Subsidies, Endogenous Technical Efficiency and the Measurement of Productivity Growth

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Abstract

The impacts of program subsidy on productivity growth is investigated in this study. Mundlak's concept of endogeneity is applied to technical efficiency and generalized within a dual framework. Technology is described by an aggregate cost function while technical efficiency is conditional on a vector of state variables. Empirical evidence from the U.S. dairy sector supports the hypothesis that protectionism, in the form of program subsidy, is the source of considerable technical inefficiencies.

Key Words: dairy sector, endogenous technical efficiency, productivity growth, subsidy

Introduction

Since the pioneering work by Schultz (1956), agricultural productivity measures have enjoyed a great deal of interest among researchers. As a result, a large body of the literature focused on measuring productivity rates for comparative purposes between regions or time periods. Further, a great deal of attention has been given to productivity decomposition work. Of particular interest has been the influence of research expenditures (both private and public), extension, and schooling on productivity growth. Interestingly enough, literature on the role of government protectionist policies in determining productivity rates is limited. What should one expect to be the effects of government intervention on productivity growth? Few studies have investigated this relationship and the empirical evidence provided is mixed.

In a provocative article over twenty years ago Stigler (1971) argued that the most obvious contribution a group may ask the government for is a cash subsidy. Numerous agricultural groups have been quite successful in securing direct income transfers from the government in the form of cash subsidy. It has also been argued, however, that such direct transfers are likely to generate technical inefficiencies (Leibenstein). The main purpose of this study is to investigate how protectionism in the form of direct subsidies affects agricultural productivity growth. In particular, the following hypothesis is investigated:

Agricultural protectionism in the form of program subsidies are the source of considerable technical inefficiencies which in turn reduce productivity growth.

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This hypothesis is empirically tested within the framework of the U.S. dairy sector. The dairy industry has been subjected to more government involvement or regulation than most other domestic agricultural industries. However, faced with the ever growing costs of dairy programs, coupled with the problem of excess milk supply, significant provisions aimed primarily at reducing protection to the sector have been recently added to federal dairy programs.

Implicit in the hypothesis that government subsidies influence technical efficiency and productivity growth is the assumption of endogenous technical efficiency. This assumption is maintained throughout the study. To accommodate such assumption in the empirical analysis, Mundlak's concept of endogeneity is applied to technical efficiency and generalized within a dual framework. As a result, production technology is described by an aggregate cost function while technical efficiency is conditional on a vector of state variables. Parametric expressions of the analytically derived cost function are subsequently employed to empirically measure the effects of appropriate state variables (government subsidies) on technical efficiency and productivity growth.

The rest of the paper is organized as follows. Section 2 reviews the literature on protectionism, efficiency, and productivity growth. Section 3 develops the framework that links subsidies to total factor productivity growth. Section 4 discusses the empirical model and restrictions for its theoretical consistency. Data and estimation procedure are presented in section 5. Results and estimates of the impact of the subsidy on productivity growth is presented in section 6, and section 7 concludes.

Protection, Efficiency, and Productivity Growth

Most studies on costs of protection assumed that much of the inefficiencies attributable to protectionism are the result of misallocation of resources. Empirical evidence, as summarized by Leibenstein (1966), suggested that welfare gains that can be achieved by reducing such allocative inefficiency are rather small. On the other hand, technical inefficiency or X-inefficiency, as labeled by Leibenstein, was found to increase costs of protection by up to 50 percent. Leibenstein argued that X-inefficiency involves firms failing to operate at the outer-bound of their production possibilities frontiers. He further maintained that this failure is related to the allocation of managerial effort by the firm and in many instances this phenomenon is the result of protection.

Corroborating empirical evidence for Leibenstein's contention was provided by Bergsman (1974) and Balassa (1975). The authors argued that protectionism, by increasing technical inefficiency, generate substantial welfare costs unaccounted for by conventional costs of protection calculations. Indeed, traditional costs of protection studies often ignored the dynamic effects protection has on the level of competitive pressure and technical efficiency. This same theme was highlighted in Scitovsky (1958), and explained the often exceedingly small computed costs of protection.

Corden (1974), building on the concept of X-inefficiency, analyzed the theoretical effects of protectionism on managerial effort. First, the author equated the reduction in managerial effort with an increase in X-inefficiency. Then, using a partial equilibrium model, he analyzed the effect of a tariff on managerial effort in the import competing sector. Corden concluded that the effect of a tariff on managerial effort is, a priori, *ambiguous*. Whether managers relax and become less efficient depends upon whether the income effect of the tariff outweighs the substitution of effort for leisure.

Building on Corden's model, Martin (1978) set forth the conditions that are needed to generate the result that protectionism increases X-inefficiency by reducing managerial effort. Using profit curves and owner-manager's preference map diagram, the author was able to explain the ambiguity of response to the tariff in terms of the income and substitution effect of effort for leisure. Martin concludes that protection increases X-inefficiency by reducing managerial effort if: (a) there is an income distribution effect that raises managerial profits, (b) leisure is a normal good, (c) income effects outweigh the substitution effects. Further, he shows (d) one needs only to look at the industry in question; there are no further X-efficiency effects in other sectors of the economy.

Martin and Page (1983), focussing on the allocation of effort to the management of an enterprise, extended the above model of managerial behavior by adding an external managerial labor market component in the model. This latter was then tested using firm level data in two subsidized industries in Ghana. Empirical results were found to support the hypothesis that subsidies to private enterprise can have an adverse effect on efficiency.

Additional support for the existence of X-inefficiency in agricultural production is provided by Kalaitzandonakes and Bredahl (1993 and 1994). The authors extended the model by Martin and Page to include the missing effect of price protection on technical change. The resulting model was then used to examine the effects of price protection on each component of productivity growth. They concluded that the effect of protectionism on productivity growth is a priori *ambiguous*. However, based on few assumptions, they argued that protection may have a positive effect on productivity growth for low income industries by encouraging investment and technical innovation. For high income industries, protection is likely to have an adverse effect on productivity growth by generating technical and scale inefficiencies. These theoretical considerations were then supported by empirical evidence from two agricultural industries that have been recently liberalized, namely, the Japanese pork and the New Zealand beef and sheep industries.

This study provides more empirical evidence and a better understanding as to the nature of the relationship between protectionism and technical efficiency. It departs from previous studies in a sense that it attempts to generalize Mundlak's endogeneity concept within a dual framework and apply it to technical efficiency.

Methodological Framework

In this section an empirical model is developed where technical efficiency is endogenous and responsive to state variables which are exogenous to the firm. In this sense, the firm is assumed to observe a set of exogenous state variables and make a decision about input level usage and hence its efficiency level. Mundlak (1988) developed the theoretical basis for endogenous technology approach to productivity measurement. Fulginiti and Perrin (1993) used a similar approach focussing their investigation mainly on the effects of prices as technology changing variables.

In this paper Mundlak's concept of endogeneity is applied to technical efficiency and, for empirical relevance, it is generalized on the dual side. That is, technology is defined by an aggregate cost function conditional on a vector of state variable S. For the purpose of this study the focus is on program subsidies as a state variable. The rationale behind including subsidies is clear: protectionist policies (e.g., program subsidies) are hypothesized to have an impact on economic performance, both by distorting resource usage and by increasing X-inefficiency. Both of these effects are reflected by an increase in production costs. Indeed, use of non optimal factors of production will result in higher costs of producing a given level of output. Similarly, program subsidies, by increasing X-inefficiency, will also result in higher unit costs of production.

The model development starts with Mundlak's unobserved (true) aggregate production function (p.320),

$$F(X^*,S) = y^* \tag{1}$$

where y^* denotes total optimal output; X^* the optimum level of input vector X; and S is a vector of state variables. Variations in state variables affect not only the location on a given production function but also determines the choice of the technology and impacts efficiency. Thus, within this framework, choice of the technology becomes dependent on state variables S. Dual to this aggregate production function, we specify an aggregate (true) cost function of the form:

$$C = C(W^*,y^*,S) \tag{2}$$

where W^* denotes a vector of factor prices for which the input vector chosen by the firm is optimal; y^* and S are as defined above. Note that (W^*, y^*) in aggregate cost (2) are unobserved. By allowing for a discrepancy between observed actual costs and minimum costs, $C(W^*, y^*, S)$ can be approximated by a set of functions such as the general linear form:[1]

$$C(W^*,y^*,S) \cong C(W,y,S) \equiv \sum_{i=1}^{N} a_i h_i(W,y,S) \tag{3}$$

where $C(W^*, y^*, S)$ is the true function; $C(W, y, S)$ is the approximating function; each h_i is a known, twice continuously differentiable, numeric function of (W, y, S); and each a_i is a parameter to be estimated. Expression (3) is attractive in that parameter values a_i can be chosen to ensure that, for any arbitrary $C(W^*, y^*, S)$, the expansion approximates the value of the function, its first and second partial derivatives in a neighborhood of (W^*, y^*). To generate this parsimonious flexible form we expand $C(w^*, y^*, S)$ using Taylor series approximation to the second-order about a point (W^*, y^*). Let

$$\begin{aligned} a_0 &= C(W^*,y^*,S), & h_0 &= 1 \\ a_1 &= \nabla C(W^*,y^*,S), & h_1 &= \begin{pmatrix} W-W^* \\ y-y^* \end{pmatrix} \\ a_2 &= \nabla^2 C(W^*,y^*,S), & h_2 &= \frac{1}{2}\begin{pmatrix} W-W^* \\ y-y^* \end{pmatrix}\begin{pmatrix} W-W^* \\ y-y^* \end{pmatrix} \end{aligned} \tag{4}$$

It then follows that:

$$\begin{aligned} C(W,y,S) &= C(W^*,y^*,S)+(W-W^*)'\nabla_w C(W^*,y^*,S) \\ &+ (y-y^*)'\nabla_y C(W^*,y^*,S) \\ &+\frac{1}{2}(W-W^*)'\nabla^2_w C(W^*,y^*,S)(W-W^*) \\ &+\frac{1}{2}(y-y^*)'\nabla^2_y C(W^*,y^*,S)(y-y^*) \\ &+\frac{1}{2}(W-W^*)'\nabla^2_{yw} C(W^*,y^*,S)(y-y^*) \\ &+\frac{1}{2}(y-y^*)'\nabla^2_{wy} C(W^*,y^*,S)(W-W^*) \end{aligned} \tag{5}$$

which after rearranging terms yields,

$$\begin{aligned} C(W,y,S) &= \Gamma(W^*,y^*,S) \\ &+ W'\mathrm{B}(W^*,y^*,W,S) \\ &+ y'\Omega(W^*,y^*,y,S) \end{aligned} \tag{6}$$

where:

$$\begin{aligned} \Gamma(W^*,y^*,S) &= C(W^*,y^*,S) - W^{*\prime}\nabla_w C(W^*,y^*,S) \\ &- y^{*\prime}\nabla_y C(W^*,y^*,S) + \frac{1}{2}W^{*\prime}\nabla^2_w C(W^*,y^*,S)W^* \\ &+ \frac{1}{2}y^{*\prime}\nabla^2_y C(W^*,y^*,S)y^* + W^{*\prime}\nabla^2_{yw} C(W^*,y^*,S)y^* \end{aligned} \tag{7}$$

$$\begin{aligned} \mathrm{B}(W^*,y^*,W,S) &= \nabla_w C(W^*,y^*,S) - \nabla^2_w C(W^*,y^*,S)W^* \\ &+ \frac{1}{2}\nabla^2_w C(W^*,y^*,S)W - \nabla^2_{yw} C(W^*,y^*,S)y^* \end{aligned} \tag{8}$$

$$\begin{aligned} \Omega(W^*,y^*,y,S) &= \nabla_y C(W^*,y^*,S) - \nabla^2_y C(W^*,y^*,S)y^* \\ &+ \frac{1}{2}\nabla^2_y C(W^*,y^*,S)y - y'\nabla^2_{wy} C(W^*,y^*,S)W^* \end{aligned} \tag{9}$$

Estimation of $C(W, y, S)$ requires the estimation of $\Gamma(\cdot)$, $\mathrm{B}(\cdot)$, and $\Omega(\cdot)$ which are unknown functions in S and the unobserved variables (W^*, y^*). Following Mundlak (1988), we consider Γ, B, and Ω as composite functions in S and expand the function around S. This yields:

$$\Gamma(W^*,y^*,S) \cong \pi_{00} + S'\pi_{10} + S'\pi_{20}S \tag{10}$$

$$\mathrm{B}(W^*,y^*,W,S) \cong \pi_{01} + \pi_{11}\begin{pmatrix} S \\ W \end{pmatrix} + Q(y^*,S,W) \tag{11}$$

$$\Omega(W^*,y^*,y,S) \cong \pi_{02} + \pi_{12}\begin{pmatrix} S \\ y \end{pmatrix} + Q(W^*,S,y) \tag{12}$$

where the πs represent coefficients of the approximating function, and the Qs are quadratic terms to be dropped from the model as their multiplication by w or y yields third degree terms that are unlikely to be relevant in the empirical part. Combining equation (10), (11), and (12) along with equation (6) yields the following estimable aggregate cost function:

$$C(W,y,S) = \pi_{00} + S'\pi_{10} + S'\pi_{20}S + W'\pi_{01} + W'\pi_{S1}S + W'\pi_{W1}W + y'\pi_{02} + y'\pi_{S2}S + y'\pi_{Y2}y \tag{13}$$

Introduction of state variables, as described by S, is exactly what differentiates this model from earlier ones. Subsidy, being an argument in the above function, should allow the identification of the impacts of program subsidy on technical efficiency and productivity growth.

Subsidy, Efficiency and TFP

A decomposition of the general form of (13) allows further insights on the role of subsidies on productivity growth. Let $S=(s,t)$ where s denotes program subsidy and t technical change. Then, the general form of (13) is:

$$C = C(W,y,s,t) \tag{14}$$

Totally differentiating (14) with respect to t and omitting the argument wherever ambiguity does not result, yields:

$$\frac{dC}{dt} = \sum_j \frac{\partial C}{\partial w_j}\frac{\partial w_j}{\partial t} + \frac{\partial C}{\partial y}\frac{\partial y}{\partial t} + \frac{\partial C}{\partial s}\frac{\partial s}{\partial t} \quad \frac{\partial C}{\partial t} \tag{15}$$

Applying Shephard's lemma and dividing through by C yields:

$$\dot{C} = \sum_j \frac{w_j x_j}{C}\dot{w}_j + \frac{\partial C}{\partial y}\frac{y}{C}\dot{y} + \frac{\partial C}{\partial s}\frac{s}{C}\dot{s} + \frac{1}{C}\frac{\partial C}{\partial t} \tag{16}$$

Where a dot over a variable denotes the logarithmic time derivative. If we define $\dot{TC} = \frac{\partial C}{\partial t}\frac{1}{C}$ to be the productivity contribution of technological change we can write

$$\dot{TC} = \dot{C} - \sum_j \frac{w_j x_j}{C}\dot{W}_j - \varepsilon_{cy}\dot{y} - \varepsilon_{cs}\dot{s} \tag{17}$$

Where $\varepsilon_{cy} \equiv \frac{\partial C}{\partial y}\frac{y}{C}$ *and* $\varepsilon_{cs} \equiv \frac{\partial C}{\partial s}\frac{s}{C}$ stand for the cost flexibility of output and the cost flexibility of subsidy, respectively. Consider now differentiating both sides of $C = \Sigma_j w_j x_j$ logarithmically with respect to time and arranging terms yields:

$$\dot{C} - \sum_j \frac{w_j x_j}{C}\dot{w}_j = \sum_j \frac{w_j x_j}{C}\dot{x}_j \tag{18}$$

Substituting equation (18) into (17) yields:

$$\sum_j \frac{w_j x_j}{C}\dot{x}_j = \varepsilon_{cs}\dot{s} + \varepsilon_{cy}\dot{y} + \dot{TC} \tag{19}$$

Defining the rate of change of total factor productivity as:

$$\dot{TFP} = \dot{y} - \sum_j \frac{w_j x_j}{C}\dot{x}_j \tag{20}$$

which is the difference between output and input growth rates. Substituting above one obtains:

$$\dot{TFP} = [-\varepsilon_{cs}\dot{s}] + [(1-\varepsilon_{cy})\dot{y}] + [-\dot{TC}]. \tag{21}$$

Equation (21) decomposes total factor productivity growth to its three components: technical efficiency, scale efficiency, and technological change. These components of TFP can be illustrated in the figure below. The first component represents the subsidy effect on technical efficiency and can be characterized by the vertical distance AB between actual unit cost and potential unit cost. An improvement in scale efficiency can be characterized by a movement along the average cost curve from *B* to *C*. This movement is captured by the second term of equation (21). Finally, technological change is captured by the third term of equation (21). This component can be characterized by a downward shift of the average cost curve and is represented by the distance CD.

Empirical estimation of (13) allows all components of (21) to be quantified. In this way the exact impact of subsidies on technical efficiency can be separated from scale efficiency and technical change. In the next section these procedures are empirically employed for the US dairy industry.

Empirical Model: An Application to US Dairy Sector

Policy background of the U.S. dairy sector

Most federal dairy programs have their origins in the legislation enacted in the 1930s and 1940s. The Agricultural Marketing Agreement Act of 1937 provided for classified pricing and revenue pooling in fluid milk markets under federal milk marketing orders[2]. The Agricultural Act of 1949 provided for a permanent program of dairy price supports. These two programs, along with import restrictions, constitute the major dairy programs in the United States. Import quota restrictions on manufactured dairy products are used to prevent imports of lower costs and subsidized dairy products from overwhelming the U.S. dairy price supports.[3]

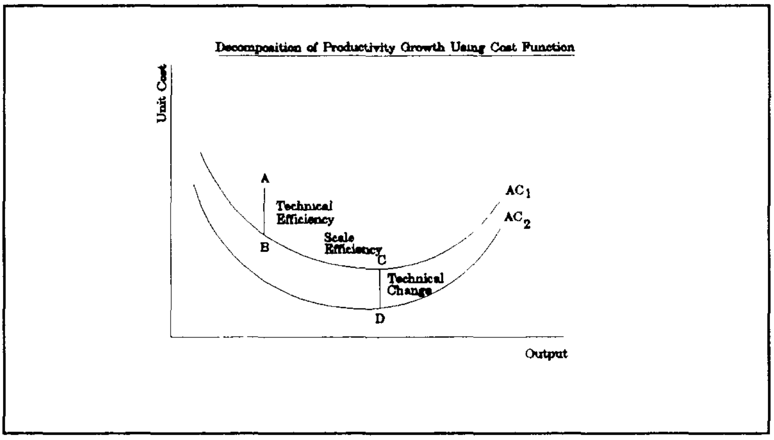
The basic structure of the dairy price support program remained the same from 1949 to 1981. Mainly, the federal government supported milk prices through purchases of butter, nonfat dry milk, and American cheese. Purchase price of the above products are set in a way to enable manufacturers to pay farmers the announced support price for milk. However, faced with continued surpluses and rising costs for this program, new legislation was enacted in 1981 to relate minimum support levels to the size of CCC purchases.[4] This represented a major departure from traditional price support policies. In 1981, legislation was passed to freeze support prices for two years and provided for a total deduction of $1 per hundredweight (cwt) from milk producers receipts to partially pay for the rising costs of the program.

In 1983, the federal government amended the 1949 Act to provide for a milk diversion program. Under this program, producers who elect to participate must agree to reduce their milk marketings by up to 30 percent below their base period production. By doing so producers received a fixed payment of $10 per cwt of reduction in their milk marketings. The main objective of this program was to bring milk production in line with demand for dairy products.

Recently, a new amendment to the 1949 Act provided for a voluntary dairy termination program, also known as the whole herd buy-out. According to the terms of this program, milk producers submit competitive bids to remove milk production for at least 5 years based on their 1985 marketings. Participating producers would slaughter or export all their female cattle. Further, a contracted producer could not use the plant for milk production or dairy cattle. One main objective of this program was the reduction of U.S. milk production capacity by removal of excess resources attracted to the dairy sector. Other changes in dairy price supports on January 1, 1988, 1989, and 1990, were linked to annual government purchases. Provisions authorized the secretary of agriculture to reduce the support price 50 cents per cwt if net price support purchases are to exceed 5 billion pounds milk equivalent or increase the support price if purchases are below 2.5 billion pounds milk equivalent.

The above are the major price support actions that have taken place since the passage of the 1949 Agricultural Act. Much of this period and up to the 1983 Dairy and Tobacco Adjustment Act, dairy programs, with the exception of import restrictions, have been used as income enhancing tools[5]. This resulted in excess resources used in milk production and processing. Increased revenues through the program were realized from higher milk prices, which resulted in increased production. Indeed, in 1983 dairy producers produced 10

Figure 1. Decomposition of *TFP* Using Cost Functions



percent more milk than consumers were willing to buy at the supported prices. In response to this situation, legislative changes of the early 1980s have come to address the issues of excess supply and rising government costs. Price support program nominal costs have exceeded 1 billion dollars a year since 1979-80. Costs reached a record high of 2.6 billion dollars in the marketing year 1982-83. Program costs for the 1988-89 marketing year were down to 698 million dollars. This represented an average of 5 thousand dollars per commercial dairy farmer.

This reduction in price supports, coupled with the dairy diversion program and the dairy termination program resulted in a better control of milk supply and program costs. Reduction in the dairy capacity by removal of excess resources should bring about more efficient use of resources, lower costs of production, and make the U.S. dairy sector more competitive.

Model specification

The impacts of program subsidy on technical efficiency level of the dairy sector is investigated within the framework of an endogenous technical efficiency cost function. Particularly, a restricted form of aggregate cost function in (13) is used while a translog specification is chosen for the empirical estimation (Christensen, Jorgenson, and Lau 1973). Such specification allows for a flexible description of the technology and subsidy effects. In particular, the following empirical form for the aggregate cost function is specified:

$$\begin{aligned}\ln C = \alpha_0 + \sum_j A_j Ln\, W_j + \frac{1}{2}\sum_j \sum_i B_{ji} Ln\, W_j Ln\, W_i \\ + \sum_j D_{js} Ln\, W_j Ln\, s + A_y Ln\, Y + G_s Ln\, s \\ + \frac{1}{2} G_{ss}(Ln\, s)^2 + V_t T + \frac{1}{2} V_{tt} T^2 \end{aligned} \qquad (22)$$

Where i, j denote inputs. For theoretical consistency of our specification, homogeneity of degree one in factor prices and symmetry conditions on the cross price effects are imposed. These conditions imply the following restrictions.

$\Sigma_j A_j \quad = 1,$

$\Sigma_j B_{ji} \quad = 0, \qquad$ for all $i = 1, ..., n$

$\Sigma_j D_{js} \quad = 0,$

$B_{ji} \quad = B_{ij}. \qquad$ for all $i, j = 1, ..., n$

The cost share equations, which are used in the estimation below, are derived using Shephard's lemma:

$$CS_j = \frac{\partial Ln\, C}{\partial Ln\, W_j} = A_j + \sum_i B_{ij} Ln\, W_i + D_{js} Ln\, s \qquad (23)$$

The translog cost formulation above allows for both neutral and biased subsidy effects. Neutral subsidy effect acts as a pure shift of the cost function leaving factor shares unchanged. This effect is characterized by the parameters G_s and G_{ss}. Biased subsidy effects represent shifts in the level of input utilization that alter the equilibrium factor shares, holding factor prices constant and are characterized by the parameter D_{js}. The cost elasticity of subsidy and the cost elasticity of output are derived as follows:

$$\varepsilon_{cs} \equiv \frac{\partial Ln\, C}{\partial Ln\, s} = G_s + G_{ss} Ln\, s + \sum_j D_{js}\; Ln\, W_j \quad (24)$$

$$\varepsilon_{cy} \equiv \frac{\partial Ln\, C}{\partial Ln\, y} = A_y \quad (25)$$

Estimates of the above cost elasticity of output and of the subsidy are used to account for the different sources of total factor productivity (*TFP*) and assess the effect of program subsidy on efficiency.

Data and Estimation Procedure

To implement the above specified model, annual data from 1972 to 1992 of the U.S. dairy sector were used. In particular, data on output, input prices, government expenditures on dairy support, and milk production costs were required. Three broad categories of milk production costs were assumed: costs of feed (*F*), costs of labor (*L*), and costs of capital and material (*M*). Feed costs included the costs of concentrate, hay, silage and haylage, pasture and other feeds. Labor costs included costs of hired labor and family labor. Capital and material costs included the costs of fuel, electricity, machinery, dairy supplies and other miscellaneous material inputs. All above costs were measured in dollars per hundredweight. For each of these categories of inputs a Tornqvist price index is computed; and 1977 was used as a base year. Milk production was measured in millions of hundredweight. Government expenditures on dairy support is measured in millions of dollars. Sources of these data are various issues of the *Economic Indicators of Farm Sector: Costs of Production-Livestock and Dairy*; as well as issues of *Agricultural Prices: Annual Summaries.*

The procedure used to estimate the above model follows Berndt and Christensen (1973*b*). The empirical cost function developed here is considered an approximation to the true underlying cost function. Hence, the cost function specified in (22) is jointly estimated with the cost share equations (23). Imposition of the homogeneity in factor prices and the symmetry condition across equations requires that one cost share be omitted. Iterated seemingly unrelated regression (ITSUR), which is invariant with respect to which share equation is dropped, is used for the estimation of the system (22) and (23).

Results

Table 1 presents the ITSUR estimates of the parameters of the translog model. Most of the parameters are statistically significant at the 5 percent significance level. Further, using the point estimates it is verified that the translog is well behaved at each sample point. That is monotonicity and concavity conditions are found to hold for each year.

To determine whether the subsidy had a major effect on costs of production, the value of the cost elasticity of subsidy is computed for every sample point making use of equation (24). As expected ε_{cs} was positive for every observation, implying that a 10 percent increase in subsidy had increased costs by up to 1.8 percent. This finding comes to corroborate the argument advanced by Leibenstein that protectionism may lead to up 50% increase in costs of protection. Part of this cost increase can be explained by the industry's failure to use the least-cost mix of inputs due to the biased effects of the subsidy. That is policies such as program subsidy can create distortions of optimal factor use. Indeed, parameter estimates of the translog function reveal that the effect of the subsidy has been input biasing. Namely, the subsidy has been feed saving (D_{1s} <0), neutral with respect to labor (D_{2s} is statistically insignificant), and capital and material using (D_{3s} >0).

Next, given estimates of the cost elasticity of subsidy ε_{cs} and the cost elasticity of output ε_{cy}, equation (21) is used to account for the different sources of TFP growth and assess the implications of subsidies on it. Accounting for these sources are presented in table 2. A closer look at the annual observations reveals the adverse effects of government subsidies on technical efficiency. This

Table 1. ITSUR Estimates of the Translog Cost Function Under SUR Error Terms Assumption

Parameter	Parameter Estimate	Standard Error	T for H0: Param=0
Intercept	-6.332083	7.188826	-0.881
A1	0.484337	0.118559	4.085
A2	0.291208	0.075984	3.832
A3	0.216350	0.061125	3.539
B11	-0.020288	0.053315	-0.381
B12	0.038375	0.031608	1.214
B13	-0.015050	0.001549	-9.715
B22	-0.062648	0.028275	-2.216
B23	0.024030	0.002073	11.591
B33	-0.008980	0.003049	-2.944
D_{1s}	-0.021702	0.006229	-3.484
D_{2s}	-0.003884	0.005993	-0.648
D_{3s}	0.025290	0.001230	20.560
A_y	1.163529	0.999017	1.165
G_s	0.316508	0.133315	2.374
G_{ss}	-0.037038	0 024142	-1.534
V_t	-0.110028	0.016854	-6.528
V_{tt}	0 006356	0.001602	3.969

1= Feed, 2= Labor, 3= Material, Y= Output, S= Subsidy, T= Technological change.
System R-square: 0.892.

Table 2. Accounts for Annual TFP Growth Rates and Program Subsidy

YEAR	$\dot{TFP}$	$\dot{TE} = [-\epsilon_{cp}\dot{s}]$	$\dot{SE} = [(1-\epsilon_{cy})\dot{y}]$	$\dot{TC}$	SUBSIDY
1972-73	0.18925	0.08564	0.00629	0.09732	135.8
1973-74	0.35668	0.26586	-0.00013	0.09096	31.4
1974-75	-0.14808	-0.23295	0.00026	0.08460	485.8
1975-76	0.37748	0.30588	-0.00663	0.07825	69.6
1976-77	-0.10178	-0.17034	-0.00333	0.07189	709.8
1977-78	0.10989	0.04276	0.00159	0.06554	446.4
1978-79	0.12589	0.06923	-0.00252	0.05918	244.3
1979-80	-0.04346	-0.08972	-0.00656	0.05282	1274.0
1980-81	0.02411	-0.01689	-0.00546	0.04647	1967.2
1981-82	0.03197	-0.00481	-0.00333	0.04011	2231.3
1982-83	0.02438	-0.00452	-0.00485	0.03376	2592.0
1983-84	0.05629	0.02385	0.00504	0.02740	1588.1
1984-85	-0.00044	-0.02248	-0.00900	0.02104	2168.8
1985-86	0.01082	-0.00374	-0.00012	0.01469	2401.9
1986-87	0.05106	0.04225	0.00047	0.00833	1221.7
1987-88	-0.00497	-0.00417	-0.00277	0.00198	1317.7
1988-89	0.04932	0.05269	0.00101	-0.00438	679.2
1989-90	0.01215	0.02743	-0.00454	-0.01074	504.8
1990-91	-0.05543	-0.03810	-0.00023	-0.01709	838.9
1991-92	0.12740	0.15473	-0.00387	-0.02345	232.0

latter has been the lowest (negative rates) for the years when government expenditures on dairy support has been the highest (1980-1986). This finding corroborates the advanced hypothesis that government subsidies are a source of technical inefficiencies.

Finally, input demand elasticities with respect to the subsidy were estimated to assess the impacts of subsidy on factor demands. The mean values of these estimates over the period of investigation are 0.028, 0.057, and 0.143 for feed, labor and capital and material, respectively. These estimates reveal the effect of program subsidy on input demand. Namely, a 10 percent increase in subsidy resulted in an increase of up to 0.2, 0.5, and 1.4 percent in the demand for feed, labor and capital and material, respectively.

Summary and Conclusions

The effects of protectionist policies in the form of program subsidy on technical efficiency was investigated in this study. Particularly, a negative relationship between protectionism and technical efficiency was hypothesized and tested in the U.S. dairy sector. To achieve this end and accommodate the endogeneity assumption of technical efficiency, Mundlak's concept of endogeneity is applied to technical efficiency and generalized within a dual framework. As a result production technology is described by an aggregate cost function defined conditional on a vector of state variables (i.e., subsidy) which in turn determines the level of technical efficiency. Subsidies, being an argument in the resulting cost function allow the identification of their impacts on technical efficiency and productivity growth. Implied in the analysis is that only changes in government subsidies affect technical efficiency; other potential influences of efficiency are assumed away.

The major finding of this study are as following: Subsidies in the dairy industry have been factor-biased. Namely, subsidy has been feed saving, neutral with respect to labor, and material using. Consequently, this distortion in input utilization has, in part, resulted in an increase in total costs of production by up to 1.8 percent for each 10 percent increase in subsidy.

Efficiency measurement indicates that dairy farmers have been the least efficient during the years when program subsidies reached record highs. This finding corroborates the advanced hypothesis and Leibenstein's *X*-inefficiency theory. Government dairy price supports have been for the most part of the period of investigation used as income enhancing tools, which might have contributed to reduce managerial motivation, effort, and led to negative technical efficiency rates.

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Endnotes

1. The general linear form has been used for most general numeric approximations. It's attractive for several reasons: It can depict as many effects as the number of parameters it contains. It's linear in parameters. Finally, it can approximate (under relatively weak assumption) any arbitrary, twice continuously differentiable function.

2. Classified pricing is the Federal order pricing system under which regulated processors pay into the pool for grade A milk according to the class in which it is used. With revenue pooling producers are paid a weighted average, or "blend", price for all uses of milk in a particular order or market. Producers participating in the pool receive identical uniform blend prices, with adjustments for butterfat content and location of the farm.

3. Imports of manufactured dairy products are set at 2.5 billion pounds of milk equivalent. This represents only 2 percent of U.S. milk production in 1989.

4. Commodity Credit Corporation (CCC): A government-owned and operated corporation authorized to borrow funds from the U.S. treasury to operate the USDA's price and income support programs, to manage government-owned stocks, and to administer their disposal through domestic and export programs.

5. Import quotas enhance prices to milk producers.