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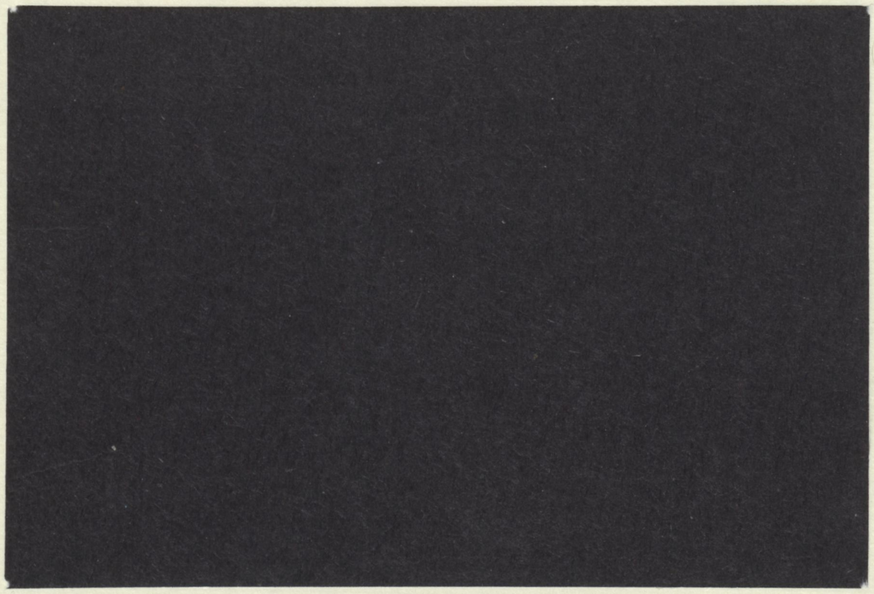

The Impact of Product Demand and Government Intervention on Milk Prices

by

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Abstract

This paper develops a framework to assess the impact of government intervention on the U.S. dairy industry. The model consists of markets for raw milk and three dairy products. The empirical results suggest that had the dairy price support program been eliminated in 1989, the grade B price of milk would have still remained 90 cents per hundredweight above the milk support price despite a significant collapse in the wholesale price of butter. This indicates that other factors contributed relatively more to strong milk prices in 1989 than butter and cheese purchases.

Key words: dairy, econometric model, policy analysis.

The Impact of Product Demand and Government Intervention on Milk Prices

Kenneth W. Bailey, Abner Womack, and Scott Brown[1]

The farm price of manufacturing grade milk (grade B) has rarely varied more than 8 percent above or below the milk support price over the period 1961-87.[2] The farm price was maintained close to the support price via Commodity Credit Corporation (CCC) purchases of manufactured dairy products such as butter, nonfat dry milk, cheese, and evaporated milk. The dairy title to the Food Security Act of 1985 was adopted with the intention of moving the dairy industry towards greater market orientation in order to limit milk supply increases, government purchases, and budget exposure. This was accomplished in part by the dairy termination program which allowed producers whose bids were accepted to sell their whole herds to the government, and continued use of support price triggers which were linked to the level of CCC dairy product purchases. Since implementation of the 1985 Act, the milk support price has declined from an average $11.98 per hundredweight (cwt) in 1985 to $10.10 by 1990; net CCC purchases have declined from 13 billion pounds in 1985 to 9 billion in 1989 (Figures 1-2). Additionally, the grade B price of milk has exceeded the support price by $1.74 per cwt in 1989 and is projected to be $2.92 above the support price in 1990 (FAPRI).

Given this greater market orientation, previous approaches to modeling the U.S. dairy industry may not adequately reflect both government intervention and market forces in determining milk and dairy product prices. Most studies ignored the product market and estimated a quasi reduced-form equation for the demand for manufacturing grade milk (Wilson and Thompson; Prato; LaFrance and de Gorter; Kaiser, Streeter, and Liu; and Hallberg). Others included the product market, but directly linked the farm price of grade B milk to the wholesale prices of cheese, butter, and nonfat dry milk (Salathe, Price, and Gadson; and Novakovic and Thompson). Novakovic and Bunch used a similar specification for the milk price, but linked the wholesale product prices directly to the respective CCC purchase prices. While these studies have made a significant contribution to our understanding of the impact of government policy on the U.S. dairy industry, they do not simultaneously determine prices in the milk and dairy products sectors.

The objective of this paper is to develop an analytical framework and specification to assess the impact of government intervention on the dairy product markets and the farm price of milk. More specifically, the grade B price of milk and the wholesale prices of butter, nonfat

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[1]Authors are Program Director and Research Assistant Professor, Co-Director and Professor, and Research Associate, respectively, with the Food and Agricultural Policy Research Institute (FAPRI), Department of Agricultural Economics, University of Missouri-Columbia. The authors would like to express their appreciation to Gary Adams for his programming of the Newton solution algorithm. Additional thanks are extended to Abraham Subotnik, John Kruse, and Lori Lund for their contributions.

[2]The exception was 1973 and 1974 when the grade B price of milk exceeded the support price by 16 percent and 13 percent, respectively.

Figure 1. Grade B Milk and Support Prices

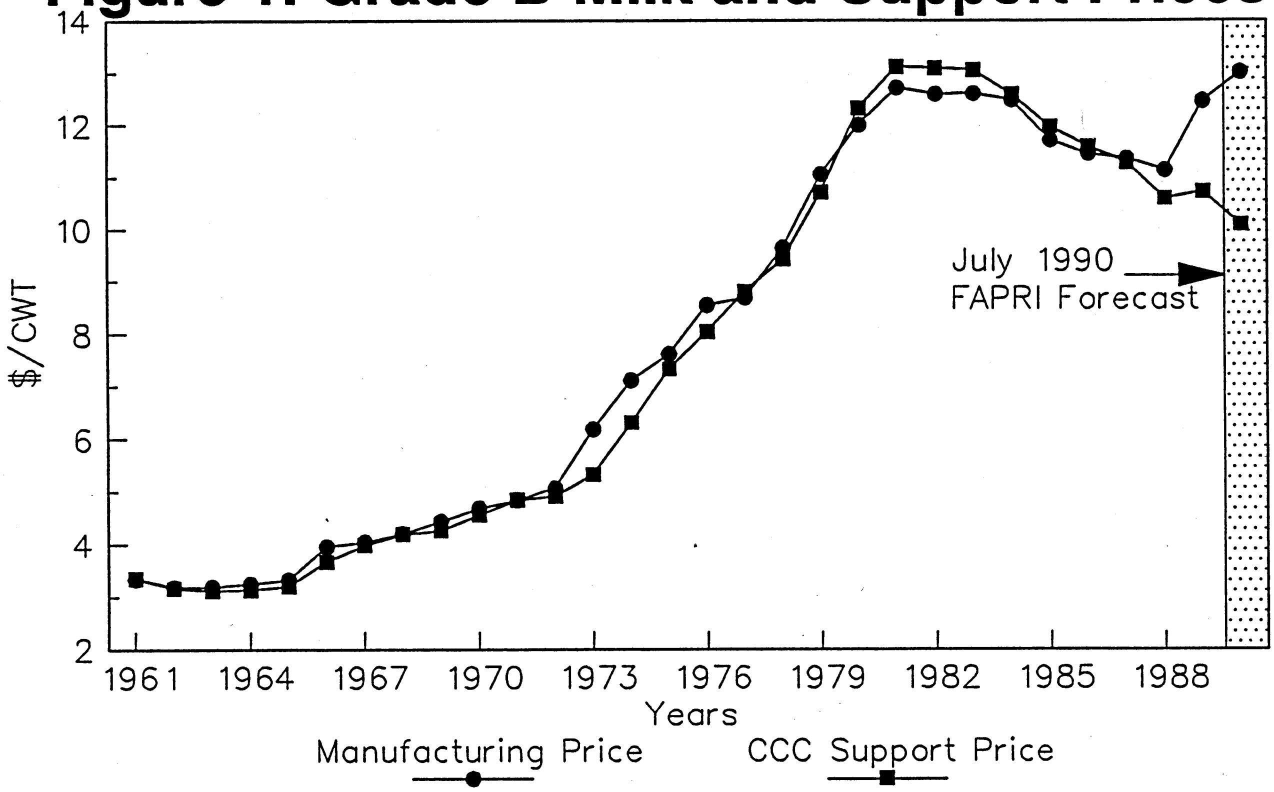
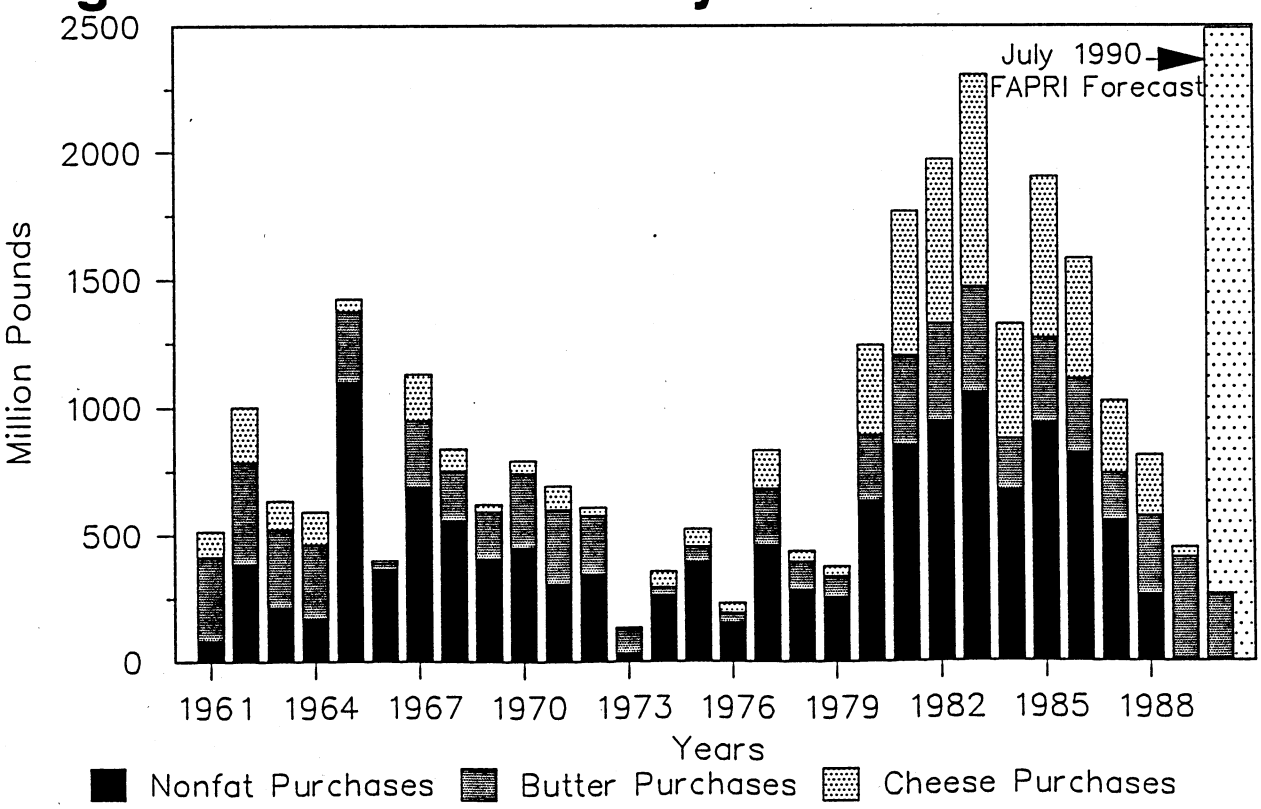


Figure 2. USDA Net Dairy Product Purchases



dry milk, and cheese will be determined under supply and demand conditions, rather than formally linked to the support price of milk. In addition, government removals will be determined at the product level rather than in the aggregate. The model will consist of farm-level supply and wholesale demand for raw milk, and three product markets for butter, nonfat dry milk, and cheese.

The Model

Prior studies analyzed the supply of milk within a dynamic framework by determining feeding rates and production per-cow under profit maximizing conditions (Dahlgran; Chavas and Klemme; and Howard and Shumway). Additions and slaughter have also been endogenized using investment theory (Trapp and Salathe et al.). Following Salathe et al., the supply of milk is,

$$(1) \quad PPC_t = PPC(EP_t^{am} / EP_t^{fr}, TR_t)$$

$$(2) \quad CA_t = CA(CN_t, ER_t^m, P_t^h)$$

$$(3) \quad CS_t = CS(CN_t, ER_t^m, P_t^c)$$

$$(4) \quad CN_t = (1 - d)*CN_{t-1} - CS_{t-1} + CA_{t-2}$$

$$(5) \quad MS_t = PPC_t * (CN_t + CN_{t+1})/2$$

Milk production per-cow (PPC) is a function of the expected farm price for milk (EP^{am}) relative to expected feed prices (EP^{fr}), and technology (TR). Additions to the herd (CA), or heifers bred a year ago, is a function of the herd size at the beginning of each year (CN), the expected discounted present value of gross returns per cow (ER^m), and the market price of the heifer (P^h). The estimated coefficient on CN represents the average replacement rate. Cattle slaughter (CS) is a function of cattle numbers and ER^m, and the salvage value of the cow (P^c). Thus investment in the herd in terms of additions occurs whenever the discounted expected future returns from the heifer entering the herd exceeds its' current market value. Disinvestment in the herd, or slaughter, occurs whenever the slaughter price of the cow exceeds its' discounted expected future earnings. Dairy cow numbers at the beginning of the year equals dairy cow numbers at the beginning of last year less death loss during that year (d is the proportion of the herd that dies each year), less last years' slaughter, plus dairy heifers bred two years ago. Equation 5 determines milk supply (MS) which is equal to production per-cow times cow numbers at mid year.

The farm prices for milk are specified below according to the operations of the federal milk marketing orders,

$$(6) \quad P_t^{fm} = P_t^{mm} + DIF_t$$

$$(7) \quad P_t^{am} = a*P_t^{mm} + (1-a)*P_t^{fm}$$

The farm price of fluid eligible milk (P^{fm}) is equal to the farm price of grade B milk (P^{mm}) plus a fluid price differential. The blended price producer's receive from marketed milk (P^{am}) is a weighted average of the grade B price and the fluid price, where "a" is the proportion of milk sales that consist of grade B milk.

The demand for raw milk can be derived at the processor level under conditions of profit maximization as follows,

$$(8) \quad MU_t^{bnf} = MU^b(P_t^{mm}, WP_t^b, WP_t^{nf}, Z_t^{bnf})$$

$$(9) \quad MU_t^c = MU^c(P_t^{mm}, WP_t^c, Z_t^c)$$

$$(10) \quad MU_t^f = MU^f(CD_t^f)$$

$$(11) \quad MD_t = MU_t^b + MU_t^c + MU_t^o + MU_t^f$$

where MU^i is the amount of milk demanded for the production of product i (i=bnf for butter and nonfat dry products, c for cheese, and f for fluid products), WP^i are the wholesale prices of dairy products i (b=butter, nf=nonfat dry), and Z^i is a vector of input costs for the manufacture of product i. The wholesale demand for milk in the manufacture of product i is thus inversely related to the grade B price of milk and other input costs, but shifts to the right with increases in the wholesale price of product i. Since butter and nonfat dry milk are joint products, both prices are included in equation (8).

Milk is also consumed directly, thus the demand for milk used for fluid consumption (MU^f) is correlated with the retail demand for fluid milk (CD^f). A separate wholesale/retail market was not developed for fluid milk since the retail price of milk is highly correlated with the grade B price of milk. The retail demand for fluid milk is specified as follows,

$$(12) \quad CD_t^f/POP_t = f(RP_t^f, Y_t/POP_t, X_t^f)$$

$$(13) \quad RP_t^m = RP^m(P_t^{fm}, W_t^f, M_t^f)$$

Per-capita retail demand for fluid milk (CD^f/POP) is expressed as a function of the retail price of milk (RP^f), real per capita income (Y/POP), and other demand shifters (X^f). The retail price of milk is then linked to the farm price of fluid-eligible milk (P^{fm}), wage rates at the retail level (W^f), as well as other components of the farm-to-retail marketing margin (M^f).

The farm-level supply and the wholesale milk market can be solved simultaneously for the grade B price of milk. The blend price of milk is linked to the grade B price of milk in equations 6 and 7, thus allowing the supply of milk to be expressed as a function of the grade B price of milk. In addition, the retail price of milk is linked to the farm-level price of fluid eligible milk in equation 13, which in turn is a function of the grade B price of milk in equation

6. Thus the equilibrium conditions for farm-level supply and wholesale demand for raw milk are expressed as follows,

$$(14) \quad MS_t(P_t^{mm*}) = MD_t(P_t^{mm*})$$

where P^{mm*} is the equilibrium price of grade B milk, MS is the supply of raw milk from equation 5, and MD is the demand for raw milk from equation 11.

The supply and demand for butter, nonfat dry milk, and cheese can next be expressed at the product level as follows,

$$(15) \quad PS_t^i = MU_t^i * CF_t^i + IMP_t^i$$

$$(16) \quad CD_t^i/POP_t = f(RP_t^i,\ Y_t/\ POP_t,\ X_t^i,\ DON_t^i)$$

$$(17) \quad RP_t^i = RP^i(WP_t^i,\ W_t^i,\ M^i)$$

$$(18) \quad GS_t^i = GS_{t-1}^i + R_t^i - D_t^i - EX_t^i$$

$$(19) \quad PS_t^i = TXP_t^i + CD_t^i(RP_t^{i*}) + CS_t^i + GS_t^i = PD_t^i(RP_t^{i*})$$

Supply of product i (PS^i) is determined in the wholesale milk sector and is equal to the quantity of raw milk used in the production of product i (MU^i) times a milk-equivalent/product conversion factor (CF^i), plus imports of product i (IMP^i), where i = b for butter, nf for nonfat dry milk, and c for cheese. Per-capita consumption for product i (CD^i/POP) is inversely related to the retail price of product i (RP^i) and government donations (DON^i), and positively related to real per-capita income and other demand shifters (X^i). It is hypothesized that government donations offset some commercial demand in the aggregate. A retail-wholesale linkage equation for product i (RP^i) is also included which differentiates the two prices via retail wage rates (W^i) and other marketing factors which affect the margin (M^i). Government stocks for product i (GS^i) are equal to carryin stocks plus government purchases (R^i) less domestic donations (DD^i) and CCC sales and exports (EX^i). Commercial stocks are considered exogenous to the model.

The market for product i thus clears in equation 19 with the retail price of product i (RP^{i*}). Product supply (PS) is set equal to product demand (PD), where the latter is defined as commercial plus government-assisted exports (TXP), plus commercial demand (CD), commercial stocks (CS), and government stocks (GS).

In the absence of government programs, retail product prices are determined from the intersection of the supply and commercial demand schedules. The government dairy program, however, acts to distort this equilibrium via product purchases which indirectly support the grade B price of milk. This program allows the CCC to purchase unlimited quantities of products at the CCC purchase price level. Government purchases occur whenever the wholesale price of a product falls below the CCC purchase price. Thus the product demand schedule becomes perfectly elastic when prices fall to the CCC purchase price. Prices determined at the product level are therefore affected by (a) the supply of the product, (b) commercial demand expressed at the retail level, and (c) government demand expressed at the wholesale level.

The CCC purchase prices are linked to the announced support price of grade B milk. These product support prices are determined in order to return the milk support price to the producer, on average, but does not guarantee that the grade B price of milk will remain above the announced support price. In fact, the grade B price of milk has been 10 to 50 cents below the support price since the early 1980's. In addition, the CCC purchase prices must be set to ensure that a dairy processor will be indifferent between the production of butter and nonfat dry milk, and cheese.

The CCC purchase prices are specified as follows,

$$(20) \quad SP_t^{nf} = (SP_t^{mm} + MA_t^{bnf})*b/8.13$$

$$(21) \quad SP_t^{b} = (SP_t^{mm} + MA_t^{bnf})*(1-b)/4.48$$

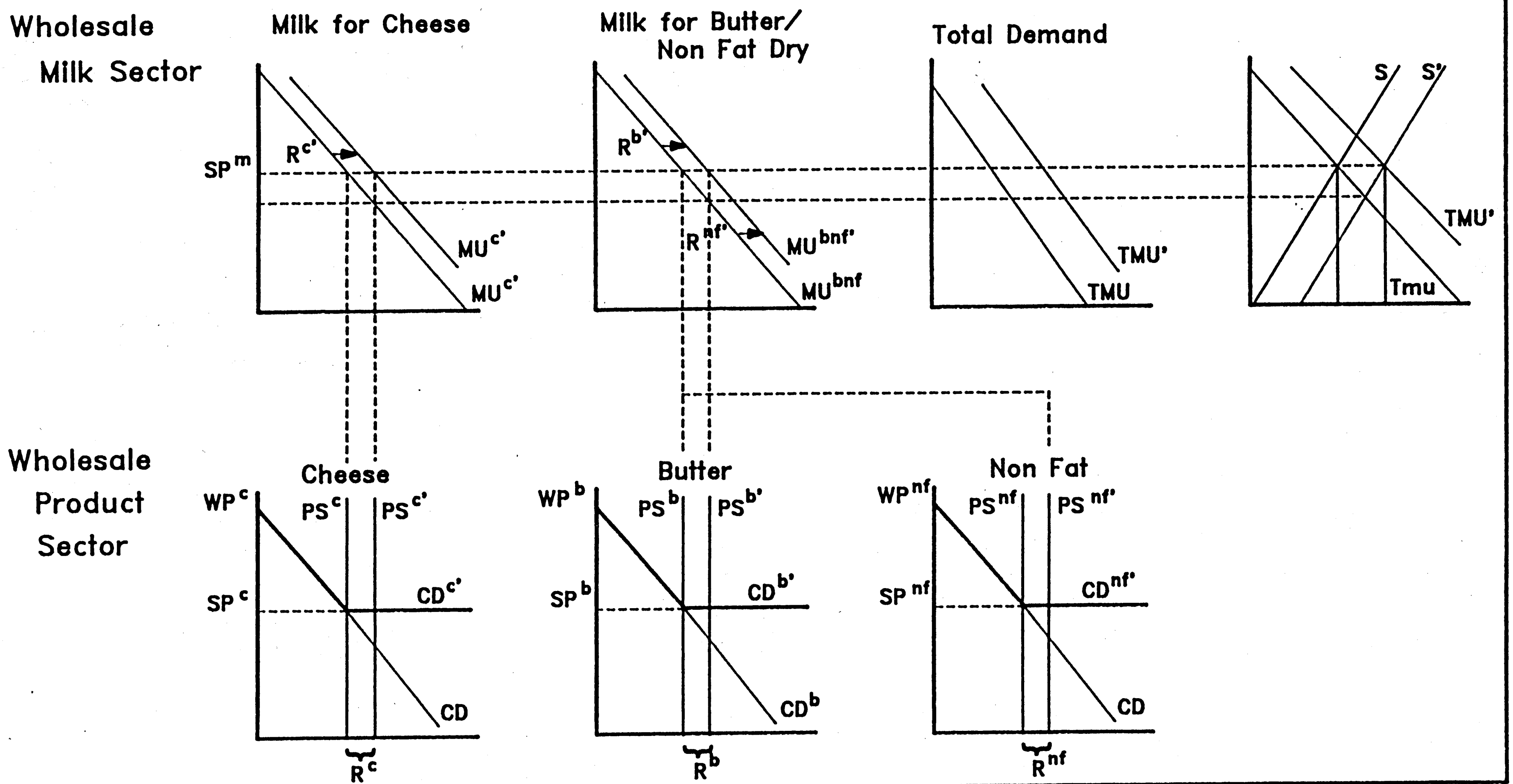
$$(22) \quad SP_t^{c} = (SP_t^{mm} + MA_t^{c} - 0.25*SP_t^{b})/10.1$$

The CCC purchase prices for product i are equal to the support price for grade B milk (SP^{mm}), plus a "make allowance" (MA) which covers the costs of manufacturing the product from raw milk, divided by a milk-equivalent/product conversion factor. Equations 20 and 21 define the CCC purchase prices for butter (SP^b) and nonfat dry milk (SP^{nf}). Since these two products are jointly determined, these equations are multiplied by the proportion of support that is afforded each product, where "b" denotes the proportion for nonfat dry milk. Equation 22 determines the CCC purchase price for cheese (SP^c). Note that the value of whey cream, a by-product of cheese production that is later converted into butter, is subtracted from the support price for milk ($0.25*SP^b$). This occurs in order to avoid double counting the value of whey cream in a hundredweight of milk to the processor.[3]

The impact of government intervention in the product market for butter, nonfat dry milk, and cheese is next illustrated graphically in Figure 3. Assume that the milk and product markets are at an equilibrium in which the grade B price of milk and product prices are at support price levels. Assume that the supply of milk shifts from S to S'. As a result, the grade B price of milk begins to fall and demand for manufacturing grade milk increases. Product supplies then shift from PS^i to $PS^{i\prime}$, acting to depress the wholesale and retail prices of these products. The government intervenes in these markets by purchasing unlimited quantities of each product at the respective CCC purchase prices. This creates a floor for wholesale product prices of butter, nonfat dry milk, and cheese and acts to support the grade B price of milk. Demand for product i is thus perfectly elastic at SP^i which creates an effective product demand schedule $CD^{i\prime}$. Thus, in this example, an expansion in milk supply to S' results in government purchases of R^i units

[3]A hundredweight of milk will produce 10.1 pounds of butter and 0.25 pounds of whey cream. Thus 0.25 times the CCC purchase price of butter approximates the value of whey cream in a hundredweight of milk.

Figure 3 Impact of the Dairy Support Program on Milk and Product Prices



of product i which maintains product prices at CCC purchase price levels. The grade B price of milk is therefore effectively supported as purchases converted to milk equivalent units shift the demand for manufacturing grade milk from TMU to TMU'.

The simultaneous nature of the model can be more fully understood once all four markets are linked (Figure 4). The farm-level supply and the wholesale demand for milk are linked via equations 7 and 14 in order to simultaneously determine the grade B price of milk. The farm/wholesale milk market is linked to the product markets via equation 15. Since all four markets are linked, changes in any one market will affect the other three. For example, if cow numbers were to increase due to some exogenous factor, then the supply of milk would increase, which in turn would depress the grade B price of milk. Lower milk prices would increase the demand for milk for fluid and manufacturing uses, which in turn would shift the product supply functions for butter, nonfat dry milk, and cheese to the right and thus depress these wholesale product prices, assuming these lower prices are still above the respective CCC purchase prices. However, lower product prices would shift the wholesale demand for manufacturing grade milk to the left, thus lowering product production and offsetting some of the initial decline in product prices.

Model Estimates

The model was estimated over the period 1965-87 using ordinary least squares (OLS). All of the OLS parameter estimates have correct signs and most are statistically significant within a 5-percent confidence interval.[4] Three-stage least squares (3SLS) would be a more appropriate estimator to use since the specified model is simultaneous both within and across four markets. However, one problem with using 3SLS is that one misspecified equation could result in some degree of bias in all the other parameter estimates. Thus this estimator is reserved for future use once more research is completed on the model specification. Major changes over the OLS estimates, however, are not expected since an earlier version of this model was estimated with 3SLS.

A summary of the model elasticities is presented in Table 1. The percent root mean square errors for all of the endogenous variables are within 10 percent, with the exception of the wholesale price of nonfat dry milk (13.7 percent). The estimated elasticities are for the most part reasonable. It is anticipated, however, that the own- and cross-price elasticities for the demand for milk used in the cheese production equation are much too large in magnitude. Given a retail cheese demand elasticity of -0.216, it is expected that the model will be unstable and difficult to simulate. One explanation for the large magnitude of the elasticities in the milk demand for cheese production equation is that the price variables used in the equation were not deflated since doing so rendered them statistically insignificant. Another problem with this equation and the milk demand for butter and nonfat dry milk is that government purchases were not in these equations. This suggests the need for further research on more appropriate specifications.

[4]See the appendix for the model documentation and Lund for the database.

Figure 4 Simultaneous Dairy Model

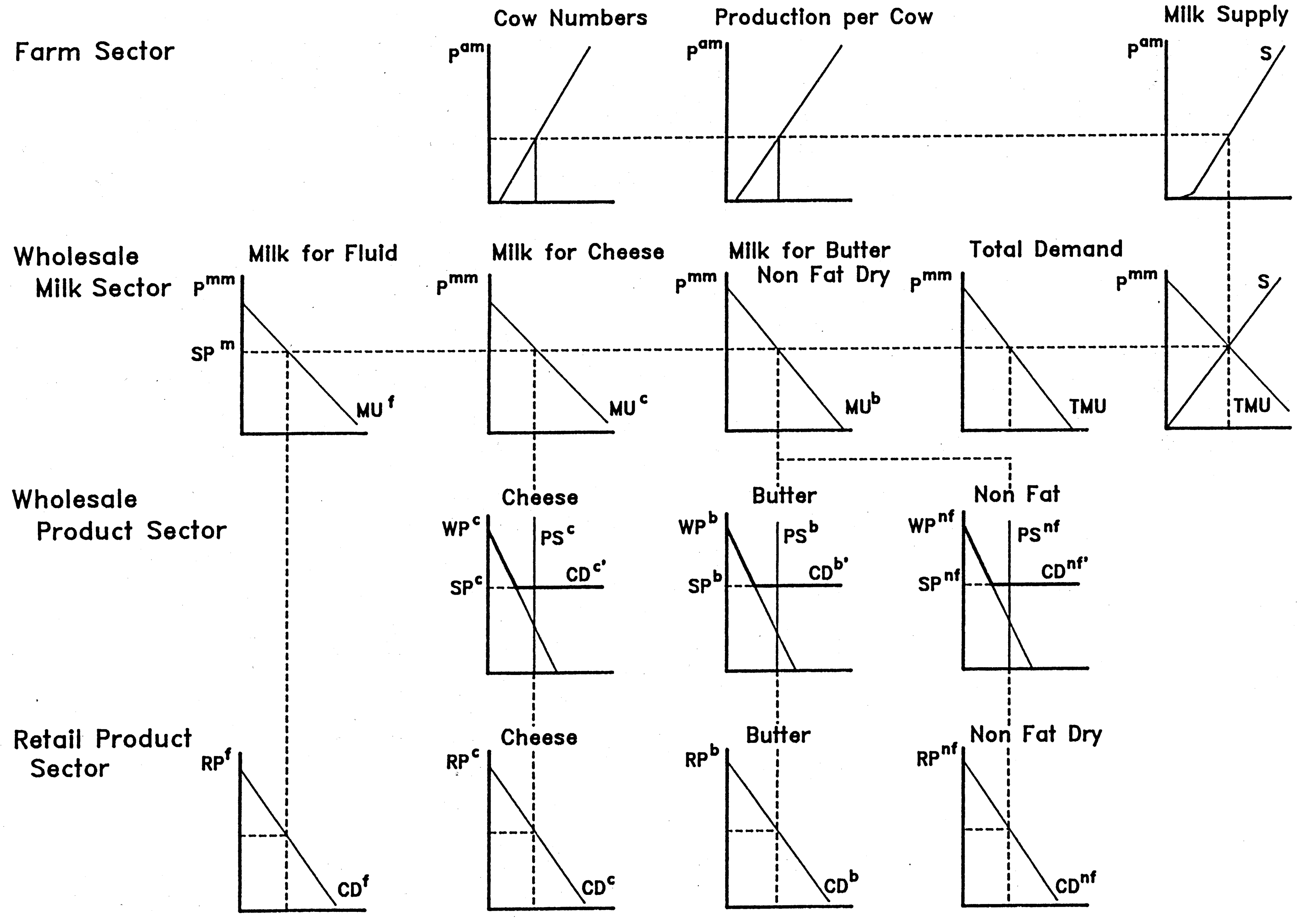


Table 1. Selected Model Elasticities Evaluated at the Mean

	Milk Prices			Wholesale Product Prices			Retail Prices	
	All Milk	Grade B	Retail	Butter	Powder	Cheese	Butter	Cheese
Supply:								
Cow numbers	-.02	--	--	--	--	--	--	--
Prod./Cow	.13	--	--	--	--	--	--	--
Processor Milk Demand:								
Per-capita Fluid	--	--	-.48	--	--	--	--	--
Butter/Powder	--	-.94	--	.55	.17	--	--	--
Cheese	--	-2.69	--	--	--	3.5	--	--
Per-cap Product Demand:								
Butter	--	--	--	--	--	--	-.37	--
Nonfat Dry	--	--	--	--	-.60	--	--	--
Cheese	--	--	--	--	--	--	--	-.20

Once the model was estimated via OLS, it was dynamically simulated using the Newton solution algorithm for nonlinear systems. Earlier attempts to use the Gauss-Seidel approach resulted in exploding iterations and a lack of convergence. The Gauss-Seidel solution algorithm is an order-dependent approach that reaches an equilibrium by solving for endogenous variables using starting values. After the first iteration is solved, the values of these endogenous variables are then fed back into the system and a new solution is reached. This procedure continues until the change in the levels of the endogenous variables in the last iteration relative to the previous iteration are within some convergence criterion. The Newton method, however, is not order dependent and reaches an equilibrium by inverting the Jacobean matrix of the system of equations specified in generalized form. Thus a solution can be reached as long as the Jacobean matrix is invertible. Given the unstable nature of the estimated system of equations, the Newton approach was judged superior to the Gauss-Seidel solution algorithm.

Impact Multipliers

The impact of government purchase of dairy products on milk and wholesale product prices was assessed next. This is expected to provide the analyst with information on how sensitive a particular product is to product purchases, and what impact this will have on other prices.

Impact multipliers were developed by shocking purchases of each product one at a time and assessing the effects on product prices. The amount by which purchases of each product were increased was arbitrarily set at 10 million pounds. The results are provided in Table 2.

An increase in butter purchases shifts the demand for butter to the right, thus raising the butter price. This acts to shift the demand for milk for butter and nonfat dry milk production to the right, having the dual effect of raising the price of milk and increasing butter and nonfat dry milk production. Since the production of nonfat dry milk has increased and demand for the product has not shifted, the price of nonfat dry milk falls. The butter price, while moderating somewhat, remains above the original level due to the increase in butter purchases. The demand

Table 2. The Impact of Government Purchases on Milk and Dairy Product Prices

	Changes in Purchases of 10 Million lb. Each		
	Butter	Nonfat Dry	Cheese
	Dollars per Hundredweight		
Price Changes[a]			
Butter	2.11	-0.54	0.13
Nonfat Dry	-0.48	2.24	0.11
Cheese	0.27	0.09	0.23
Grade B Milk	0.04	0.01	0.02

[a]The change in wholesale prices relative to a 10 million pound change in a product's purchases, holding all else the same.

for milk for cheese production falls due to the rise in the milk price. This reduces cheese production and raises the price of cheese. Therefore, a 10 million pound increase in butter purchases increases the wholesale price of butter \$2.11 per cwt, depresses the wholesale price of nonfat dry milk 48 cents per cwt, raises the wholesale price of cheese 27 cents per cwt, and raises the grade B price of milk by 4 cents per cwt.

The impacts of purchases of nonfat dry milk and cheese have similar impacts, but with some exceptions. An increase in purchases of nonfat dry milk raises the price of the product, but reduces the price of butter since the two are jointly determined. An increase in cheese purchases, however, raises all prices since the rise in the grade B price of milk reduces the amount of milk demanded for butter and nonfat dry milk production.

Empirical Results

To illustrate the contribution of government intervention on milk prices, a scenario was developed in which government stocks were reduced to zero. The resulting impact on milk and product prices was then calculated. The analysis was conducted for 1989 since it was hypothesized that government purchases in the product markets had little effect in raising the grade B price of milk 90 cents per cwt above the average support price of \$10.73 per cwt.

Government stocks of butter and cheese were reduced to zero by first eliminating purchases for that year, and then equating domestic donations and CCC exports and sales. Thus butter stocks were reduced by 257 million pounds and cheese 5 million pounds. There were no nonfat dry milk purchases in 1989 and government ending stocks were at zero by year-end, thus no changes were required.

The results are presented in Table 3 and indicate that eliminating the dairy price support program in 1989 would have resulted in lowering the milk price 6.7 percent from \$12.47 per cwt to a level that would have still been 90 cents per cwt above the average milk support price. Eliminating butter purchases of 413 million pounds and reducing government butter stocks to zero would have reduced the wholesale price of butter by 44 percent to \$71.66 per cwt, which would have been \$54.50 per cwt below the CCC purchase price of butter. The wholesale price of nonfat dry milk, however, would have increased 21 percent to \$127.82 per cwt as the elimination of butter purchases and the drop in the butter price would have reduced the demand

Table 3. The Impact of Reducing Government Stocks of Butter and Cheese to Zero in 1989

	Baseline	Scenario	Percent Change
	- Dollars per Hundredweight -		
Prices[a]:			
Grade B Milk	12.47	11.63	-6.74
Butter	127.96	71.66	-44.00
Nonfat Dry	105.54	127.82	21.11
Cheese	138.81	131.91	-4.97

[a]Wholesale prices

for milk for butter and nonfat dry milk production. Eliminating cheese purchases of 38 million pounds and reducing cheese government stocks to zero would have had much less of an impact on wholesale cheese prices. They fell just 5 percent to $131.91 per cwt, still $15.39 above the CCC purchase price of cheese which averaged $116.52 per cwt in 1989.

Summary and Conclusions

This paper developed an analytical framework with which to assess the impact of government programs on the U.S. dairy industry. An econometric model was estimated which consisted of markets for raw milk and three products: butter, nonfat dry milk, and cheese.

Unlike previous specifications involving predetermined or direct price linkage equations, this approach addresses the simultaneous nature of the dairy industry. This formulation is essential in capturing the current situation where milk and product prices are significantly above support price levels. Also, since the price of milk is supported via purchases of specific dairy products, this approach can explain why sizable purchases were required for butter only.

The empirical results suggest that had the dairy support price program been eliminated in 1989, the grade B price of milk would have still remained 90 cents per cwt above the milk support price despite a significant collapse in the wholesale price of butter. This would suggest that other factors, such as the drop in the rate of increase in milk production and strong commercial demand for fluid milk, cheese, and nonfat dry milk, contributed relatively more to strong milk prices in 1989 than butter and cheese purchases of 413 and 38 million pounds, respectively. These results confirm the decision of the U.S. Department of Agriculture to reduce the CCC purchase price of butter relative to that of nonfat dry milk both on January and April of 1990.

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Appendix--FAPRI Dairy Model Documentation

Dairy Farm Sector

1. Dairy Ration Value

$$DYMKRTVL_t = 0.726502 + 0.417529 * CRPFRM_{t-1}$$

(5.71) (3.67)
<0.15>

$$+ 0.00298893 * SMP44D_{t-1} + 0.071531 * AQPFMU9_t$$

(2.29) (14.90)
<0.09> <0.65>

2. Number of Milk Cows on Farms

$$DYMKNCOF_t = 1987.61 + 0.789737 * DYMKNCOF_{t-1}$$

(4.20) (35.71)
<0.79>

$$+ 150.744981 * DYMKPAMW_t/DYMKRTVL_t$$

(0.58)
<.022>

$$+ 18.166351 * DYMKPAMW_{t-1}/DYMKRTVL_{t-1} + 349.271976 * DUM65_t$$

(0.07) (2.49)
<0.003>

$$- 508.086340 * DUM87_t$$

(-4.38)

3. Milk Production Per Cow

$$DYMKMPPC_t = 6847.16 + 865.437061 * DYMKPAMW_t/DYMKRTVL_t$$

(20.40) (3.96)
<0.13>

$$+ 221.245496 * TREND_t$$

(46.62)

4. Milk Production Identity

$$DYMKSPRD_t = (DYMKNCOF_t * DYMKMPPC_t)/1000$$

5. Milk Fed to Calves

$$DYMKDFTC_t = 232.447342 + 0.122303 * DYMKNCOF_t$$

(1.41) (8.72)
<0.85>

$$+ 576.889552 * DUM84_t - 152.750750 * D801_t$$

(7.46) (-2.70)

--continued

Dairy Farm Sector-continued

6. Milk Used in Farm Churned Butter Production

$$DYMKDFCB_t = \underset{(38.35)}{11228.17} + \underset{\substack{(-5.66)\\ \langle -0.58 \rangle}}{6933.90} * DYMKPAMW_t/CPIBUT_t$$

$$- \underset{(-40.03)}{2820.39} * \log(TREND_t + 10) - \underset{(2.46)}{285.669454} * DUM65_t$$

7. Farm Price for Fluid Milk

$$DYMKPFLD_t = \underset{(29.33)}{1.442870} + \underset{\substack{(178.20)\\ \langle 0.85 \rangle}}{.979663} * DYMKPMNG_t$$

8. Farm Price for All Milk

$$DYMKPAMW_t = \underset{(21.62)}{0.959733} + \underset{\substack{(202.98)\\ \langle 0.90 \rangle}}{1.006643} * DYMKPMNG_t$$

Wholesale Milk Sector

9. Milk Used in Whey Cream Production

$$DYMKDWCR_t = \underset{(-3.75)}{-98.807216} + \underset{\substack{(103.58)\\ \langle 1.04 \rangle}}{.091113} * DYMKDUCT_t$$

10. Milk Used in Butter/Nonfat Dry Production

$$DYMKDUBT_t = \underset{(24.60)}{31047.48} - \underset{\substack{(-9.98)\\ \langle -0.94 \rangle}}{1047619.77} * DYMKPMNG_t/PPIFAE_t$$

$$+ \underset{\substack{(9.66)\\ \langle 0.55 \rangle}}{2219.28} * DYBTNFWA_t/PPIFAE_t - \underset{\substack{(-2.44)\\ \langle -0.13 \rangle}}{18854.48} * ZWAGFFA_t/PPIFAE_t$$

$$+ \underset{(2.24)}{1958.64} * DUM83_t - \underset{(-2.72)}{2362.52} * DUM84_t$$

Calculated Variable:

$$DYBTNFWA_t = ((\underset{\langle 0.55 \rangle}{DYBTPWHL_t} * 100/4.48) + (\underset{\langle 0.17 \rangle}{DYNFPWHL_t} * 100/8.13))$$

--continued

Wholesale Milk Sector--continued

11. Milk Used in Cheese Production

$$DYMKDUCT_t = 5652.16 - 9272.33 * DYMKPMNG_t + 1503.11 * DYCTPWPI_t$$

(9.31) (-9.11) (11.66)
<-2.69> <3.50>

$$- 3162.10 * DUM75_t$$

(-3.09)

12. Milk Used in Evaporated and Condensed Milk

$$DYMKDUEV_t = 8012.43 - 30124.62 * DYMKPMNG_t/PPI_t$$

(17.76) (-8.54)
<-1.32>

$$- 111.121763 * TREND_t$$

(-22.16)

13. Milk Used in Frozen Dairy Products

$$DYMKDUFZ_t = 9194.49 - 8169.05 * DYMKPMNG_t/PPI_t$$

(6.08) (-1.63)
<-0.09>

$$+ 1977.93 * CPIFZD_t/PPI_t + 126.977199 * TREND_t$$

(2.14) (27.05)
<0.17>

$$+ 497.523920 * DUM75_t - 258.033150 * D812_t$$

(3.64) (-2.61)

14. Milk Used in Other Manufactured Products

$$DYMKDUOT_t = 897.852557 + 242.134015 * DYMKPMNG_t/PPI_t$$

(2.43) (0.11)
<0.013>

$$+ .600774 * DYMKDUOT_{t-1} - 455.132478 * DUM67_t$$

(5.03) (-4.66)
<0.60>

$$+ 262.736129 * DUM71_t + 246.13771 * DUM79_t$$

(2.69) (2.40)

--continued

Wholesale Milk Sector--continued

15. Milk Market-clearing Identity

$$DYMKSPRD_t + DYMKSIMP_t + DYMKSNCH_t = DYMKDUCT_t + DYMKDFTC_t$$

$$+ DYMKDFCB_t + DYMKDFLD_t + DYMKDUBT_t + DYMKDUEV_t + DYMKDUFZ_t$$

$$+ DYMKDUOT_t + DYMKDRSD_t$$

16. M-W Manufacturing Grade Price

$$DYMKPMNW_t = \underset{(1.33)}{0.037855} + \underset{\substack{(308.54)\\ \langle 0.99 \rangle}}{0.984781} * DYMKPMNG_t$$

<u>Fluid Milk</u>

17. Per Capita Consumption of Milk

$$PCMILK_t = \underset{(-2.11)}{-108.698387} - \underset{\substack{(-4.53)\\ \langle -0.48 \rangle}}{105.022225} * CPIWMK_t/CPINDF_t$$

$$+ \underset{\substack{(2.98)\\ \langle 0.25 \rangle}}{588.441101} * ZPDI_t/(POPTOT_t * CPINDF_t)$$

$$+ \underset{\substack{(1.91)\\ \langle 0.07 \rangle}}{19.126595} * CPIBNAL_t/CPINDF_t + \underset{\substack{(8.70)\\ \langle 0.41 \rangle}}{1150.84} * POPU20_t/POPTOT_t$$

Calculated Variables:

$$POPU20_t = POP0004_t + POP0509_t + POP1014_t + POP1519_t$$

18. Milk Used for Fluid Products

$$DYMKDFLD_t = PCMILK_t * POPTOT_t$$

19. CPI for Whole Milk

$$CPIWMK_t = \underset{(13.65)}{16.749159} + \underset{\substack{(10.94)\\ \langle 0.26 \rangle}}{0.299281} * ZWAGFFA_t + \underset{\substack{(13.86)\\ \langle 0.51 \rangle}}{3.879398} * DYMKPFLD_t$$

--continued

Butter

20. Butter Production

$$DYBTSPRD_t = (DYMKDWCR_t + DYMKDUBT_t)/DYBTCONV_t$$

21. Per Capita Consumption of Butter

$$PCBTD_t = \underset{(6.37)}{1.654221} - \underset{\substack{(3.19)\\ \langle -0.37\rangle}}{0.540893} * \log(CPIBUT_t/CPINDF_t)$$

$$+ \underset{(8.29)}{0.054494} * TREND73_t + \underset{\substack{(0.91)\\ \langle 0.0071\rangle}}{0.099326} * \log(ZPDI_t/POPTOT_t * CPINDF_t))$$

$$- \underset{\substack{(-3.42)\\ \langle -0.04\rangle}}{0.00043993} * DYBTDDON_t - \underset{(-0.79)}{0.031159} * DUM74_t + \underset{(1.69)}{0.054648} * DUM79_t$$

22. Butter Commercial Demand Identity

$$DYBTDCOM_t = PCBTD_t * POPTOT_t$$

23. Butter Market-clearing Identity

$$DYBTDCES_{t-1} + DYBTDGES_{t-1} + DYBTSPRD_t + DYBTSIMP_t = DYBTDCOM_t$$

$$+ DYBTDEXP_t + DYBTDSHP_t + DYBTDDON_t + DYBTDCES_t + DYBTDGES_t$$

24. Butter Government Ending Stocks

$$DYBTDGES_t = DYBTDGES_{t-1} + DYBTDREM_t - DYBTDDON_t - DYBTDOES_t$$

25. Butter, Wholesale Price

$$DYBTPWHL_t = \underset{(2.56)}{6.425173} - \underset{\substack{(-5.21)\\ \langle -0.32\rangle}}{0.513137} * ZWAGFFA_t + \underset{\substack{(15.59)\\ \langle 1.24\rangle}}{1.928944} * CPIBUT_t$$

26. CCC Purchase Price of Butter

$$DYBTPCCC_t = (DYMKPCCC_t + 1.22)*(1-b)/4.48$$

--continued

<u>Cheese</u>

27. Cheese Production Identity

$$DYCTSPRD_t = DYMKDUCT_t/DYCTCONV_t$$

28. Per Capita Consumption of Cheese

$$PCCTD_t = \underset{(10.59)}{2.459852} - \underset{\substack{(-1.96)\\ \langle -0.20 \rangle}}{0.197590} * \log(CPICHZ_t/CPIMTOT_t)$$

$$+ \underset{\substack{(1.49)\\ \langle 0.13 \rangle}}{0.126271} * \log(ZPDI_t/(POPTOT_t * CPINDF_t)) + \underset{(16.62)}{0.043032} * TREND_t$$

$$+ \underset{(3.10)}{0.056492} * DUM74_t + \underset{(2.55)}{0.049446} * D767_t - \underset{\substack{(-5.51)\\ \langle -0.0024 \rangle}}{0.00017652} * DYCTDDON_t$$

29. Cheese Commercial Demand Identity

$$DYCTDCOM_t = PCCTD_t * POPTOT_t$$

30. Cheese Government Ending Stocks

$$DYCTDGES_t = DYCTDGES_{t-1} + DYCTDREM_t - DYCTDDON_t - DYCTDOES_t$$

31. Cheese Market-clearing Identity

$$DYCTDCES_{t-1} + DYCTDGES_{t-1} + DYCTSPRD_t + DYCTSIMP_t = DYCTDCOM_t$$

$$+ DYCTDEXP_t + DYCTDSHP_t + DYCTDDON_t + DYCTDCES_t + DYCTDGES_t$$

32. Cheese, Wholesale Price

$$DYCAP40L_t = \underset{(-2.79)}{-16.716944} - \underset{\substack{(-5.85)\\ \langle -0.89 \rangle}}{1.287073} * ZWAGFFA_t - \underset{\substack{(-1.37)\\ \langle -0.11 \rangle}}{0.025659} * PPIFAE_t$$

$$+ \underset{\substack{(7.85)\\ \langle 2.18 \rangle}}{3.024747} * CPICHZ_t + \underset{(2.89)}{12.540300} * DUM79_t$$

33. Cheese, Wholesale Price Index

$$DYCTPWPI_t = \underset{(-1.54)}{-1.883222} + \underset{\substack{(61.19)\\ \langle 1.03 \rangle}}{0.737949} * DYCAP40L_t$$

--continued

Appendix--continued

Cheese--continued

34. CCC Purchase Price of Cheddar

$$DYCAPCCC_t = (DYMKPCCC_t + 1.37 - 0.25*DYBTPCCC_t)/10.1$$

Nonfat Dry Milk

35. Nonfat Dry Milk, Production Identity

$$DYNFSPRD_t = (DYMKDWCR_t + DYMKDUBT_t)/DYNFCONV_t$$

36. Per Capita Consumption of Nonfat Dry Milk

$$\begin{array}{llll} PCNFD_t = & 0.817549 & - \; 0.604327 & * \log(DYNFPWHL_t/CPIWMK_t) \\ & (0.82) & (-2.40) & \\ & & \langle -0.60 \rangle & \end{array}$$

$$\begin{array}{llll} - \; 0.128740 & * \log(ZPDI_t/(POPTOT_t * PPI_t)) & - \; 0.544150 & * SHFT81_t \\ (-0.31) & & (-7.77) & \\ \langle -0.13 \rangle & & & \end{array}$$

$$\begin{array}{llll} + \; 0.362867 & * DUM73_t & - \; 0.00008592 & * DYNFDDON_t \\ (3.82) & & (-0.05) & \\ & & \langle -0.0024 \rangle & \end{array}$$

37. Nonfat Dry Commercial Demand Identity

$$DYNFDCOM_t = PCNFD_t*POPTOT_t$$

38. Nonfat Dry Government Ending Stocks

$$DYNFDGES_t = DYNFDGES_{t-1} + DYNFDREM_t - DYNFDDON_t - DYNFDOES_t$$

39. Nonfat Dry Milk Market-clearing Identity

$$DYNFDCES_{t-1} + DYNFDGES_{t-1} + DYNFSPRD_t + DYNFSIMP_t = DYNFDCOM_t + DYNFDEXP_t + DYNFDSHP_t + DYNFDDON_t + DYNFDFAW_t + DYNFDCES_t + DYNFDGES_t$$

40. CCC Purchase Price of Nonfat Dry Milk

$$DYNFPCCC_t = (DYMKPCCC_t + 1.22)*b/8.13$$

Dairy Model Variable Definitions

Variables	Definition	Units
Endogenous		
CPIBUT	CPI, Butter	index: 1982-84 = 100
CPICHZ	CPI, Cheese	index: 1982-84 = 100
CPIWMK	CPI, Whole Milk	index: 1982-84 = 100
DYBTDCOM	Butter, Commercial Use	mil lbs
DYBTDGES	Butter, Government Ending Stocks	mil lbs
DYBTDREM	Butter, CCC Net Removals	mil lbs
DYBTPCCC	Butter, CCC Purchase Price	$/cwt
DYBTPWHL	Butter, Wholesale Price, Grade A Chicago	cents/lb
DYBTSPRD	Butter, Production	mil lbs
DYCAP40L	Cheese, 40-lb Blocks, Wholesale Price	$/cwt
DYCAPCCC	Cheese, Cheddar, CCC Purchase Price	$/cwt
DYCTDCOM	Cheese, Commercial Use	mil lbs
DYCTDGES	Cheese, Government Ending Stocks	mil lbs
DYCTDREM	Cheese, CCC Net Removals	mil lbs
DYCTPWPI	Cheese, Wholesale Price Index	index: 1982=100
DYCTSPRD	Cheese, Production	mil lbs
DYMKDFCB	Milk, Used in Farm Churned Butter Production	mil lbs MEU
DYMKDFLD	Milk, Used for Fluid Products	mil lbs
DYMKDFTC	Milk, Fed to Calves	mil lbs MEU
DYMKDUBT	Milk, Used in Butter/Nonfat Dry Production	mil lbs MEU
DYMKDUCT	Milk, Used in Cheese Production	mil lbs MEU
DYMKDUEV	Milk, Used in Evaporated and Condensed Milk	mil lbs
DYMKDUFZ	Milk, Used in Frozen Dairy Products	mil lbs MEU
DYMKDUOT	Milk, Used in Other Manufactured Products	mil lbs MEU
DYMKDWCR	Milk, Used in Whey Cream Production	mil lbs MEU
DYMKMPPC	Milk, Production Per Cow	lbs
DYMKNCOF	Number of Milk Cows on Farms, Calendar Year	1000 head
DYMKPAMW	All Milk, Wholesale Farm Price	$/cwt
DYMKPFLD	Fluid Milk, Wholesale Farm Price	$/cwt
DYMKPMNG	Manufacturing Grade Milk, Wholesale Farm Price	$/cwt
DYMKPMNW	M-W Manufacturing Grade Price	$/cwt
DYMKRTVL	Dairy Ration Value	$/cwt
DYMKSIMP	Milk, Net Imports of Ingredients	mil lbs
DYMKSPRD	Milk, Production	mil lbs MEU
DYNFDCOM	Nonfat Dry Milk, Commercial Use	mil lbs
DYNFDGES	Nonfat Dry Milk, Government Ending Stocks	mil lbs
DYNFDREM	Nonfat Dry Milk, CCC Net Removals	mil lbs
DYNFPCCC	Nonfat Dry Milk, CCC Purchase Price	$/cwt
DYNFPWHL	Nonfat Dry Milk, Wholesale Price, Central States	cents/lb
DYNFSPRD	Nonfat Dry Milk, Production	mil lbs
PCBTD	Per Capita Consumption of Butter	mil lbs
PCCTD	Per Capita Consumption of Cheese	lbs
PCMILK	Per Capita Consumption of Milk	lbs
PCNFD	Per Capita Consumption of Nonfat Dry Milk	lbs
Exogenous		
AQPFMU9	Alfalfa Hay Price, Calendar Year	$/ton
b	Proportion of Support for Nonfat Dry Milk	ratio
CPIBNAL	CPI, Nonalcholic Beverages	index: 1982-84 = 100
CPIFZD	CPI, Frozen Deserts	index: 1982-84 = 100
CPIMTOT	CPI, Total, Meats	index: 1982-84 = 100
CPINDF	CPI, Nondurables Less Food	index: 1982-84 = 100
CRPFRM	Average Corn Price Received by Farmers, Sept/Aug	$/bu
D801	Dummy Variable, Equals 1 in 1980 and 81, 0 Elsewhere	
D812	Dummy Variable, Equals 1 in 1981 and 82, 0 Elsewhere	

-- Continued --

Dairy Model Variable Definitions, continued

Variables	Definition	Units
Exogenous, continued		
DUM65	Dummy Variable, Equals 1 in 1965, 0 Elsewhere	
DUM67	Dummy Variable, Equals 1 in 1967, 0 Elsewhere	
DUM71	Dummy Variable, Equals 1 in 1971, 0 Elsewhere	
DUM73	Dummy Variable, Equals 1 in 1973, 0 Elsewhere	
DUM74	Dummy Variable, Equals 1 in 1974, 0 Elsewhere	
DUM75	Dummy Variable, Equals 1 in 1975, 0 Elsewhere	
DUM79	Dummy Variable, Equals 1 in 1979, 0 Elsewhere	
DUM83	Dummy Variable, Equals 1 in 1983, 0 Elsewhere	
DUM84	Dummy Variable, Equals 1 in 1984, 0 Elsewhere	
DUM87	Dummy Variable, Equals 1 in 1987, 0 Elsewhere	
DYBTCONV	Milk to Butter Conversion Ratio	lbs
DYBTDCES	Butter, Commercial Ending Stocks	mil lbs
DYBTDDON	Butter, CCC Domestic Donations	mil lbs
DYBTDEXP	Butter, Exports	mil lbs
DYBTDOES	Butter, CCC Exports and Foreign Donations	mil lbs
DYBTDSHP	Butter, Shipments	mil lbs
DYBTSIMP	Butter, Imports	mil lbs
DYCTCONV	Milk to Cheese Conversion Ratio	lbs
DYCTDCES	Cheese, Commercial Ending Stocks	mil lbs
DYCTDDON	Cheese, CCC Domestic Donations	mil lbs
DYCTDEXP	Cheese, Exports	mil lbs
DYCTDOES	Cheese, CCC Exports and Foreign Donations	mil lbs
DYCTDSHP	Cheese, Shipments	mil lbs
DYCTSIMP	Cheese, Imports	mil lbs
DYMKDRSD	Milk, Residual Use	mil lbs
DYMKPCCC	Milk, Support Price	$/cwt
DYMKSNCH	Milk, Net Change in Storage Cream	mil lbs
DYNFCONV	Milk to Nonfat Dry Milk Conversion Ratio	lbs
DYNFDCES	Nonfat Dry Milk, Commercial Ending Stocks	mil lbs
DYNFDDON	Nonfat Dry Milk, CCC Domestic Donations	mil lbs
DYNFDEXP	Nonfat Dry Milk, Exports	mil lbs
DYNFDFAW	Nonfat Dry Milk, Feed and Waste	mil lbs
DYNFDOES	Nonfat Dry Milk, CCC Exports and Foreign Donations	mil lbs
DYNFDSHP	Nonfat Dry Milk, Shipments	mil lbs
DYNFSIMP	Nonfat Dry Milk, Imports	mil lbs
POP0004	U.S. Population, Ages 0 to 4	mil
POP0509	U.S. Population, Ages 5 to 9	mil
POP1014	U.S. Population, Ages 10 to 14	mil
POP1519	U.S. Population, Ages 15 to 19	mil
POPTOT	U.S. Total Population Including Armed Forces Overseas	mil
POPU20	U.S. Population, Ages 0 to 19	mil
PPI	PPI, All Items	index: 1982 = 100
PPIFAE	PPI, Fuel and Energy	index: 1910-14 = 100
SHFT81	Shift Variable, Equals 1 After 1980, 0 Elsewhere	
SMP44D	Decatur 44% Protein Soybean Meal Price, Sept/Aug	$/ton
TREND	Trend Variable, Equals 1 in 1965, 2 in 1966, etc.	
TREND73	Trend Variable, Equals 8 in 1965, 7 in 66, ..., 0 from 73 On	
ZPDI	Personal Disposable Income	bil $
ZWAGFFA	Weekly Compensation per Employee in Ag, Forest, & Fish	$/wk