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Modeling the U.S. Dairy Sector with Government Intervention

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The federal dairy price support program was enacted in 1949 as a means to improve farm prices and incomes. Under this program, the government attempts to support raw milk prices by buying an unlimited quantity of manufactured dairy products at the wholesale level whenever the market price falls below the announced government purchase price. The intervention of the government in this market has broad reaching effects not only on the farm level, but also on the wholesale and retail levels. The objectives of the paper are to: (1) investigate the implications of this type of intervention on the econometric specification of a structural model of the U.S. dairy industry, and (2) to examine the empirical ramifications of not using the appropriate specification in policy analyses.

When considering how prices in the dairy sector are determined, the potential for government intervention introduces a special problem. Prices are determined by different forces depending upon whether the price established by competitive supply and demand conditions is above or below the government price floor. If the competitively determined market price for wholesale manufactured dairy products is above the government purchase price, a "market equilibrium" regime holds. In this

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case, the observed wholesale manufactured price is the equilibrium price and hence government intervention does not influence the price formation process in the dairy sector. On the other hand, if the competitively determined market price is below the purchase price, then a "government support" regime holds. In this case, the observed wholesale manufactured price equals the government price and the government buys the excess supply at that level. Hence, government intervention influences the type of price formation process that operates in the market as well as the level of prices.

Is the U.S. dairy sector really characterized by a mixture of the two regimes? Due to recent large amounts of annual government purchases, it is tempting to describe the dairy sector exclusively as a government support regime. However, this observation is not appropriate when examining the market on a quarterly or monthly basis, particularly prior to the 1980's. More importantly, using government purchases (rather than the relationship between the government price and market price) for regime identification is flawed for the dairy sector. Some specialized manufacturing plants package products according to government standards and are not equipped to sell in commercial markets even when the competitive price exceeds the government price. Using the price relationship as a criterion to identify regime, the results in Figure 1 show that the competitive regime held for 42% of the period 1975-87. Even during the 1980's when dairy surpluses were relatively large, the competitive regime occurred in 22% of that sample. Hence, with data from 1975 through 1987, it appears that the two-regime system should be considered when specifying a model of the dairy sector.

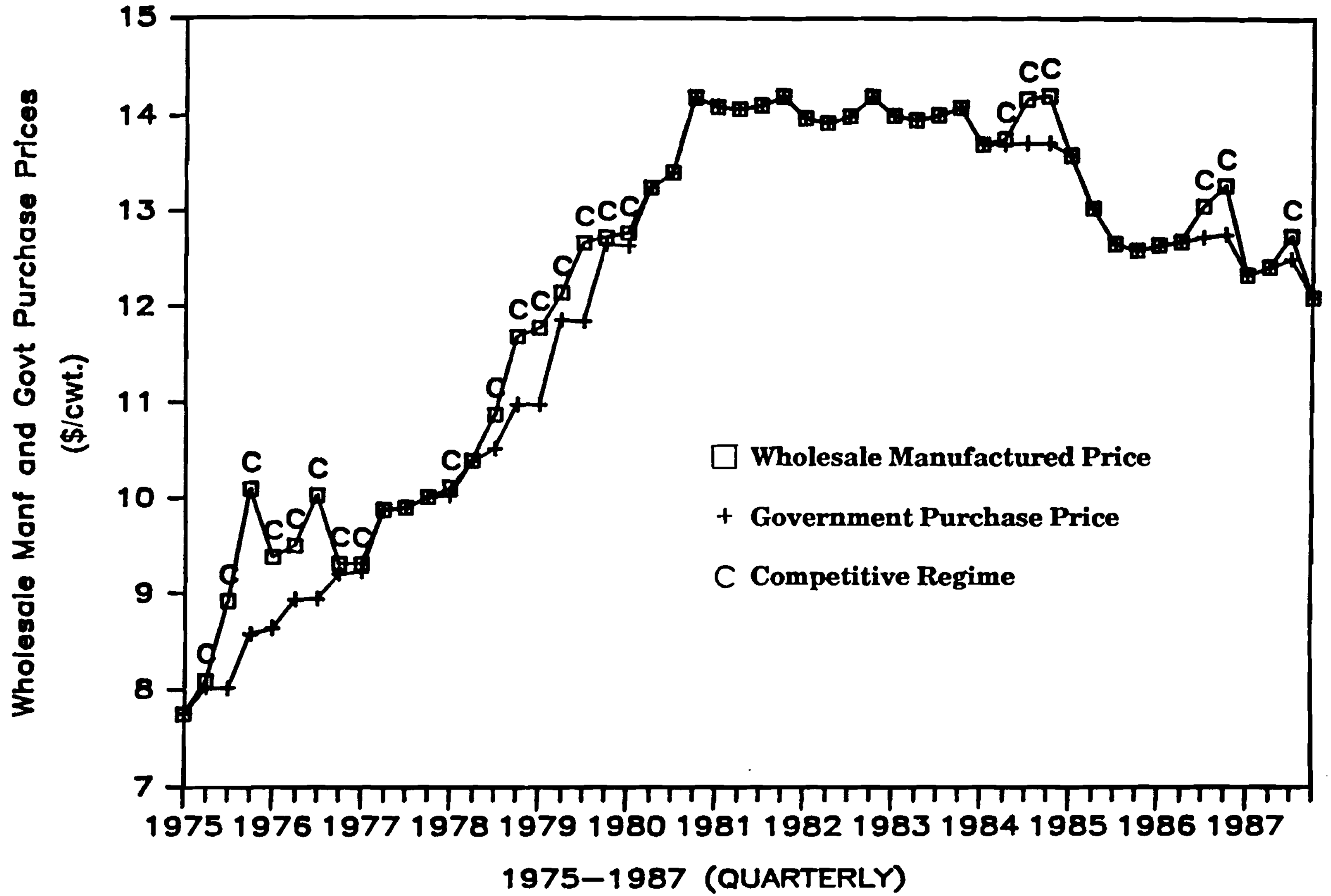
To date, econometric studies of the dairy sector have not distinguished between the two regimes, and have instead assumed that the government regime always occurs (Kaiser, Streeter and Liu; LaFrance and de Gorter). Failure to account for switching between regimes raises the problem of selectivity bias, implying that conventional least squares estimates are biased and inconsistent. Furthermore, since a structural system of equations is involved, these problems are not limited to the market associated with the intervention. Bias from a single source can distort all equations in the system. The issue here is to determine whether these distortions are important for policy analysis.

In the following sections, an econometric framework for estimating a two-regime dairy structural system is presented. Correcting for selectivity bias implies modifying the first stage of a conventional two stage least squares estimator, and providing an alternative set of instruments for the second stage. Since the conventional two stage least squares model is not nested in the bias-corrected model, Atkinson's test for non-nested models is used to determine which one is supported best by the data. It is shown that the bias-corrected model is supported in all equations, but the conventional model is rejected in four out of five equations. Finally, the ramifications of using the bias-corrected rather than conventional model in policy analyses are investigated by shocking policy variables in both models. The resulting impact on key endogenous variables are found to be significantly different between the two models.

A Conceptual Framework

The econometric model of the dairy industry consists of a farm, wholesale, and retail level. At the farm level, raw milk is produced

Figure 1. Relationship Between the Wholesale Manufactured and Government Purchase Price, 1975-1987



and sold to wholesalers, who in turn process and sell it to retailers. Both wholesale and retail levels are divided into a manufactured and a fluid market. The construction is similar to a previous model by Kaiser, Streeter, and Liu in that milk products are divided into fluid and manufactured dairy products. However, the previous model only considered the retail and the farm levels. The extension to include a wholesale level in this study facilitates the incorporation of government intervention in the wholesale manufactured market. A schematic view of the various components of the dairy sector is in Figure 2.

In the retail manufactured market, a general specification for supply, demand and the equilibrium condition can be written as:

$$(1.1) \qquad Q_s^{rm} = \alpha_s^{rm} P^{rm} + \beta_s^{rm} P^{wm} + \gamma_s^{rm} Z_s^{rm} + \mu_s^{rm}$$

$$(1.2) \qquad Q_d^{rm} = \beta_d^{rm} P^{rm} + \gamma_d^{rm} Z_d^{rm} + \mu_d^{rm}$$

$$(1.3) \qquad Q_s^{rm} = Q_d^{rm} \equiv Q^{rm}$$

where Q_s^{rm} and Q_d^{rm} are the retail manufactured quantity supplied and demanded; P^{rm} and P^{wm} are the equilibrium retail manufactured price and wholesale manufactured price; Z_s^{rm} and Z_d^{rm} are vectors of exogenous supply and demand shifters pertaining to the retail manufactured market; and Q^{rm} denotes the equilibrium retail manufactured quantity.

The retail fluid supply, demand and equilibrium condition can be written following the form of the retail manufactured market as follows:

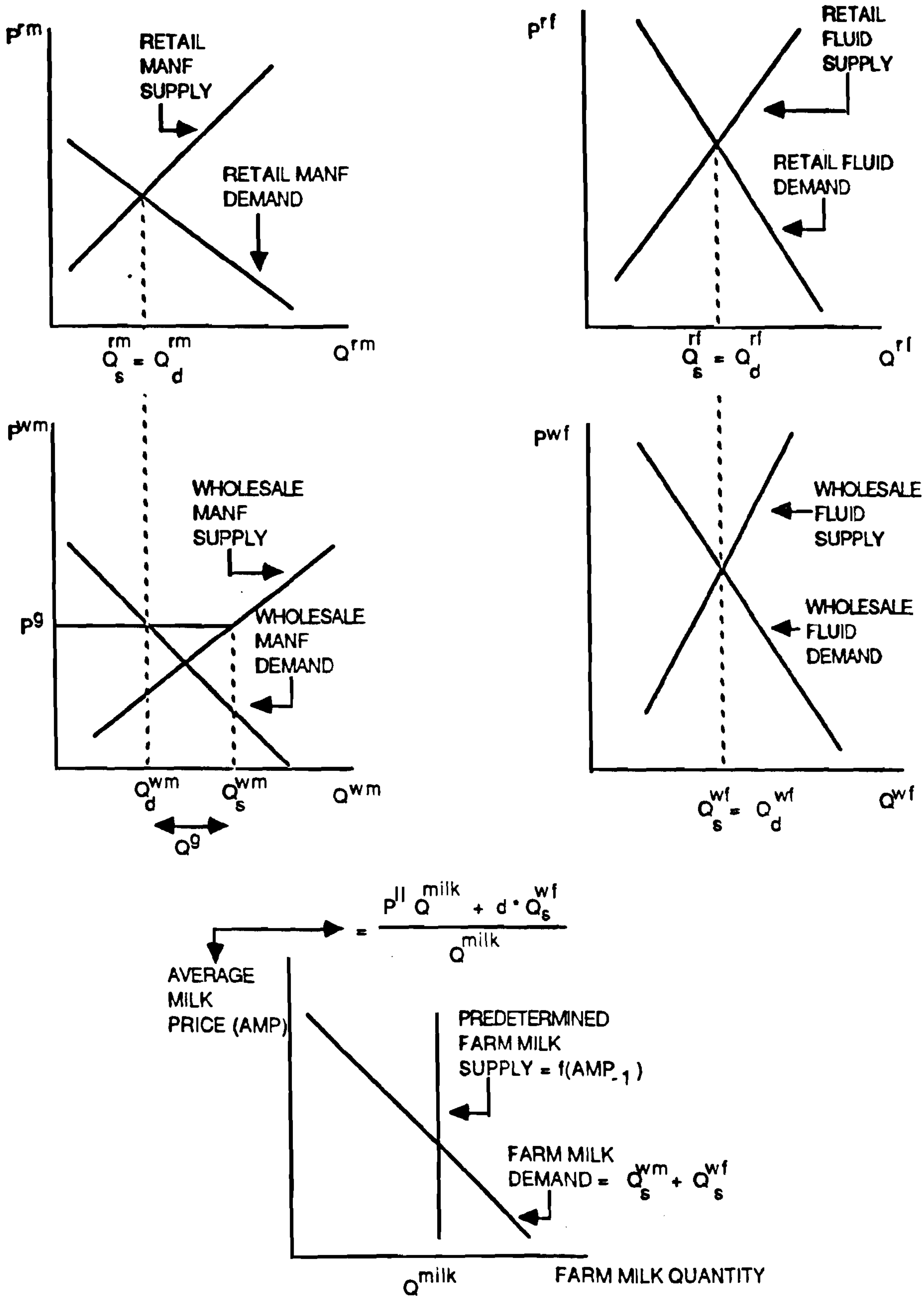
$$(2.1) \qquad Q_s^{rf} = \alpha_s^{rf} P^{rf} + \beta_s^{rf} P^{wf} + \gamma_s^{rf} Z_s^{rf} + \mu_s^{rf}$$

$$(2.2) \qquad Q_d^{rf} = \beta_d^{rf} P^{rf} + \gamma_d^{rf} Z_d^{rf} + \mu_d^{rf}$$

$$(2.3) \qquad Q_s^{rf} = Q_d^{rf} \equiv Q^{rf}$$

where superscripts rf's and wf's represent the retail and wholesale fluid markets, respectively.

Figure 2. Conceptual model of U.S. Dairy Market.*



* Ignores changes in commercial inventories, specialized plant quantity, and farm use, for simplicity.

The wholesale manufactured supply, demand and equilibrium condition (without government purchases) are:

$$(3.1) \qquad Q_s^{wm} = \alpha_s^{wm} P^{wm} + \beta_s^{wm} P^{II} + \gamma_s^{wm} Z_s^{wm} + \mu_s^{wm}$$

$$(3.2) \qquad Q_d^{wm} = Q^{rm}$$

$$(3.3) \qquad Q_s^{wm} = Q_d^{wm} + QSP + \Delta INV$$

where P^{II} is the Class II price, QSP is the quantity of milk sold to the government by specialized plants, ΔINV is change in commercial inventories of manufactured products, and all other variables are similarly defined with superscript wm's denoting variables pertaining to the wholesale manufactured market. Equation (3.2) specifies that the wholesale manufactured demand should equal the equilibrium retail manufactured quantity as all the quantity variables are expressed on a milk equivalent basis. Finally, the variables QSP and ΔINV are treated as exogenous in this study because they comprise a very small and rather constant portion of manufactured quantity.[2]

The wholesale fluid supply, demand and equilibrium condition can be written following the form of the wholesale manufactured market as follows:

$$(4.1) \qquad Q_s^{wf} = \alpha_s^{wf} P^{wf} + \beta_s^{wf} (P^{II} + d) + \gamma_s^{wf} Z_s^{wf} + \mu_s^{wf}$$

$$(4.2) \qquad Q_d^{wf} = Q^{rf}$$

$$(4.3) \qquad Q_s^{wf} = Q_d^{wf} \equiv Q^{wf}$$

where d is the exogenous Class I differential. All other variables are defined as above with superscript wf's denoting that the variables pertain to the wholesale fluid subsector.

2 Even though the magnitude of commercial inventory changes over time, its first difference (ΔINV) appears to be stationary with a strong seasonal pattern.

The model is completed by imposing the following farm level equilibrium condition:

$$(5) \qquad Q^{milk} = Q_s^{wf} + Q_s^{wm} + FUSE$$

where Q^{milk} is the "predetermined" raw milk supply, and FUSE is on-farm use of milk, assumed to be exogenous. The farm supply is predetermined due to the standard assumption that dairy farmers' price expectations are based on lagged prices only (e.g., Chavas and Klemme; Kaiser, Streeter and Liu; LaFrance and de Gorter). In the case where Q^{milk} is endogenous, the farm supply equation should be estimated simultaneously with the rest of the system, but this does not change the essence of the discussion that follows.

The wholesale manufactured price appearing in (1.1) and (3.1) is constrained by the dairy price support program. That is, since the government sets a purchase price for storable manufactured dairy products and is willing to buy surplus quantities of the products at that price, the following constraints holds:

$$(6) \qquad P^{wm} \geq P^{g}$$

where P^{g} is the aggregate government purchase price for the manufactured products at the wholesale level.

When the government support regime holds, P^{wm} simply equals P^{g} which is exogenous. However, the quantity of government purchases emerges as an additional endogenous variable balancing the number of equations with the number of unknowns. Accordingly, the equilibrium condition of (3.3) for the wholesale manufactured market becomes:

$$(3.3_*) \qquad Q_s^{wm} = Q_d^{wm} + QSP + \Delta INV + Q^{g}$$

where Q^{g} is government purchases measured on a milk equivalent basis.

To summarize, the above system encompasses two possible regimes. In the case of the market equilibrium regime, the endogenous variables are: retail manufactured demand and supply and wholesale manufactured demand ($Q_d^{rm} = Q_s^{rm} = Q_d^{wm}$), wholesale manufactured supply (Q_s^{wm}), retail and wholesale fluid supply and demand ($Q_d^{rf} = Q_s^{rf} = Q_d^{wf} = Q_s^{wf}$), retail manufactured price (P^{rm}), wholesale manufactured price (P^{wm}), retail fluid price (P^{rf}), wholesale fluid price (P^{wf}), and Class II price (P^{II}). The exogenous variables, denoted by Z, are:

$$Z = (Z_s^{rm}, Z_d^{rm}, Z_s^{rf}, Z_d^{rf}, Z_s^{wm}, Z_s^{wf}, Q^{milk}, d, FUSE, QSP, \Delta INV)$$

In the case of the government support regime, Q^g replaces P^{wm} as an endogenous variable in the above list, and the exogenous variables, denoted by Z_*, are

$$Z_* = (Z, P^g)$$

The Switching System Estimation Procedure

Taking the unconditional expectation of the structural equations (1.1), (1.2), (2.1), (2.2), (3.1), and (4.1) yields:

$$(7.1) \qquad E[Q_s^{rm}] = \alpha_s^{rm} E[P^{rm}] + \beta_s^{rm} E[P^{wm}] + \gamma_s^{rm} Z_s^{rm}$$

$$(7.2) \qquad E[Q_d^{rm}] = \beta_d^{rm} E[P^{rm}] + \gamma_d^{rm} Z_d^{rm}$$

$$(7.3) \qquad E[Q_s^{rf}] = \alpha_s^{rf} E[P^{rf}] + \beta_s^{rf} E[P^{wf}] + \gamma_s^{rf} Z_s^{rf}$$

$$(7.4) \qquad E[Q_d^{rf}] = \beta_d^{rf} E[P^{rf}] + \gamma_d^{rf} Z_d^{rf}$$

$$(7.5) \qquad E[Q_s^{wm}] = \alpha_s^{wm} E[P^{wm}] + \beta_s^{wm} E[P^{II}] + \gamma_s^{wm} Z_s^{wm}$$

$$(7.6) \qquad E[Q_s^{wf}] = \alpha_s^{wf} E[P^{wf}] + \beta_s^{wf} (E[P^{II}] + d) + \gamma_s^{wf} Z_s^{wf}$$

The estimation procedure is analogous to conventional two-stage least squares, consisting of the following two steps. The first step is to estimate the expected prices in the right-hand-side of (7.1) - (7.6) to be used as price instruments. Once the price instruments are obtained, the second step involves a straightforward application of

$$1\text{-}\Phi = PROB\ (P^{wm} > P^{g})$$

Assuming that ϵ^{wm} is normally distributed, a consistent estimate of $E[P^{wm}|\ P^{wm} > P^{g}]$ can be obtained by using a maximum likelihood Tobit procedure on (8.1) and can be expressed as (Maddala, p. 160):

$$(9) \qquad E[P^{wm}|\ P^{wm} > P^{g}] = \pi^{wm} Z + \sigma\ (\phi(c)/[1\text{-}\Phi(c)])$$

where $\Phi(c)$ and $\phi(c)$ are the cumulative standard normal and the standard normal density, both evaluated at c which is defined as $(P^{g} - \pi^{wm} Z) / \sigma$ and σ^2 is $Var[\epsilon^{wm}]$. The last term in (9) is the Heckman correction term for selectivity bias.

Making use of the definition of Φ, the unconditional expectation (i.e., the instrument) of the wholesale manufactured price in (7.1) and (7.5) is:

$$(10) \qquad E[P^{wm}] = (1\text{-}\Phi)\ E[P^{wm}|\ P^{wm} > P^{g}] + \Phi\ P^{g}$$

Then, by substituting (9) into (10), the price instrument for the wholesale manufactured price is:

$$(11) \qquad E[P^{wm}] = (1\text{-}\Phi)\ \pi^{wm} Z + \Phi\ P^{g} + \sigma\ \phi$$

Now consider the reduced form equations for the unconstrained prices (i.e., retail manufactured price, retail fluid price, wholesale fluid price, and Class II price) in (8.2) and (8.2_{*}). Combining the two reduced form equations for the two solution regimes weighted by their respective probabilities, and taking the unconditional expectation of the resulting expression yields:

$$(12) \qquad E[P^{i}] = (1\text{-}\Phi)\ (\pi^{i} Z + E[\epsilon^{i}|\ P^{wm} > P^{g}]) + \Phi\ (\pi^{i}_{*} Z_{*} + E[\epsilon^{i}_{*}|\ P^{wm} \leq P^{g}])$$

Assuming the joint density of ϵ^{wm} and ϵ^{i} is bivariate normal and making use of (8.1), the following holds:[3]

---

(13) $$E[\epsilon^{i} | P^{wm} > P^{g}] = E[\epsilon^{i} | \epsilon^{wm} > P^{g} - \pi^{wm} Z] = (\sigma^{i}/\sigma) \{\phi(c)/[1-\Phi(c)]\}$$

where σ^{i} is $COV[\epsilon^{wm}\ \epsilon^{i}]$.

Similarly, assuming the joint density of ϵ^{wm} and ϵ_{*}^{i} is bivariate normal and making use of (8.1), the following holds:

(14) $$E[\epsilon_{*}^{i} | P^{wm} \leq P^{g}] = E[\epsilon_{*}^{i} | \epsilon^{wm} \leq P^{g} - \pi^{wm} Z] = - (\sigma_{*}^{i}/\sigma) \{\phi(c)/\Phi(c)\}$$

where σ_{*}^{i} is $COV[\epsilon^{wm}\ \epsilon_{*}^{i}]$.

The price instrument for the retail manufactured price may be obtained by substituting (13) and (14) into (12) to give:

(15) $$E[P^{i}] = \pi^{i} [(1-\Phi) Z] + \pi_{*}^{i} [\Phi Z_{*}] + (\sigma^{i} - \sigma_{*}^{i}) [\phi/\sigma]$$

With estimates of Φ, ϕ, and σ from the Tobit estimation in (9), the parameters π^{i}, π_{*}^{i}, and $(\sigma^{i}-\sigma_{*}^{i})$ in (15) can be estimated by ordinary least squares with the observed values of P^{i} replacing $E[P^{i}]$ in (15).

To summarize, rather than regressing each endogenous variable on all exogenous variables to obtain the price instrument, the reduced form equation for the wholesale manufactured price should be estimated by a Tobit procedure while those for other endogenous prices should be fitted to a weighted average of the exogenous variables from each regime with a Heckman-like correction term appended.

Tests Against the Conventional Model

To investigate whether the above bias-corrected procedure matters empirically, the following tests can be applied to the reduced form

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[3] Assuming that the joint density of x and y is bivariate normal with zero means, Johnson and Kotz show that
$E[x| y > z] = \{ COV[x,y] / SD[y] \} \{ \phi(\xi) / (1- \Phi(\xi)) \}$, and
$E[x| y < z] = - \{ COV[x,y] / SD[y] \} \{ \phi(\xi) / \Phi(\xi) \}$,
where COV and SD are the covariance and standard deviation operators and ξ is defined as $z/SD[y]$.

equations. With respect to the wholesale manufactured price reduced form equation in (9), the second term on the right-hand-side is the Heckman correction term for selectivity bias. Hence, a t-test for the estimate of σ can be used to determine the existence of the bias if ordinary least squares is used instead of the Tobit procedure.

With respect to the remaining four unconstrained price reduced form equations in (15), a procedure based on the Atkinson non-nested models test is used to compare models (Judge et. al., p438). Specifically, there are two non-nested models that need to be compared; the bias-corrected model represented by (15) and the conventional two-stage least squares reduced form model which is:

(16) $$E[P^i] = \pi^i_* \quad Z_*$$

Following Atkinson, a comprehensive model composed of both (15) and (16) is constructed to test the two competing models. The comprehensive model is obtained by augmenting the government purchase price (P^g) into the exogenous vector Z in the first term of (15):

(17) $$E[P^i] = \pi^i_a \; [(1-\Phi) \; Z_*] + \pi^i_* \; [\Phi \; Z_*] + (\sigma^i - \sigma^i_*) \; [\phi/\sigma]$$

where the augmented parameter vector π^i_a contains π^i and an additional parameter (ξ^i) for the government purchase price.

The bias-corrected model in (15) can be obtained by imposing the following single restriction on the comprehensive model (17):

(18) $$\xi^i = 0$$

An F-test on (18) can be used to determine the appropriateness of the bias-corrected model. Similarly, an F-test on the following set of restrictions can be used to determine the appropriateness of the conventional model in (16):

(19) $$\pi^i_a - \pi^i_* = 0$$

$$\sigma^i - \sigma_*^i = 0$$

The Estimation Results

Based on the conceptual model, there are six structural equations that need to be estimated including: retail fluid demand, retail manufactured demand, retail fluid supply, wholesale fluid supply, retail manufactured supply, and wholesale manufactured supply. These equations are estimated simultaneously by the switching regime estimation procedure discussed above using quarterly data from 1975 through 1987. A detailed description of the data and their sources can be found in Liu. et al. (a).

The retail fluid and manufactured demand equations are estimated on a per capita basis, while the retail and wholesale supply equations are estimated on a total quantity basis because population is not a supply determinant. Both demand equations are expressed as functions of their own price, per capita income, price of substitutes, advertising, time trend, harmonic seasonal variables, and other shifters. The supply equations are expressed as functions of their own price, input prices, lagged supply, harmonic seasonal variables, and other shifters. The estimation results are in Table 1. All the estimated coefficients have correct signs and are significant at conventional confidence levels (as indicated by the t-values in parentheses). The adjusted R-squared, Durbin-Watson statistics, and Durbin-h statistics suggest good fit of the data. A more specific explanation of the equations follows.

Per capita retail fluid demand (Q_d^{rf}/POP) is estimated as a function of the ratio of fluid milk price index (P^{rf}) to per capita income (INC); the ratio of retail non-alcoholic beverage price index (PBEV) to per capita income; deflated generic fluid advertising

Table 1: Estimated Structural Equations (The Bias-Corrected Model)

Reta. Fluid Demand

$$
\begin{aligned}
\ln Q_d^{rf} = {} & \underset{(-14.88)}{-\,2.236} \underset{(-2.34)}{-\,0.282} \ln (P^{rf}/INC) + \underset{(2.31)}{0.154} \ln (PBEV/INC) + \underset{(2.01)}{.0025} \ln DGFA \\
& + \underset{(2.01)}{0.004} \ln DGFA_{-1} + \underset{(2.01)}{0.0045} \ln DGFA_{-2} + \underset{(2.01)}{0.004} \ln DGFA_{-3} + \underset{(2.01)}{0.0025} \ln DGFA_{-4} \\
& \underset{(-6.79)}{-\,0.179} \ln TIME \underset{(-3.60)}{-\,0.028} SIN1 + \underset{(10.70)}{0.083} COS1 + \underset{(3.24)}{0.517} u^{rf}_{d_{-1}} + \ln POP
\end{aligned}
$$

Adj. R^2 = 0.88 Durbin-Watson = 1.84

Reta. Manu. Demand

$$
\begin{aligned}
\ln Q_d^{rm} = {} & \underset{(-10.42)}{-\,2.467} \underset{(-2.68)}{-\,0.928} \ln (P^{rm}/INC) + \underset{(2.29)}{0.645} \ln (PMEA/INC) + \underset{(1.64)}{0.0009} \ln DGMA \\
& + \underset{(1.64)}{0.0014} \ln DGMA_{-1} + \underset{(1.64)}{0.0016} \ln DGMA_{-2} + \underset{(1.64)}{0.0014} \ln DGMA_{-3} + \underset{(1.64)}{0.0009} \ln DGMA_{-4} \\
& \underset{(-2.09)}{-\,1.436} \ln DPAFH + \underset{(2.64)}{0.071} \ln TIME \underset{(-4.92)}{-\,0.050} SIN1 \underset{(-8.29)}{-\,0.085} COS1 + \ln POP
\end{aligned}
$$

Adj. R^2 = 0.85 Durbin-Watson = 2.07

Reta. Flui. Supply

$$
\begin{aligned}
\ln Q_s^{rf} = {} & \underset{(6.00)}{2.809} + \underset{(1.82)}{0.940} \ln (P^{rf}/P^{wf}) \underset{(-3.68)}{-\,0.111} \ln (PFE/P^{wf}) \underset{(-3.95)}{-\,0.015} UNEMP \\
& + \underset{(1.76)}{0.237} \ln Q^{rf}_{s_{-1}} \underset{(-1.98)}{-\,0.227} \ln Q^{rf}_{s_{-4}} \underset{(-1.90)}{-\,0.001} TIME \underset{(-3.90)}{-\,0.052} SIN1 + \underset{(8.14)}{0.094} COS1
\end{aligned}
$$

Adj. R^2 = 0.90 Durbin-h = 1.60

Whol. Flui. Supply

$$
\begin{aligned}
\ln Q_s^{Wf} = {} & \underset{(4.03)}{2.184} + \underset{(2.66)}{0.381} \ln (P^{Wf}/(P^{II}+d)) \underset{(-2.85)}{-\,0.093} \ln (PFE/(P^{II}+d)) \underset{(-3.98)}{-\,.016} UNEMP \\
& + \underset{(1.79)}{0.240} \ln Q^{Wf}_{s_{-1}} \underset{(-1.96)}{-\,0.223} \ln Q^{Wf}_{s_{-4}} \underset{(-3.74)}{-\,0.003} TIME \underset{(-3.74)}{-\,0.050} SIN1 + \underset{(8.18)}{0.094} COS1
\end{aligned}
$$

Adj. R^2 = 0.90 Durbin-h = 1.13

Reta. Manu. Supply

$$
\begin{aligned}
\ln Q_s^{rm} = {} & \underset{(-1.69)}{-\,1.507} + \underset{(2.37)}{0.683} \ln (P^{rm}/P^{wm}) \underset{(-1.51)}{-\,0.334} \ln (MWAGE/P^{wm}) \underset{(-2.78)}{-\,0.042} COS1 \\
& + \underset{(2.21)}{0.163} \ln Q^{rm}_{s_{-1}} + \underset{(6.55)}{0.581} \ln Q^{rm}_{s_{-4}}
\end{aligned}
$$

Adj. R^2 = 0.93 Durbin-h = 1.36

Whol. Manu. Supply

$$
\begin{aligned}
\ln Q_s^{wm} = {} & \underset{(2.70)}{0.528} + \underset{(1.50)}{0.870} \ln (P^{wm}/P^{II}) \underset{(-2.86)}{-\,0.544} \ln (MWAGE/P^{II}) \underset{(-4.37)}{-\,0.122} POLICY \\
& + \underset{(3.40)}{0.301} \ln Q^{wm}_{s_{-1}} + \underset{(4.15)}{0.351} \ln Q^{wm}_{s_{-4}} + \underset{(4.29)}{0.00017} TIME^2 + \underset{(4.08)}{0.077} SIN1 \underset{(-6.42)}{-\,0.125} COS1 \\
& + \underset{(4.05)}{0.751} u^{wm}_{s_{-1}}
\end{aligned}
$$

Adj. R^2 = 0.96 Durbin-h = 0.25

---

index is a proxy for the price of manufactured product substitutes. The away from home price index is included because a large portion of cheese is consumed away from home. The trend variable measures the increase in consumer preferences for cheese and yogurt; unlike fluid product, consumers do not perceive manufactured products such as cheese as high fat products even though they contain as much fat as whole milk (Cook, et al., p. 9).

Retail fluid supply (Q^{rf}_{s}) is estimated as a function of the ratio of retail fluid price index to wholesale fluid price index (P^{wf}); the ratio of fuels and energy price index (PFE) to wholesale fluid price index; lagged supply; unemployment rate (UNEMP); a time trend; and the harmonic seasonal variables. The specification of the retail to wholesale price ratio and energy price to wholesale price ratio is consistent with the zero homogeneity assumption for prices. The wholesale fluid and energy prices represent two of the most important costs in fluid retailing. The two lagged dependent variables are included to capture short and longer term production capacity constraints.[6] The unemployment rate is used as a proxy for the state of the economy. The time trend is included to capture other determinants of supply such as labor costs in the retail fluid sector, which are unavailable.

Wholesale fluid supply (Q^{wf}_{s}) is estimated as a function of the ratio of wholesale fluid price index to Class I price for raw milk (P^{I} =

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6 The eigenvalues for this dynamic system have real parts all less than one in absolute value indicating the equation is stable. The stability condition is also satisfied for other dynamic supply equations to be presented.

P^{II} + d); the ratio of fuels and energy price index to Class I price; lagged supply; unemployment rate; a time trend; and the harmonic seasonal variables. The Class I price is included because it represents the most important cost in fluid wholesaling.

Retail manufactured supply (Q_s^{rm}) is estimated as a function of the ratio of retail manufactured price to wholesale manufactured price (P^{wm}); the ratio of average hourly wage rate in the manufactured sector (MWAGE) to wholesale manufactured price; lagged supply; and a harmonic seasonal variable. The wholesale manufactured price accounts for the largest portion of variable costs, and the manufactured wage rate measures labor costs in manufactured retailing. The energy price and unemployment rate were included in the initial estimation of this equation, but are subsequently omitted due to their coefficients being the wrong sign. Also, the trend variable and SIN1 are omitted due to their coefficients are insignificant. The exclusion of TIME and SIN1 does not change the results of the estimation significantly.

Wholesale manufactured supply (Q_s^{wm}) is estimated as a function of the ratio of wholesale manufacturing price to Class II price (P^{II}); the ratio of manufactured wage to Class II price; lagged supply; a policy dummy variable (POLICY); a time trend; and the harmonic seasonal variables. The Class II price is included because it represents the most important variable cost in manufactured wholesaling. The policy dummy variable (equal to 1 for the first quarter of 1984 through the second quarter of 1985 and the second quarter of 1986 through the third quarter of 1987) accounts for the significant reductions in raw milk supply due to the implementation of the Milk Diversion Program and the Dairy Termination Program, which had the largest impact on the wholesale manufactured market. A first order moving average error structure is imposed to correct for serial correlation in the residuals. All the coefficients remain stable after imposing the moving average term.

Tests for Selectivity Bias in the Conventional Model

As previously indicated, a significant t-statistic for the coefficient (σ) on the Heckman correction term in (9) signifies the existence of selectivity bias in the wholesale manufactured price reduced form equation if ordinary least squares (instead of Tobit) is used. The t-statistic for the estimated σ is 5.24 using a Heckman two-step estimation procedure (Maddala, p. 159).[7] This supports the statistical relevancy of the Tobit procedure for the constrained wholesale manufactured price reduced form equation.

The tests for the remaining four reduced form equations of the unconstrained prices (retail fluid price, retail manufactured price, wholesale fluid price, and Class II price) are based on the Atkinson procedure discussed in (15) to (19). The P-values for the F-statistics are presented in Table 2. At the 95% confidence level, the bias-corrected model cannot be rejected for all the four equations. On the other hand, the conventional model is rejected for all of the price reduced forms except the retail fluid price. The result that the conventional model cannot be rejected for the retail fluid price is not that surprising because this market probably has the weakest linkage to the supported wholesale manufactured market.

The above tests provide statistical evidence that selectivity-bias is not simply a problem for the price directly influenced by government

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7 The t ratio for the estimate of σ using maximum likelihood is 6.4.

Table 2: F Tests for the Price Reduced Form Equations

Equation	Bias-Corrected Model F(1,6)	Bias-Corrected Model P-Value */	Conventional Model F(22,6)	Conventional Model P-Value
Retail Fluid Price (P^{rf}):	0.22	0.66	1.54	0.31
Retail Manuf. Price (P^{rm}):	0.61	0.47	4.21	0.04
			(REJECTED)	
Wholesale Fluid Price (P^{wf}):	3.09	0.13	4.87	0.03
			(REJECTED)	
Wholesale manuf. Price (P^{wm}):				
			(REJECTED)**/	
Class II Price (P^{II}):	0.83	0.40	5.52	0.02
			(REJECTED)	

*/ At (1 - α) % confidence level, one rejects the model if the P-value is less than α.

**/ Based on the t-ratio on the Heckman-like correction term in equ. (9).

intervention. It also affects other price reduced form equations in the system.

Empirical Implications for Policy Analysis

While the selectivity bias of the conventional model has been shown to exist, it is useful to examine the differences in the magnitudes of estimated structural parameters between the two models. It is also useful to investigate whether the two models generate different policy conclusions. To provide the basis for these comparisons, the conventional model is estimated using two stage least squares assuming the government purchase price is always binding. The estimation results are presented in Table 3.

The estimated structural equations are similar to those of the bias-corrected model with respect to goodness of fit, t-values, Durbin-Watson and Durbin-h statistics. The major difference between the two models lies in the magnitudes of the price coefficients. In general, the conventional model has smaller own price coefficients in the demand equations and larger price coefficients in the supply equations. For example, the own price coefficients in the retail manufactured supply equations are 0.897 for the conventional model and 0.683 for the bias-corrected model. On the other hand, the own price coefficients in the retail manufactured demand equations are -0.655 for the conventional model and -0.928 for the bias-corrected model.

To investigate whether the two models generate different policy conclusions, dynamic impulse analyses are conducted on the conventional and the bias-corrected models. Two policy variables are of interest: the government purchase price (P^g) and the Class I differential (d). The levels of these two variables are of interest because they have been

Table 3: Estimated Structural Equations (The Conventional Model)

Reta. Fluid Demand

$$\ln Q_d^{rf} = -\underset{(-14.61)}{2.253} - \underset{(-2.13)}{0.267}\ln(P^{rf}/INC) + \underset{(2.17)}{0.149}\ln(PBEV/INC) + \underset{(1.96)}{.0025}\ln DGFA$$

$$+ \underset{(1.96)}{0.004}\ln DGFA_{-1} + \underset{(1.96)}{0.0045}\ln DGFA_{-2} + \underset{(1.96)}{0.004}\ln DGFA_{-3} + \underset{(1.96)}{0.0025}\ln DGFA_{-4}$$

$$- \underset{(-6.46)}{0.176}\ln TIME - \underset{(-3.54)}{0.028} SIN1 + \underset{(10.51)}{0.082} COS1 + \underset{(3.15)}{0.502} u^{rf}_{d_{-1}} + \ln POP$$

Adj. R^2 = 0.87 Durbin-Watson = 1.85

Reta. Manu. Demand

$$\ln Q_d^{rm} = -\underset{(-10.97)}{2.601} - \underset{(-1.85)}{0.655}\ln(P^{rm}/INC) + \underset{(1.55)}{0.432}\ln(PMEA/INC) + \underset{(1.30)}{0.0008}\ln DGMA$$

$$+ \underset{(1.30)}{0.0013}\ln DGMA_{-1} + \underset{(1.30)}{0.0014}\ln DGMA_{-2} + \underset{(1.30)}{0.0013}\ln DGMA_{-3} + \underset{(1.30)}{0.0008}\ln DGMA_{-4}$$

$$- \underset{(-1.48)}{1.061}\ln DPAFH + \underset{(2.82)}{0.082}\ln TIME - \underset{(-4.71)}{0.050} SIN1 - \underset{(-7.98)}{0.085} COS1 + \ln POP$$

Adj. R^2 = 0.84 Durbin-Watson = 2.08

Reta. Flui. Supply

$$\ln Q_s^{rf} = \underset{(6.17)}{2.856} + \underset{(1.98)}{1.108}\ln(P^{rf}/P^{wf}) - \underset{(-3.74)}{0.111}\ln(PFE/P^{wf}) - \underset{(-4.06)}{0.016} UNEMP$$

$$+ \underset{(1.73)}{0.230}\ln Q^{rf}_{s_{-1}} - \underset{(-2.13)}{0.245}\ln Q^{rf}_{s_{-4}} - \underset{(-1.74)}{0.001} TIME - \underset{(-3.94)}{0.052} SIN1 + \underset{(8.23)}{0.096} COS1$$

Adj. R^2 = 0.90 Durbin-h = 1.75

Whol. Flui. Supply

$$\ln Q_s^{Wf} = \underset{(3.30)}{1.950} + \underset{(2.72)}{0.461}\ln(P^{Wf}/(P^{II}+d)) - \underset{(-2.49)}{0.085}\ln(PFE/(P^{II}+d)) - \underset{(-4.08)}{.016} UNEMP$$

$$+ \underset{(1.66)}{0.221}\ln Q^{Wf}_{s_{-1}} - \underset{(-1.83)}{0.203}\ln Q^{Wf}_{s_{-4}} - \underset{(-3.77)}{0.003} TIME - \underset{(-3.44)}{0.047} SIN1 + \underset{(8.33)}{0.093} COS1$$

Adj. R^2 = 0.90 Durbin-h = 1.13

Reta. Manu. Supply

$$\ln Q_s^{rm} = -\underset{(-2.09)}{2.197} + \underset{(2.64)}{0.900}\ln(P^{rm}/P^{wm}) - \underset{(-1.96)}{0.506}\ln(MWAGE/P^{wm}) - \underset{(-2.95)}{0.045} COS1$$

$$+ \underset{(2.30)}{0.167}\ln Q^{rm}_{s_{-1}} + \underset{(6.20)}{0.560}\ln Q^{rm}_{s_{-4}}$$

Adj. R^2 = 0.93 Durbin-h = 1.36

Whol. Manu. Supply

$$\ln Q_s^{wm} = \underset{(1.41)}{0.285} + \underset{(1.19)}{1.117}\ln(P^{wm}/P^{II}) - \underset{(-2.26)}{0.431}\ln(MWAGE/P^{II}) - \underset{(-3.83)}{0.113} POLICY$$

$$+ \underset{(5.01)}{0.422}\ln Q^{wm}_{s_{-1}} + \underset{(3.76)}{0.335}\ln Q^{wm}_{s_{-4}} + \underset{(3.30)}{0.00014} TIME^2 + \underset{(4.74)}{0.100} SIN1 - \underset{(-6.14)}{0.123} COS1$$

$$+ \underset{(3.54)}{0.617} u^{wm}_{s_{-1}}$$

Adj. R^2 = 0.96 Durbin-h = 0.25

the key policy instruments set by Congress and the Administration in the 1985 and the proposed 1990 farm bills. It is assumed that the dairy sector is in a steady state in which all the variables are set at a three year average of 1985 to 1987. The two models are shocked with a permanent 10% increase in the government purchase price and the impacts on the endogenous variables are simulated for 20 quarters. A similar analysis is conducted with a 10% shock in the Class I differential. The models are solved using Gauss-Seidel method.[8]

In general, the endogenous variables converge to a new steady state within two years regardless of which model is used. In addition, the pattern of the convergence from the two models is similar for most variables. However, the level of the time paths differ significantly for some variables, as illustrated in Figure 3a-3d. In these figures, the pre-shock steady state (quarters -4 to -1) and the adjustment paths, resulting from the shock (at quarter 0), for the Class II price and government purchases are presented. With a permanent 10% shock in the government purchase price, the Class II price in the conventional and bias-corrected model reaches a new steady state of \$13.40 and \$15.12, respectively, from an old steady state of \$11.33 (Figure 3a). With a permanent 10% shock in the Class I differential, government purchases decrease from an old steady state of 2.54 billion pounds per quarter to 1.64 and 1.40 billion pounds, respectively, which represents an annual

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8 The farm milk supply (Q^{milk}) in equation (5) is fixed at the three year average level. To allow for a future farm milk supply response due to a policy change, one needs to estimate an equation for the predetermined farm milk supply as a function of last period's farm milk price, which in turn is a function of last period's Class II price, Class I differential, and commercial wholesale fluid and manufactured quantities. See Liu, et al. for an example of this more detailed simulation model.

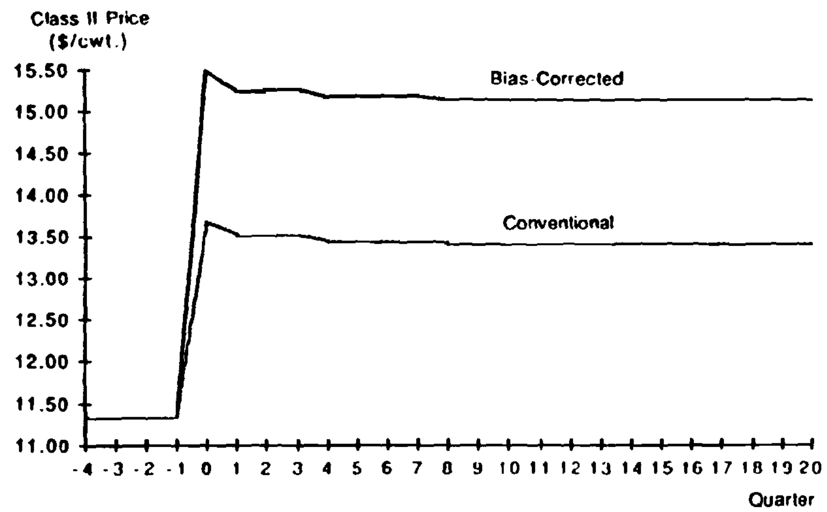

Figure 3a. Impact of 10% Permanent Shock in the Government Purchase Price on the Class II Price.

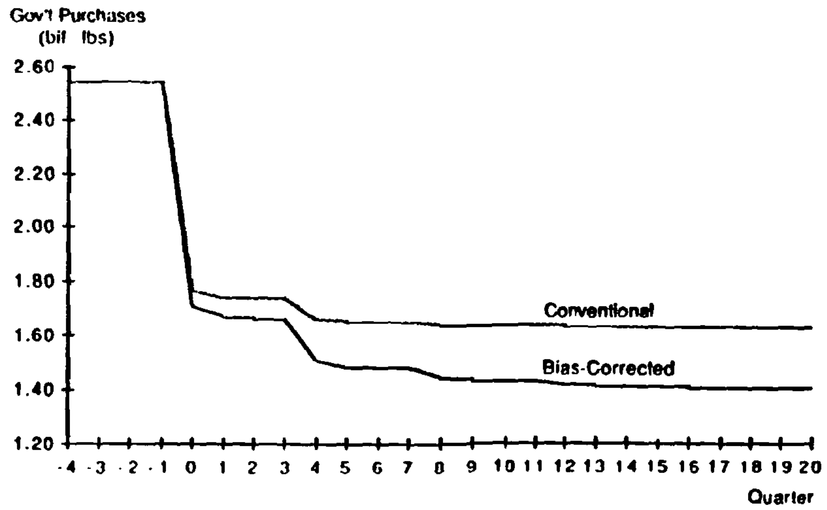

Figure 3b. Impact of 10% Permanent Shock in the Class I Differential on Government Quantity.

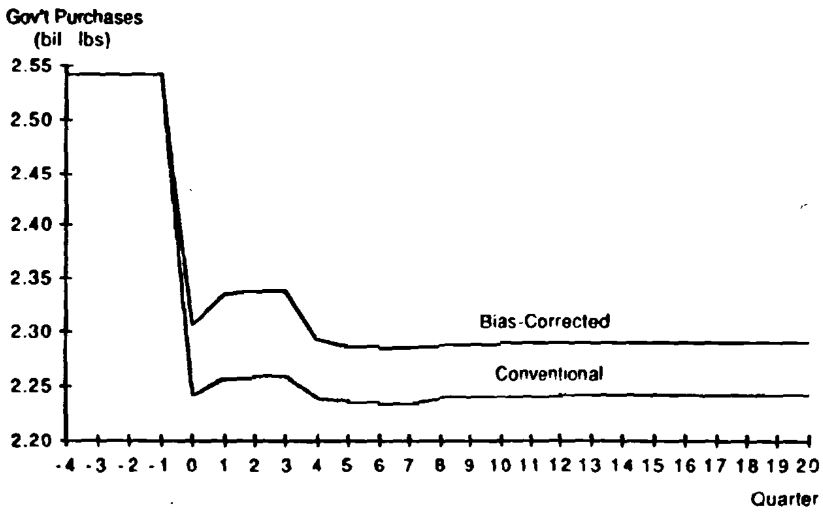

Figure 3c. Impact of 10% Permanent Shock in the Government Purchase Price on Government Quantity.

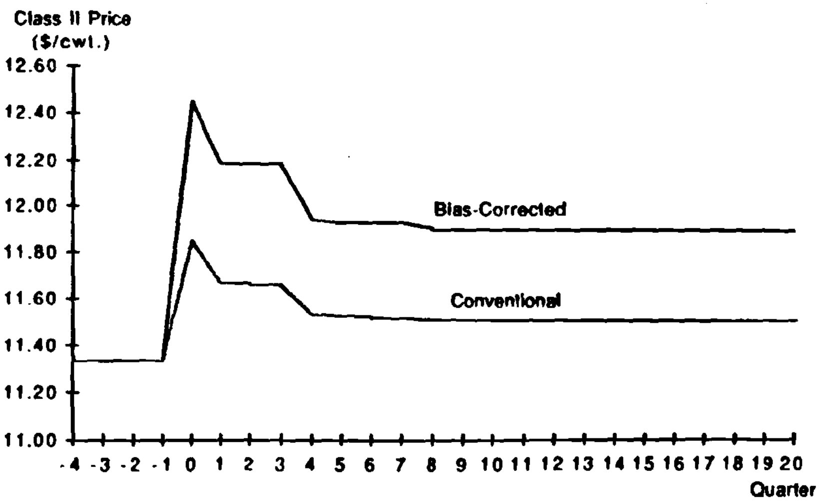

Figure 3d. Impact of 10% Permanent Shock in the Class I Differential on the Class II Price.

difference of about one billion pounds between the two models (Figure 3b).

However, the differences between models are not dramatic for all variables. For example, with a permanent 10% shock in the government purchase price, government quantity in the conventional and bias-corrected model reaches a new steady state of 2.24 and 2.29 billion pounds per quarter, respectively (Figure 3c). Also, with a permanent 10% shock in the Class I differential, the Class II price increases from an old steady state of $11.33 to $11.51 and $11.89 for the two models, respectively (Figure 3d). It should be noted that while the absolute differences are small, the relative differences may be large. For instance, the later case indicates that a 10% increase in the Class I differential results in a 2.5% increase in the Class II price when the conventional model is used; while this shock results in double that increase (5%) when the bias-corrected model is used.

The above results apply to most of the other endogenous variables as well indicating that economic analysis of the dairy sector based on the conventional model may yield policy prescriptions that are substantially different from those based on the bias-corrected model. A similar conclusion is found when shocking other exogenous variables (e.g., income and advertising) and when different initial steady state values (other than the 1985-1987 averages) for the variables in the model are used in the simulation. For additional empirical policy results using the bias-corrected model, see Liu, et al. (b).

Summary

This paper presented a multiple market switching simultaneous system model for the dairy sector. It was argued that this model is necessary for the dairy sector in order to deal with selectivity bias caused by switching between two regimes: (1) a government support regime which exists when the price determined by competitive supply and demand conditions is below the government stipulated price, and (2) a market equilibrium regime which otherwise occurs. The estimation procedure for the system is similar to conventional two-stage least squares in that an instrument is first obtained from the reduced form equation and then is substituted into the structural equation estimation. However, special procedures are needed for the reduced form estimation in order to correct for selectivity bias.

In general, both the bias-corrected and the conventional two stage least squares models fit the data reasonably well. However, based on the Heckman two-step and Atkinson non-nested test results, the restrictions required for the conventional model are not supported by the data. It was shown that selectivity bias is not only apparent in the component of the system directly affected by government intervention, but also exists in other markets in the dairy sector. In addition, the results from the impulse analyses indicate that economic analysis of the dairy sector based on the conventional model may yield policy prescriptions that are substantially different from those based on the bias-corrected model.

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