables are included. There-

⁴ The parameterization of the AE(2) model was based on the suggestion of Arthur Havenner.

fore, we replaced $\beta(1 - \lambda_1)(1 - \lambda_2)x_t$ with $\sum_i \beta_i(1 - \lambda_1)(1 - \lambda_2)x_{it}$, where x_{it} represents one of the explanatory variables. This model is specified as follows:⁵

$$(11) \quad \begin{aligned} \text{Quota Price}_t = & \alpha^* + \beta_1^*(\text{Flow Return}_t) + \beta_2^*(\text{Liquidity}_t) + \beta_3^*(\text{Fat/snf}_t) \\ & + \beta_4^*(\text{Base/Quota}_t) + \beta_5^*(\text{Rising Price Support}_t) \\ & + \beta_6^*(\text{Equalization Shock}_t) + \beta_7^*(\text{Equalization Period}_t) \\ & + \beta_8^*(\text{Dairy Termination}_t) + \beta_9^*(\text{Fixed Differential}_t) \\ & + \phi_1^*(\text{Quota Price}_{t-1}) + \phi_2^*(\text{Quota Price}_{t-2}) + u_t, \end{aligned}$$

where $\alpha^* = (1 - (\lambda_1 + \lambda_2) + \lambda_1\lambda_2)\alpha$; $\beta_i^* = \beta_i(1 - \lambda_1)(1 - \lambda_2)$; $\phi_1^* = (\lambda_1 + \lambda_2)$; and $\phi_2^* = -(\lambda_1\lambda_2)$.

Parameter Estimates

We present two models of *Quota Price* regressed on combinations of the independent variables described in the previous section (see table 2). Model 1 is *Quota Price* regressed on two lags of the *Quota Price*, *Flow Return*, *Liquidity*, *Fat/snf*, and *Base/Quota*. Model 2 is Model 1 with the event dummies added as explanatory variables.⁶

Our discussion focuses on Model 2, which includes the policy event variables. As seen from table 2, the coefficient ϕ_1 on *Quota Price*_{*t-1*} is 0.54. The coefficient ϕ_2 on *Quota Price*_{*t-2*} is 0.35. Both coefficients are significant at the 1% alpha level. The statistical significance of *Quota Price*_{*t-2*} provides support of the AE(2) model versus the AE(1) model. The roots of the lag polynomial are -2.62 and 1.09, both outside the unit circle. Thus, the model is stationary (Nelson, 1973).

The coefficients of the lagged dependent variables provide estimates of λ_1 and λ_2 from the expectations model. Solving the simultaneous equations

$$(12) \quad \phi_1 = 0.53 = (\lambda_1 + \lambda_2)$$

and

$$(13) \quad \phi_2 = 0.35 = -(\lambda_1\lambda_2)$$

generates the solutions $(\lambda_1, \lambda_2) = (0.91, -0.38)$.

The adaptive expectations model generates estimates of long-run and short-run effects. The estimated coefficient on each of the explanatory variables x_{it} of the AE(2) model is $\beta_i(1 - \lambda_1)(1 - \lambda_2)$, which is also the short-run effect of a change in x_{it} on *Quota Price*. The effect of a sustained change of x_{it} on *Quota Price* is the long-run effect or steady-state multiplier. The long-run effect assumes that $\{x_{it} = x_{it-1} = x_{it-2} = \dots\}$. In terms of the lag operator, the long-run effect is equivalent to setting the lag operator equal to one (or turning off the lag operator). Therefore, the long-run multiplier is defined as:

⁵ The functional form here can be viewed as a first-order approximation of the complex nonlinear model which would be more tightly connected to the single present value model in equation (5). While other functional forms are possible, the model of equation (11) generated economically reasonable estimates of the parameters that fit the data well.

⁶ We also examined two additional models to test the robustness of the estimates. In the first model, *Quota Price* was regressed against two lags of the *Quota Price* and *Flow Return*. In the second model, *Liquidity* was added to the previous model. The variables in all four models had similar parameter estimates, suggesting the robustness of the specification. The estimates are available from the authors upon request.

Table 2. Regression of Quota Price on Quota Market Factors (in 1992 dollars)

Variable	MODEL 1		MODEL 2	
	Coefficient	Std. Error	Coefficient	Std. Error
<i>Flow Return</i>	2.19***	0.67	1.59**	0.80
<i>Liquidity</i>	37.63***	14.25	32.36**	15.12
<i>Fat/snf</i>	-537.42***	141.30	-542.56***	142.80
<i>Base/Quota</i>	48.44***	16.46	42.95**	16.89
<i>Rising Price Support</i> (Jan. 74–Dec. 81)			-13.65***	5.79
<i>Equalization Shock</i> (July 78–Dec. 80)			5.14	6.94
<i>Equalization Period</i> (July 78–Dec. 98)			-18.56**	9.31
<i>Dairy Termination</i> (Apr. 86–Sep. 87)			-0.87	7.76
<i>Fixed Differential</i> (Jan. 94–Dec. 98)			-7.93*	5.03
<i>Quota Price</i> _{t-1}	0.55***	0.05	0.54***	0.05
<i>Quota Price</i> _{t-2}	0.37***	0.05	0.35***	0.05
Constant	182.54***	60.22	231.24***	63.31
<i>R</i> ²	0.96		0.96	
No. of Observations	348		348	

Notes: Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% alpha levels, respectively. The statistical significance is based on a two-tailed *t*-test except for the five policy event dummy variables (*Rising Price Support*, *Equalization Shock*, *Equalization Period*, *Dairy Termination*, and *Fixed Differential*) which are based on a one-tailed test.

$$\beta_{i(\text{Long Run})} = \frac{\beta_i(1 - \lambda_1)(1 - \lambda_2)}{1 - (\lambda_1 + \lambda_2) + \lambda_1\lambda_2}$$

The long-run impact of a change in x_{it} on y_t assumes a permanent change in x_{it} is observable; however, one cannot observe a permanent change in x_{it} . As a proxy for a long-run change in x_{it} , we used the change in x_{it} over the time horizon of the data set. This method was useful as a measure of the relative long-run contributions of each of the factors on *Quota Price*.

Results

Now, turn to the interpretation of the estimated coefficients. The coefficient on *Flow Return* is positive and significant at the 5% level. The positive sign is in accord with a net present value model of an asset generating a flow of benefits. The short-run coefficient is 1.59 with an elasticity of 0.03. The long-run coefficient is 13.30 and significant at the 5% level with an elasticity of 0.23 (see table 3). An increase in monthly expected *Flow Return* by \$1 in the long run would have generated an increase in *Quota Price* of \$13.30. Evaluated at the mean, a long-run *Flow Return* increase of 10% would have increased *Quota Price* by 2.3%.

From January 1970 through December 1998, *Flow Return* fell by 69.74% in 1992 dollars. Using the long-run elasticity of 0.23, the 69.74% decline in *Flow Return* implies the *Quota Price* fell by 16.04%, ceteris paribus. *Quota Price* actually fell by 37.64% over the 29-year study period. Thus, the decline in *Flow Return* accounts for a substantial share of the long-run change in *Quota Price*.⁷

⁷ Because the estimates are linear approximations of the nonlinear present value model, we are not able to calculate the share of *Quota Price* decline from each variable.

Table 3. Multiplier and Elasticities at the Mean (Model 2)

Variable	Short-Run Effect ^a	Short-Run Elasticity	Long-Run Effect ^a	Long-Run Elasticity
<i>Flow Return</i>	1.59** (0.80)	0.03	13.30** (6.68)	0.23
<i>Liquidity</i>	32.36** (15.12)	0.007	270.18** (126.31)	0.06
<i>Fat / snf</i>	-542.56*** (142.80)	-0.51	-4,530.02*** (1,191.97)	-4.24
<i>Base / Quota</i>	42.95** (16.89)	0.10	358.60*** (141.00)	0.85

Notes: Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% alpha levels, respectively, based on a two-tailed *t*-test. Values in parentheses are standard errors for the short-run effects and asymptotic standard errors based on linear approximations for the long-run effects (Greene, 1993).

^aThe short-run effect is the estimated coefficient from the OLS regression (Model 2). The long-run effect is:

$$\beta_{(Long\ Run)} = \frac{Short-Run\ Effect}{(1 - \phi_1 - \phi_2)} = \frac{Short-Run\ Effect}{(1 - 0.54 - 0.35)}$$

The coefficients on *Liquidity*, *Fat/snf*, and *Base/Quota* are statistically significant at the 1% or 5% levels. Though these variables are statistically significant, the impact of each is relatively small when considering the short- and long-run elasticities and the standard deviations of the variables. The response to *Liquidity* is extremely inelastic (table 3). Given the average month-to-month variation of 158%, the short-run effect of *Liquidity* was only about 1.11%. Long-run effects are hard to determine because the dependent variable fluctuated around its mean with no noticeable trend. The quota quality variables had small effects on the quota price. *Fat/snf* had a month-to-month variation of 3%, resulting in a short-run effect of only 1.53% (in absolute value). *Fat/snf* declined about 0.5%, giving a long-run effect of a 2.12% increase in *Quota Price*. Similarly, *Base/Quota* had a short-run effect on *Quota Price* of 0.94% given the month-to-month variation of 9.42%. However, *Base/Quota* fell by about 12%, which led to a 10.2% decline in *Quota Price*.

From these results, most of the occasional and sustained changes in *Quota Price* come from *Flow Return*, *Liquidity*, *Fat/snf*, and *Base/Quota*. However, the econometric model provides some evidence that policy events negatively affected the quota price. The coefficients on four of the five policy event dummies (*Equalization Period*, *Rising Price Support*, *Dairy Termination*, and *Fixed Differential*) were negative (table 2). The coefficient on *Equalization Shock* was positive but statistically insignificant. Because the coefficients on the dummy variables are all hypothesized to be negative, a one-tailed test is used to assess their significance. In Model 2, *Rising Price Support*, *Equalization Period*, and *Fixed Differential* have statistically significant effects at the 1%, 5%, and 10% levels, respectively.

The fact that *Rising Price Support* is statistically significant indicates the federal policy had an influence on California dairy producers. Holding constant the possible changes in *Flow Return* that the policies under *Rising Price Support* may have had, *Rising Price Support* causes *Quota Price* to fall by \$13.65/lb. snf. This change is about 3% of average *Quota Price*.

The largest coefficient of the policy event dummies (in absolute value) was for the period after equalization. One implication of the influence of *Equalization Period* was

that the quota program appeared to be failing; yet, the policy continues today. The uncertainty experienced in this period generated a decline in *Quota Price* of \$18.56/lb. snf, or more than 5% of average *Quota Price* during that period. The impact of *Fixed Differential* compared to other statistically significant policy event variables is small. This result is not surprising given differing opinions of the effect of this policy: stabilizing the flow return or fixing the flow return to phase it out over time. The *Fixed Differential* causes a decline in *Quota Price* of \$7.93/lb. snf, which is a 2.5% fall in the average *Quota Price* over that period. As with *Fixed Differential*, we now believe the periods of time specified a priori for *Equalization Shock* and *Dairy Termination* were too short to capture the full effects of the policy changes on *Quota Price*. This may explain why the result was statistically insignificant.

Changes in policies induced an industrywide shift in the perceptions of producers about the future of dairy policies in California. Overall, even with the difficulty of specifying the precise dates for the influence of the policy event variables, significant effects are found in the direction hypothesized, supporting the notion of policy default risk.

Summary and Implications

Overall, the regression results were reasonable, and the estimated values track the data well. The second-order adaptive expectations model seemed to be a sensible choice in modeling the market price of quota, especially given the significant coefficient on the second lag. The regression showed the importance of expected *Flow Return* in determining *Quota Price*. The coefficient on *Liquidity* suggests the market for quota has experienced significant liquidity constraints and that the quota market responded to the short-term financial conditions of producers. The statistical significance of *Fat/snf* and *Base/Quota* supports the relevance of specific characteristics of quota sold each month on *Quota Price*. Finally, the significance of the dummy variables of policy events confirms various adverse policy events have lowered the quota price over time relative to the expected quota flow returns, which were based on past data alone. Clearly, the major influence on the variation of the quota price was the historical variation in monthly flow of net benefits from owning quota, but policy events also have negatively affected the value of quota. Hence, the rate of return to quota rises in periods of policy uncertainty. Additionally, the results show that features of the policy, such as restrictions on ownership of quota and historical allocations, contributed to a lower *Quota Price*, and thus the increase in the rate of return to quota. Based on these findings, the risk of policy default, and other features of the policy, affected the price of quota and the wealth of California dairy producers.

In the context of pressure to reform or eliminate agricultural policy, understanding the wealth effects of agricultural policy is key. One of the most complicated elements in the debates to eliminate peanut and tobacco quota has been the value to assign these policy-created assets.

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