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The Determination of Technology and Commodity Policy in the U.S. Dairy Industry

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Abstract
United States dairy policy includes both predatory and productive components. The milk price support program is designed to transfer income to dairy farmers while research and extension expenditures are designed to increase social welfare. The purpose of this chapter is to provide an empirical example of the theory developed in the previous chapter. It has long been recognized the government research and extension policies have been significant contributors to technological advance in agriculture (Evenson and Kislev 1976, Evenson, Waggoner, and Ruttan 1979). The advent of technological change on agriculture and its policy implications was first noted by Schultz (1945, 1953). Some, like Cochrane (1958) in characterizing his famous technological treadmill thesis, argued for price supports in order to compensate farmers for the adverse effects of research on farmers' welfare. Indeed, commentators like Thurow (1981) and Schlesinger (1984) argue that public good provision in agriculture is one of the few major economic success stories of government intervention in the history of the United States. Nevertheless, one of the most stylized facts in government policy intervention in agriculture is the pervasive level and overwhelming evidence of underinvestment in public research (Ruttan 1982). Concomitant to this notion, economists have alleged that governments 'overinvest' in commodity policies because of the associated deadweight losses generated.

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CONTENTS

THE DETERMINATION OF TECHNOLOGY AND COMMODITY POLICY IN THE UNITED STATES DAIRY INDUSTRY

Harry de Gorter, David J. Nielson and Gordon C. Rausser

1. INTRODUCTION

United States dairy policy includes both predatory and productive components. The milk price support program is designed to transfer income to dairy farmers while research and extension expenditures are designed to increase social welfare. The purpose of this chapter is to provide an empirical example of the theory developed in the previous chapter. It has long been recognized that government research and extension policies have been significant contributors to technological advance in agriculture (Evenson and Kislev 1976, Evenson, Waggoner, and Ruttan 1979). The advent of technological change in agriculture and its policy implications was first noted by Schultz (1945, 1953). Some, like Cochrane (1958) in characterizing his famous technological treadmill thesis, argued for price supports in order to compensate farmers for the adverse effects of research on farmers' welfare. Indeed, commentators like Thurow (1981) and Schlesinger (1984) argue that public good provision in agriculture is one of the few major economic success stories of government intervention in the history of the United States. Nevertheless, one of the most stylized facts on government policy intervention in agriculture is the pervasive level and overwhelming evidence of underinvestment in public research (Ruttan 1982). Concomitant to this notion, economists have alleged that governments 'overinvest' in commodity policies because of the associated deadweight losses generated.

This chapter examines the way in which predatory and productive policies are determined in the context of the U.S. dairy sector. The paper develops an analytical and empirical model of the endogenous determination of research expenditures and price supports in the dairy industry. The results also provide an explanation for the persistent underinvestment in agricultural research and for the apparent contradiction between the two public policies that both increase output and yet individually have opposite effects on social welfare.

2. ANALYTICAL MODEL

In this section, a stylized model of the U.S. dairy industry is developed. This model is used to analyze the joint determination of government expenditures on cost reducing public research and on price support activities. The analysis is performed under the assumption of competitive market conditions using a deterministic, static, and partial-equilibrium representation of the dairy industry.

In the United States, the price of milk at the farm level is supported through a standing offer by the Commodity Credit Corporation (CCC) to purchase several of the manufactured dairy products at pre-announced price levels.[1] These purchases guarantee that the market price of Class II milk does not fall below the support price. Class II milk refers to that milk which is purchased for use in producing a variety of manufactured dairy products such as cheeses and butter. Class I milk used for fluid milk consumption is purchased at a fixed price above the Class II support price. The difference between these two prices is called the Class I differential and is assumed to be set exogenously in the analysis to follow. Farmers receive a blend price which is calculated as a weighted average of the Class I and the Class II prices.

In the notation adopted here, Class I and Class II prices are linked by a fixed differential, α,

$$P_I = P_{II} + \alpha \qquad (1)$$

In equilibrium, the total supply of milk is equal to the total demand for milk. The total demand is made up of the three components D_I, D_{II}, and NR; where D_I and D_{II} are the Class I and Class II levels of milk demand, respectively, and NR represents the milk equivalent units of CCC purchases of manufactured dairy products, often referred to as net removals of the government.[2] Net removals (NR) are determined endogenously according to the following expression:

$$NR = S - D_I - D_{II} \tag{2}$$

The blend price received by farmers (P_b) is given by[3]

$$P_b = \frac{P_I D_I + P_{II}(D_{II} - NR)}{S} \tag{2}$$

The government choice variable for the commodity policy is the Class II price support P_{II}. The fluid milk price faced by consumers and the blend price received by farmers are uniquely related to the choice variable, P_{II}, as described in equations (1), (2), and (3).

Government costs, G, due to the CCC price support program are given by:

$$G = \delta P_{II}(S - D_I - D_{II}) \tag{3}$$

where $\delta = 0.85$. The value of δ indicates that only 15 percent of CCC removal costs are recovered from sales (Tauer and Kaiser 1990). This number is an average figure for the past 30 years and indicates that much of the CCC resale revenues are offset by the processing, storage, and handling costs incurred by the CCC after the product has been purchased at the support price.

The government also intervenes in the dairy industry in providing publicly funded research which is designed to increase productive efficiency at the farm level. Improvements in productive efficiency have the effect of shifting outward and downward the supply schedule for milk. Public research expenditures are denoted here by E. Total expenditures on both productive and predatory policies are provided and financed by the government with consumers as taxpayers being coerced to pay for the entire budgetary costs.

In order to understand the ways in which these two policy instruments, P_{II} and E, affect the various characteristics of the market for milk, it is necessary to consider the behavior of the individual actors who comprise the demand and supply side of the market. Suppose *n* identical consumers choose their optimal level of Class I and Class II milk consumption by maximizing on a preference function represented by a twice differentiable, additive and separable utility function $U(q_j^d, Z) = U(q_j) + Z$ where j = I, II; q is the amount of milk consumption; Z is the numeraire good $= M_o - \Sigma_j p_j q_j^d - E/n - \delta P_{II}[S - \Sigma_j q_j^d]$ and M_O is endowment income. Each consumer and producer takes both P_{II} (and hence P_I and P_b) and E as given in making their consumption and production choices. At optimality, $U_q(q^d) - \lambda p = 0$ where λ is the Lagrange multiplier of the budget constraint. Assuming that the consumption behavior of individual consumers has no effect on market prices, the following are optimal consumption schedules $q_j^d = U_q^{-1}(\lambda * p_j) = q_j(p_j)$q where λ* is the constant marginal utility of income. The industry demand schedule for each class of milk is the summation over *n* consumers

$$\sum_{i=1}^{n} \sum_{j} q_{ij}^d(P_j) = D_j(P_j).$$

Suppose m producers choose their individual level of production, q^s, so as to maximize profits $\Pi = P_b q - C(q^s, E)$ where $C(q^s,E)$ represents individual i's cost function. It is assumed that $C(q^s,E)$ is everywhere increasing in q^s and decreasing in E; i.e., $\partial C/\partial q^s = C_q > 0$ and $\partial C/\partial E = C_E < 0$. It is further assumed that E decreases marginal units; i.e., $\partial^2 C/\partial q^2 \partial E = C_{QE} < 0$.

Profit maximization results in $P_b = C_q^s(q^s, E)$, which can be used to solve for the individual's supply schedule, $q^s(P_b, E) = C_q^{s-1}(P_b, E)$. The industry supply schedule, $S(P_b, E)$, is the summation over m producers,

$$\sum_{k=1}^{m} q_k^s(P_b, E) = S(P_b, E).$$

The government's choice problem is to choose the optimal levels of P_{II} and E. Because of the indirect interactive effects between the two instruments (i.e., the price supports affect the efficiency and income distribution of research, and vice-versa), a rational and informed government will choose the level of the two instruments jointly. Suppose that the government's objective function is characterized by the indirect welfare function, $V(P_I, P_{II}, P_b, P_{-j}, Y)$, where P_{-j} is the vector of all other prices in the economy and Y reflects aggregate social income[4]. We assume that the government's objectives can be characterized by the preference function $V(V_1, V_2)$. This function is assumed to be linear and additive in its arguments which consist of a weighted sum of aggregate consumer income (net of optimal consumption expenditures) and optimal producer profits. Thus, the governments decision problem is to choose P_b and E so as to satisfy the following:

$$\max_{P_b, E} V = w_1 V_1\left(P^*, M^*\right) + w_2 V_2\left(II_2\right) \tag{3}$$

where w_1, w_2 are political weights (that sum to unity)[5] assigned to the welfare of consumers and producers—respectively, $M^* = M_0 - E - P_{II} \cdot \{S^*[P_b(P_{II}, E), E] - D_I(P_I) - D_{II}(P_{II})\}$ and $\Pi^* = [P_b(P_{II}, E)]S[P_b(P_{II}, E), E] - C\{S[P_b(P_{II}, E), E], E\}$. The superscript star represents equilibrium levels.

The necessary first-order conditions for a maximum, using Roy's identity, can be written as

$$w_1\left[-D_I - D_{II} + \frac{\partial M}{\partial P_{II}}\right] + w_2 \frac{\partial \Pi}{\partial P_{II}} = 0 \tag{4}$$

$$w_1 M_E + w_2 \Pi_E = 0 \tag{5}$$

where $V_y = V_m = V_\Pi$ = marginal utility of income. The net effect of the price supports on taxpayers income is described by

$$\frac{\partial M}{\partial P_{II}} = -\delta\left[NR + P_{II} \cdot \left(\frac{\partial S}{\partial P_{II}} - \frac{\partial D_I}{\partial P_I} - \frac{\partial D_{II}}{\partial P_{II}}\right)\right] < 0. \tag{6}$$

The effect is negative and the negative impact is stronger—the larger are the values of δ, the levels of net removals, the Class II price support, and the absolute values of both the supply or the demand elasticities.

The effect of price supports on the level of producer profits is described in the equation,

$$\frac{\partial \Pi}{\partial P_{II}} = S\left(\frac{\partial P_b}{\partial P_{II}}\right) \geq 0. \tag{7}$$

This expression depends critically on the effect of a change in Class II support prices on the blend price, which is indirect and complex as shown by

$$\frac{\partial P_b}{\partial P_{II}} = \left[\frac{S + \frac{\partial D_I}{\partial P_I} \bullet (P_I - P_{II})}{S^2 + \frac{\partial S}{\partial P_b} \bullet (P_I - P_{II}) \bullet D_1}\right] S. \tag{8}$$

The effect of research expenditures on taxpayer income is given by

$$M_E = -\delta P_{II}\left(\frac{dS}{dE}\right) - 1 < 0. \tag{9}$$

Equation (8) demonstrates that the cost of research to consumers is affected by the presence of a price support. The price support has an impact upon taxpayer costs, not only through CCC purchases as reflected in the values of δ and the Class II price support but also as a result of the responsiveness of supply to research expenditures.

Impact of Research On Producer Profits

The impact of research on producer profits is given by

$$\Pi_E^* = S\left(\frac{\partial P_b}{\partial E}\right) - C_E \lesseqgtr 0. \tag{10}$$

where

$$\frac{dS}{dE} = \frac{\partial S}{\partial P_b}\frac{\partial P_b}{\partial E} + \frac{\partial S}{\partial E} \tag{11}$$

and

$$\frac{\partial P_b}{\partial E} = \frac{-dS}{dE}\left(\frac{D_I(P_I - P_{II})}{S^2}\right). \tag{12}$$

Substitution of (11) into (12) yields,

$$\frac{\partial P_b}{\partial E} = \frac{-S_E D_1 \bullet (P_I - P_{II})}{S^2 + \dfrac{\partial S}{\partial P_b} \bullet (P_I - P_{II})}. \tag{13}$$

The effect of research expenditures on the blend price of milk received by farmers is indirect in that it operates through changes in the relative weights in the blend price formula. Because research expenditures ultimately have the effect of shifting out the industry supply schedule, they increase the amount of milk produced at any given price. A change in production at given price levels affects the total consumption of Class II milk via increased NR but leaves the demand for Class I milk unchanged. Thus, it is the change in the relative percentage of the milk which is used for Class I and Class II purposes which alters the weights in the blend price formula shown in equation (2) and which results in an indirect change in the blend price, even if the Class I and Class II prices remain unchanged.

The Joint Determination of Research and Price Supports

Expressions (6) through (13) emphasize the way in which each policy affects the consumer, producers and taxpayers. Farmers always gain from the provision of Class II price supports. They may, however, lose from publicly funded research expenditures, even if a price support is present. In their role as taxpayers, consumers lose from the provision of either policy. In the case of public research expenditures, the losses which consumers feel as taxpayers can easily be offset by gains in their role as consumers. These gains to consumers are generated by the price reductions which accompany the productivity enhancing results of research.

Expressions (4) and (5) characterize the way in which the welfare of consumers and producers are balanced against each other in the government's choice of P_{II} and E. Equation (4) indicates that the level of the price support must be chosen such that the weighted marginal cost to consumers and taxpayers of increasing the price support, $[w_1(-D_I-D_{II} + \partial M/\partial P_{II})]$, is just equivalent to the weighted marginal benefit of the subsidy to producers $[w_2\partial\Pi/\partial P_{II}]$. Equation (5) dictates that E be chosen such that the weighted marginal cost to consumers of additional E (i.e., w_1M_E) is just equated with the weighted marginal benefit to producers ($w_2\Pi_E$).

Given, for the moment, a fixed level of research expenditures E, Equation (4) can be used to solve for the level of P_{II} which is consistent with an optimal solution to the government's choice problem,

$$P_{II} = \left[(D_I + D_{II})\left(1 - \frac{1}{\delta}\right) + S\left(\frac{\gamma}{\delta}\frac{dP_b}{dP_{II}} - 1\right)\right] / \frac{\partial NR}{\partial P_{11}}. \tag{4a}$$

The price support is "effective"—i.e., expression (4a) becomes positive—if $\gamma > 1$. Given that $\delta < 1$, the price support becomes ineffective if demand exceeds supply at the political optimal level of P_{II}. Expression (4a) shows that Class II support prices are positively related with the relative political weight given to farmers γ and the response of net removals to the support price $\partial NR/\partial P_{II}$.

The politically optimal level of research expenditures can be determined by substituting in the appropriate terms into equation (5)

$$\gamma\left(S\frac{\partial P_b}{\partial E}-C_E\right)\delta P_{II}\left(\frac{dS}{dE}\right)=1. \tag{5a}$$

If research expenditures are evaluated assuming equal welfare weights (i.e., $\gamma = 1$) and that no price supports exist, then the optimal condition is $-C_E = 1$. This characterizes an efficient allocation of resources, and a rationally chosen allocation, if one ignores the existence of price supports and the political component of government policy. However, the optimal level of research must reflect the effects of research on price support costs as well, as shown in equation (5a). The optimal level will also reflect the nature of the politically determined preferences as represented by γ.

It is clear from the nature of the necessary conditions for a maximum in the government's choice problem that the way in which each of the two policies affects the choice of the other is dependent upon, among other things, the value of the relative weights as reflected in γ, and whether farmers are helped or injured at the margin by the effects of additional research. Casual observation of the government involvement in the dairy industry suggests that producer income is weighted more heavily than that of consumers/taxpayers for the purpose of determining dairy policy (i.e., $\gamma > 1$). We now turn our attention to the way in which producer incomes are affected by research-induced shifts in their cost functions.

When Are Research and Price Supports Complementary Policy Instruments?

Having outlined the nature of the government's decision problem in setting each of the two policy instruments jointly, we examine whether the provision of price support activity tends to result in more or less research being provided than would otherwise be the case. It was shown in the previous chapter that it depends on the parameters of the market. It is possible that the government is able to use the price support instrument to compensate farmers for losses which they experience as a result of research-induced technical change. As shown in the previous chapter, it can occur when government places a greater weight upon producer income than it places upon consumer/taxpayer income (i.e., when $\gamma > 1$) and when farmers welfare is injured as a result of the research program. In such cases, the existence of price support policy allows a greater level of research to be provided than would otherwise be the case.

It is possible to examine whether the chosen levels of the two policies are positively related to each other in the neighborhood of the optimal pair (E^*, P_{II}^*) by totally differentiating expression (5a) after utilizing (4a) to substitute for the chosen level of P_{II}. This allows the slope of the choice of E as a function of P_{II} to be determined in the neighborhood of the chosen pair (P_{II}^*, E^*). It is convenient to work with simplified expressions (4a') and (5a') in examining the sign of the slope at this reaction function. Expressions (4a') and (5a') are derived from (4a) and (5a) under the simplifying assumption that only one demand curve is faced by producers. This allows for ease of presentation without affecting the features of interest. Operating under this simplifying assumption, expressions (4a') and (5a') take the following form:

$$P = \frac{(\gamma - 1)S}{S_p - D_p} \tag{4a'}$$

$$-C_E = \frac{1 + PS_e}{\gamma}. \tag{5a'}$$

The slope, $dE(P_{II})/dP_{II}$ is described by $(d^2V/dEdP_{II})/(d^2V/dE^2)$:

$$\frac{dE(P_{II})}{dP_{II}} = -\left\{ -\left[\frac{-\left(1+\frac{S_{PE}}{S_p S_E}\right)}{S_p - D_p} + \left(\frac{P_M\left(S_{pp}-D_{PP}\right)}{S_p - D_p}\right)\frac{1}{\eta^s\left(S_p - D_p\right)} + \left(\frac{1}{1-\gamma}\right)\frac{P}{S\eta^s} \right]\right\} / \frac{d^2V}{dE^2}.$$

The sign of $dE(P_{II})/dP_{II}$ is guaranteed to be positive if the first term in brackets in equation (14) is sufficiently negative and the second term is sufficiently positive. The first term in brackets is negative only if S_{pe} is negative, and the second term in brackets is positive only if S_{pp}-D_{pp} is positive. Notice that it is not a necessary condition that either term be of a particular value or sign for expression (14) to be positive. As for the third term in brackets, we assume that $\gamma > 1$, so that it is strictly positive.

The value and sign of S_{pe} depends upon the particular form of the response of the supply schedule to research induced technical change. A pivot-like shift in the supply curve, representing a large impact of the technical improvement on variable costs relative to fixed costs, can cause dE(P)/dP to be negative. On the other hand, if the shift in the supply schedule is a parallel one (as assumed in Alston, Edwards, and Freebairn 1988), the first term in brackets takes a value of zero and the likelihood of complementarity between E and P_{II} is increased. The value and sign of (S_{pp} - D_{pp}) represents the degree of concavity of net removals with respect to the support price. A constant elasticity supply curve with an elasticity less than one, then this term is more likely negative, increasing the likelihood that $dE(P_{II})/dP_{II}$ is positive. Note in the earlier discussion that producer welfare at the margin is more likely positive with a more inelastic supply curve. Hence, $dE(P_{II})/dP_{II}$ is more likely positive under conditions when farmers are hurt by public research expenditures. This implies that governments are more likely to choose P_{II} and E as complementary instruments when farmers lose from research. If the supply and demand functions are linear, (S_{pp} - D_{pp}) = zero, and a parallel shift in the supply curve due to research (as in Alston, Edwards, and Freebairn 1988), guarantees that dE/dP_{II} is positive.

III. EMPIRICAL EVIDENCE

In this section, we test the hypotheses put forward in the previous section. An empirical model is developed to study the market for milk at the level of the farm in the United States. This model is used to demonstrate that public research expenditures and the level of the price support for milk do appear to be capable of being employed in complementary fashion. That is to say, the model suggests that public research expenditures appear to be higher in the presence of price support then they would be otherwise. Furthermore, both consumers/taxpayers and farmers appear to be better off with the existence of price supports than they would be in their absence. In this sense, the price support policy appears to be Pareto-improving in comparison to the alternative.

This section of the paper begins by describing the relevant characteristics of the milk supply industry and the empirical model employed here to capture the features of interest. The remaining discussion focuses on the results of an empirical model of the U.S. dairy industry.

Public Research and Milk Supply

As in other agricultural sectors, the real level of public expenditures on agricultural research has increased steadily over time in the U.S. dairy sector (Figure 1). Meanwhile, productivity in the production of milk has increased dramatically. Two measures of productivity, labor per unit of output and milk produced per cow, are also reported in Figure 1. These two figures demonstrate the dramatic improvement in productivity in historical milk production. This increase in productivity has resulted in a sharp reduction over the same period of time in the number of milk cows as well as in the number of operating dairy farms in the United States. These developments in agriculture are not limited to the livestock sector but also characterize developments in the crop sectors (see Griliches 1956 classic work on the corn hybrid).

The estimated effects of public research expenditures on milk supply and on each of the inputs—grain concentrates, hay, labor, cows, and capital—are reported in Table 1. The econometric model employed in generating these estimates is specified in Nielson (1989). The model of aggregate milk production was developed from micro-level foundations. Individual firms were hypothesized to operate under a fixed coefficient technology in labor, capital and cows. They were specified to be able to substitute between hay and grain in the composition of the rations of the cows. This substitution between the feeds is captured in a standard Cobb-Douglas specification for the yield of milk per cow as a function of the amount of each of the feeds. Thus producers employ a fixed coefficient technology in some of the inputs while having the ability to substitute between the feeds. The model was constructed so as to incorporate heterogeneity between producers. Because producers are specified to differ in the relative efficiencies in which they produce milk, they also differ in their profitability. As a consequence, entry and exit of individual producers of differing abilities is observed to correspond to changes in the economic environment.

The model is constructed such that the aggregate expressions for output and for the input demands are exactly consistent with the theory of the profit maximizing behavior of the individual heterogeneous firms. At the aggregate level, substitution between each of the inputs is possible in response to changes in the economic environment. This is in contrast to the fixed coefficient technology which prevails between some of the inputs at the micro-level. This feature of substitutability at the aggregate level is a consequence of the entry and exit from the industry to firms with differing abilities.

The aggregation procedure, combined with the distribution of the efficiency abilities between individual producers, leads to long run expressions for aggregate output and aggregate input demands which are log linear in the prices. The parameters of these aggregate expressions are related to each other both within and across equations as a direct implication of the theory.[6] These restrictions are imposed to comply with the implications of the theoretical model.

The empirical results reported in Table 1 indicate that the long-run elasticity of milk supply with respect to public research is 0.25. This estimate is similar to that found in a recent study on the effects of research on milk supply in Canada by Fox, Roberts, and Brinkman (1990). Their study reported long-run elasticities of Canadian milk supply to be 0.258, 0.57, and 0.707 with respect to provincial, federal and U.S. research expenditures, respectively. The estimate of 0.25 is somewhat below the estimate of 0.538 for the United States which was reported by Bredahl and Peterson (1976) in one of the earliest studies to report an elasticity of milk supply with respect to research expenditures. Although the elasticity of research found in this study is somewhat lower than those reported in those benchmark studies, the level of responsiveness of milk production to research expenditures which is reported here is still quite sufficient to allow research expenditures to have an important impact upon the industry.

The long-run own-price elasticity of milk supply is estimated to be 0.94. This estimate is lower than reported in most of the previous studies, many of which estimate supply to be significantly own-price elastic (perhaps as high as 5) in the long run (for an example, see Chavas and Klemme 1986). Most existing estimates of the own-price elasticity of the supply of milk have not been estimated in a procedure which explicitly isolates the impact of research on supply. The positive influence of research on productivity has been confounded with the price term in past studies such that higher supply elasticities are generated compared to when the two effects have been explicitly accounted for as in this study.

The Joint Determination of P_{II} and E in the U.S. Dairy Sector

The big question is whether or not consumers are better off in having the government implement price supports to compensate farmers for the negative effects of research on profits. This section derives the outcome for the U.S. dairy sector. The results of model simulations are presented incorporating all of the theoretical features and empirical supply estimates of the U.S. dairy sector derived above. The supply model with the expressions described in Table 1 are incorporated for milk supply and the input demands (grain, hay, capital, labor, and cow numbers). Constant elasticity demand functions are specified for Class I and Class II milk consumption with elasticities of -0.25 and -0.55, respectively.[7] All parameters are evaluated at their long-run values in the simulations. Specific details of U.S. dairy policy such as the producer assessment levied in the early 1980s are also included in the analysis.[8]

From the baseline simulation, we generated the actual values of the relative political weights, γ, defined in each of the first-order conditions, (4) and (5). Note that each first-order condition is determined from the maximization of the government objective function with respect to each policy instrument P_{II} and E. The value of γ in each case is determined independently of each other; let us denote γ_p as the relative political weight determined from equation (4) and γ_e as the relative political weight determined from equation (5). These weights can be viewed as the revealed preferences of the government with respect to the choice of each policy instrument.

The values for γ_p and γ_e are presented in Table 2. The estimated values of γ_p are very stable. Furthermore, it is surprising how close the values of γ_p are to those of γ_e for many of the time periods under consideration. The values of each weight are derived from very different estimated parameters as to how each instrument affects the dairy market. Nevertheless, the estimated weights are in the same range of values for the entire time period. This is a very important result and lends strong support to our hypothesis that governments rationally choose price supports and research expenditures jointly, and that the interaction effects between the two policies are explicitly recognized by politicians.

The baseline values for the key parameters are given in Table 3. The actual blend price received by farmers, the predicted supply, actual research expenditures and initial (status quo) producer welfare are presented. Because the absolute value of consumer welfare is undefined in the constant elasticity case, only changes in consumer and hence in net social welfare are reported in the following policy simulation runs.

To determine the importance of how governments choose price supports and research expenditures jointly, a special policy simulation was undertaken whereby research expenditures were set to zero and price supports remained endogenous; i.e., determined by the political process. This scenario evaluates the implication of fixing research (in this particular example, it is set at zero) and allowing commodity policy to be determined by governments. The results are given in Table 4. The blend price increases substantially but not enough to offset the supply decreasing effects of zero research expenditures. Hence, output declines compared to the baseline solution. Farmers benefit in this scenario while consumers lose substantially. Taxpayers, on the whole, benefit because supplies have decreased and costs of surplus disposal declines. Farmers gain in this scenario due to the inelasticity of the demand curve. Limiting supply by reducing E to zero allows them to capture more profits than was possible in the base scenario. However, the final column in Table 4 indicates that society as a whole is worse off under this set of policies than it is under the base scenario.

The results in Table 4 confirm the theoretical model's prediction that, under conditions of an inelastic demand curve, a relatively more elastic supply curve and a significant effect of research on costs, farmers can be hurt as a result of research expenditures. Because dairy farmers do lose from research, price supports are used to partially compensate them. If price supports were not available to governments but research was determined endogenously, farmers would lose so much from the elimination of price supports that research expenditures would also be eliminated. Results in Table 5 confirm that, when price supports are eliminated, i.e., prices are determined where supply equals demand and no price discrimination occurs, research expenditures, although determined endogenously through the political process, are driven to zero. Farmers benefit relative to the status quo but consumer and net social welfare declines sharply. Hence, it is in society's interest to have price supports in order to compensate farmers for the profit reducing effects of public research expenditures.

Finally, the "social optimal" levels of research expenditures as prescribed by welfare economists who typically ignore the political process (i.e., set γ_e and γ_p equal to one) are given in Table 6. As expected, price supports are not employed in this scenario; and prices are determined solely by market supply and demand forces. The results indicate that optimal research expenditures with farmers and consumers having equal political weights are slightly over 4 times the actual research expenditures (see Table 3 for values of the latter). This result is consistent with Griliches (1964, p. 969) who estimated that a fourfold increase in research expenditures for agriculture would yield positive net social benefits for the U.S. economy. More recently, Fox (1985) finds that optimal expenditure levels for public research were on the order of four times recent actual expenditure in U.S. agriculture. Hence, the results of this paper are entirely consistent with recent studies. As expected, farmers lose with research expenditures inducing an increase in supply compared to the status quo. As a result, market prices fall substantially. However, net welfare for society as a whole improves.

V. IMPLICATIONS AND CONCLUDING REMARKS

In the evaluation of agricultural policy, it should be recognized that interactions between research and commodity policy may result in these two types of policies being selected jointly. Research increases social welfare; but, under the conditions which characterize the dairy industry, producers lose while consumers gain. Because dairy farmers have significant political influence, it appears that commodity policy allows governments to partially compensate producers and increase research expenditures from what they otherwise would be so that a Pareto improvement can occur. This is the case, despite the presence of the deadweight losses which accompany price intervention policies. The model results also indicate the way in which the joint determination of the two policies can lead to underinvestment in research in U.S. agriculture.

Strong support for the hypothesis that governments choose research and price supports jointly was given by the almost identical values of the political weights generated from each of the two policy-decision rules. Empirical results support the hypothesis of the paper that price supports and public research expenditures are used as complementing instruments. Consistent with intuition, the model predicts that governments will intervene with price supports more heavily in sectors with a more inelastic demand, elastic supply, and highly productive research. These same industries are expected to have a greater level of underinvestment.

A current empirical example of the interaction between the two types of policies in the U.S. dairy industry has arisen in the public debate over the introduction of the bovine growth hormone. This growth hormone is a protein which occurs naturally in cows. When the natural level of the hormone is supplemented by injections, the amount of milk which each cow can produce is increased, even if all other inputs are held constant. The research efforts which ha e made this biotechnology available were, to a significant degree, publicly funded. The adoption of the bovine growth hormone will push out the supply schedule for milk and will increase the amount of milk which will be produced for any fixed level of price support.

It is widely recognized that such a development will increase the cost of maintaining any given level of the price support. It is also widely feared among farmers that this will lead to a lowering of the level of the price support. These farmers feel that the price of milk will be lowered to the point that, despite their now lower-per-unit costs of production, they will generate less profit in the new environment than they are currently able to generate. Accordingly, they expect the price policy to react to the presence of the new technology. They realize that the research policy has results which interact with the price policy selection.

Dairy industry participants also recognize that the research policy which has made the introduction of the growth hormone possible is endogenous to the market for milk. Of course, the characteristics of this market are heavily influenced by the level of the support price. The endogeneity of the research policy to such characteristics is evident in the public response to the anticipated widespread adoption of the bovine growth hormone. Many have called for a halt to the further development of the growth hormone. Wisconsin and Minnesota, both important dairying states, have passed temporary legislation to ban the use of the bovine growth hormone. While these developments have revealed some concern about the effect of the hormone on the quality of the milk, more important concerns have focused on the anticipated economic consequences of the widespread adoption of the hormone.

This episode, as it unfolds in the dairy industry, is indicative of an awareness among industry participants that interactions between the two types of policies do exist. Furthermore, participants and observers of the dairy industry believe that, to at least some extent, the two types of policies are jointly determined. They are actively engaged in attempting to influence the portfolio of policies which will be implemented. In the U.S. dairy industry, further research-induced technical advancement is being blocked (or, at the least, slowed down) while a price-support policy continues to channel income from consumers and taxpayers to producers. This outcome is one in which research and research-induced advances may well appear to be underutilized or underfunded from a purely social welfare perspective. However, the existence of a price support indicates that the welfare of the two groups is not weighted equally by policymakers. Moreover, since interactions between the two policies necessitate that the two instruments be jointly determined, it follows that the two instruments are complements. What would otherwise appear to be a combination of "underinvestment" in the advancement of technology and "overinvestment" in a price-support intervention can be understood within the framework advocated in this paper.

Footnotes

[1]The CCC has made positive net purchases each year since 1955. However, market prices often are above Class II support prices during a year, since CCC purchases are seasonal. The Class II support price P_{II} was found to be 99.9 percent of the market price on average for the time period 1955-1988. Hence, we ignore the distinction between P_{II} and the market price for manufacturing products in this study.

[2]For a review on the mechanics of the U.S. dairy program, see Ippolito and Masson (1978).

[3]Imports of manufacturing milk products in the United States are very low and stable throughout the historical time period under investigation. Hence, they are ignored throughout the analysis, without consequence for our results.

[4]This formulation assumes negligible income effects with expenditures on price supports and research; i.e., it is assumed that income is independent of changes in the price vector. This is equivalent to asserting that the same goods do not serve as both inputs and outputs (Varian, p. 276).

[5]These implicit weights put on producer and consumer welfare by government reflect the manner in which changes in economic welfare affect political support. The underlying conceptual framework that generates these political weights is not elaborated upon in this paper. The weights are simply taken as given.

[6]See Nielson (1989) and Nielson, Rausser, and de Gorter (1990) for a detailed presentation of the economic model and the methodology underlying this econometric specification of the supply model.

[7]The assumed elasticities are taken from Sullivan et al. The weighted average total demand for milk for the time period 1955-1988 is -0.418. Tauer and Kaiser estimate a total demand function with an elasticity of -0.39.

[8]A complete documentation of the model simulation input and output with data are available from the authors upon request.

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Table 8-1. Estimated Milk Supply and Input Demand Functions, 1955-1988

Independent Variables	S	G	H	L	K	C
	Dependent Variables					
Pb	0.94722	1.9472	1.9472	1.9472	1.9472	1.9472
E	0.25521	0.25521	0.25521	0.25521	0.25521	0.25521
PG	-0.85502	-1.8550	-1.8550	-1.8550	-1.8550	-1.8550
PH	0.54771	0.54771	-0.45229	0.54771	0.54771	0.54771
PL	0.70151	0.70151	0.70151	-0.29849	0.70151	0.70151
PK	-0.36867	-0.36867	-0.36867	-0.36867	-1.36867	-0.36867
PC	0.02725	0.02725	0.02725	0.02725	0.02725	0.97275
PAST	-0.0247	-0.00636	-0.014244	-0.00630	0.00589	-0.00555
Trend	0.00102	0.00922	-0.01259	-0.05700	0.06087	0.00428
Interest Rate	0.02512	-0.00523	0.02100	-0.00939	-0.05995	0.02172
Constant	1.5443	1.1351	4.0687	4.0491	9.2980	9.6684
R^2	0.52	0.52	0.50	0.94	0.52	0.64
Durbin Watson	0.85	0.86	0.96	0.52	0.86	1.17

Note: S = ln (milk production in the United States)[a]
G = ln (grain concentrates fed to dairy cows)[b]
H = ln (hay fed to dairy cows)
L = ln (labor allocated to milk production)
K = ln (shipments of dairying equipment ($1,000 units))
C = ln (milking cows)

Pb = ln (price received for milk)a
E = ln (publish research expenditures)b
PG = ln (price of grain concentrates)
PH = ln (price of hay)
PL = ln (price of hired agricultural labor)
PK = ln (index price of farm machinery)
PC = ln (non-feed cost of owning one cow one year)
PAST = measure of pasture conditions as a percent of normal (100% indicates normal conditions)
Trend = time period (1955=1, ...,1 988 = 34)

[a]All prices and dollar denominated variables are deflated to constant 1988 U.S. dollars.

bThis variable is constructed as a weighted average of the total public expenditures on dairy-related research each year for the ten years prior to the current year. The weights employed are the inverse of the degree of lag of the year in which the expenditures were made. This corresponds roughly to the declining yet lingering effect of research dollars over time which other studies have adopted.

Source: D.J. Nielson, G.C. Rausser, and H. de Gorter. "A Supply Model for Studying Change in the U.S.. Dairy Industry." Department of Agricultural and Resource Economics Working Paper No. 551, University of California at Berkeley, 1990.

Table 2. The Predicted Values of γ_p and γ_E, 1955-1988

				γ_p					
1955	2.190	1956	2.198	1957	2.311	1958	2.350	1959	2.273
1960	2.271	1961	2.383	1962	2.374	1963	2.530	1964	2.320
1965	2.305	1966	2.186	1967	2.157	968	2.227	1969	2.194
1970	2.188	1971	2.151	1972	2.080	1973	2.243	1974	2.518
1975	2.293	1976	2.170	1977	2.144	1978	2.119	979	2.192
1980	2.189	1981	2.173	1982	2.112	1983	2.214	1984	2.196
1985	2.224	1986	2.239	1987	2.318	1988	2.275		
				γ_E					
1955	2.422	1956	2.325	1957	2.842	1958	3.261	1959	3.259
1960	3.130	1961	5.652	1962	5.339	1963	30.377	1964	4.269
1965	4.422	1966	3.182	1967	3.407	1968	4.505	1969	4.133
1970	3.802	1971	3.578	1972	2.970	1973	4.071	1974	8.327
1975	4.140	1976	3.563	1977	3.169	1978	2.695	1979	2.878
1980	2.510	1981	3.032	1982	2.951	1983	3.678	1984	3.281
1985	3.185	1986	3.201	1987	2.898	1988	2.570		

Table 3. Baseline Values of Key Variables, 1969-1988

	Blend Price ($/cwt)	Predicted Milk Supply (billion) pounds)	Research Expenditures (million dollars)	Initial Producer Welfare ($10 million)
1969	5.49	122.301	0.50103	1,054.976
1970	5.71	122.761	94.39174	1,039.875
1971	5.87	130.145	97.34285	1,086.583
1972	6.07	151.464	100.3818	1,265.831
1973	7.14	111.208	107.1495	1,029.180
1974	8.338	6.768	119.9956	844.208
1975	8.75	104.950	130.7995	982.870
1976	9.66	130.308	137.1910	1,273.619
1977	9.72	132.899	145.4188	1,227.809
1978	10.6	140.471	158.4417	1,314.672
1979	12.	124.828	179.5407	1,188.736
1980	13.	125.111	202.5284	1,137.001
1981	13.8	124.358	230.7399	1,086.943
1982	13.55	143.015	244.5635	1,156.407
1983	13.57	126.941	254.1655	960.712
1984	13.46	134.356	260.2187	966.869
1985	12.75	128.014	274.6003	866.214
1986	12.51	131.880	280.6629	844.156
1987	12.54	118.829	295.5395	741.682
1988	12.24	123.663	312.7387	736.304

Table 4. Effects of Eliminating Research Expenditures with Endogenous Price Supports

	Milk Supply	Blend Price	Δ in Δ in Consumer Welfare	Δ in Δ in Producer Welfare	Δ in Δ in Taxpayer Welfare	Δ in Δ in Net Social Welfare
	billion pounds	$/cwt	$10 million			
1969	92.420	9.155	-1,127.977	274.455	123.547	-729.976
1970	92.842	9.530	-1,108.503	272.716	114.599	-721.188
1971	98.707	9.827	-1,107.096	292.999	77.477	-736.620
1972	115.653	10.234	-1,175.139	363.779	-14.776	-826.137
1973	89.161	12.674	-1,443.006	435.566	-2.376	-1,009.816
1974	81.400	17.454	-2,113.333	815.270	-325.827	-1,623.889
1975	87.310	16.150	-1,586.360	526.331	-90.136	-1,150.165
1976	99.288	16.250	-1,416.303	358.876	107.094	-950.333
1977	101.509	16.393	-1,324.148	353.870	72.390	-897.888
1978	107.699	17.949	-1,385.764	392.095	33.129	-960.540
1979	96.692	20.541	-1,474.183	387.422	83.275	-1,003.486
1980	95.875	22.001	-1,347.728	337.604	107.866	-902.258
1981	95.846	23.487	-1,329.552	339.466	93.506	-896.5808
1982	109.176	22.757	-1,212.466	317.418	70.944	-824.1046
1983	98.288	22.872	-1,191.486	312.209	82.838	-796.4399
1984	102.175	22.253	-1,118.500	267.385	124.608	-726.5077
1985	101.989	22.383	-1,200.217	350.600	8.265	-841.3538
1986	104.561	21.682	-1,145.781	329.920	22.298	-793.5637
1987	102.698	23.865	-1,379.697	489.942	-147.340	-1,037.0958
1988	103.770	22.798	-1,234.718	414.531	-87.058	-907.2444

Table 5. Effects of Eliminating Price Supports with Endogenous Research Expenditures

	Milk Supply	Blend Price	Δ in Consumer Welfare	Δ in Producer Welfare	Δ in Taxpayer Welfare	Δ in Net Social Welfare
	billion pounds	$/cwt)		$10 million		
1969	90.059	8.908	-1,044.075	205.581	163.244	-675.250
1970	89.950	9.217	-1,009.017	190.044	172.191	-646.782
1971	91.781	9.100	-886.389	101.357	264.499	-520.533
1972	98.494	8.638	-695.179	-94.451	509.885	-279.745
1973	88.390	12.559	-1,412.135	409.638	-2.376	-1,004.873
1974	80.468	17.243	-2,065.589	776.461	-325.827	-1,614.955
1975	86.510	15.994	-1,552.447	498.017	-90.136	-1,144.566
1976	96.079	15.696	-1,295.264	252.255	202.716	-840.293
1977	95.508	15.372	-1,118.629	167.625	267.502	-683.502
1978	98.479	16.331	-1,081.782	105.269	358.974	-617.538
1979	96.162	20.422	-1453.950	369.720	83.275	-1,000.955
1980	95.253	21.851	-1,325.015	317.988	107.866	-899.161
1981	95.532	23.416	-1,319.507	329.872	93.506	-896.129
1982	100.422	20.911	-971.380	96.678	323.536	-551.165
1983	98.475	22.442	-1,140.169	316.998	82.838	-740.332
1984	102.352	21.797	-1,064.527	271.913	128.442	-664.172
1985	101.701	22.187	-1,177.348	343.635	8.265	-825.448
1986	104.519	21.324	-1,104.208	329.033	22.298	-752.876
1987	102.529	23.574	-1,347.618	485.846	-147.340	-1,009.112
1988	103.228	22.673	-1,220.729	402.223	-87.058	-905.564

Table 6. The Effects of `Social Optimal' Levels of Research (Prices determined where supply=demand)

	Milk Supply	Blend Price	Δ in Consumer Welfare	Δ in Producer Welfare	Δ in Net Social Welfare
	billion pounds	$/cwt	million $	$10 million	
1969	125.472	3.85	371.300	-294.797	406.797
1970	125.739	3.97	397.796	-298.455	411.445
1971	128.407	3.93	407.883	-368.113	499.635
1972	139.030	3.70	448.631	-556.726	733.208
1973	124.561	5.33	491.357	-167.149	265.829
1974	113.294	7.27	564.999	118.087	168.933
1975	122.324	6.75	623.843	-98.848	170.773
1976	137.255	6.60	687.760	-355.760	534.104
1977	136.228	6.47	722.444	-389.031	560.100
1978	142.013	6.77	872.355	-465.570	660.795
1979	138.984	8.42	1,016.078	-259.397	417.132
1980	138.146	8.92	1,204.774	-275.158	417.940
1981	136.518	9.992	1,102.576	-223.021	363.145
1982	142.261	9.099	1,070.620	-380.163	543.214
1983	138.906	9.947	1,002.231	-161.846	366.567
1984	145.280	9.566	1,090.792	-195.143	414.416
1985	144.022	9.741	1,139.142	-113.996	220.385
1986	147.980	9.386	1,152.238	-113.015	256.893
1987	146.360	1,0.160	1,355.084	13.533	58.850
1988	147.061	9.768	1,424.773	-37.555	71.149

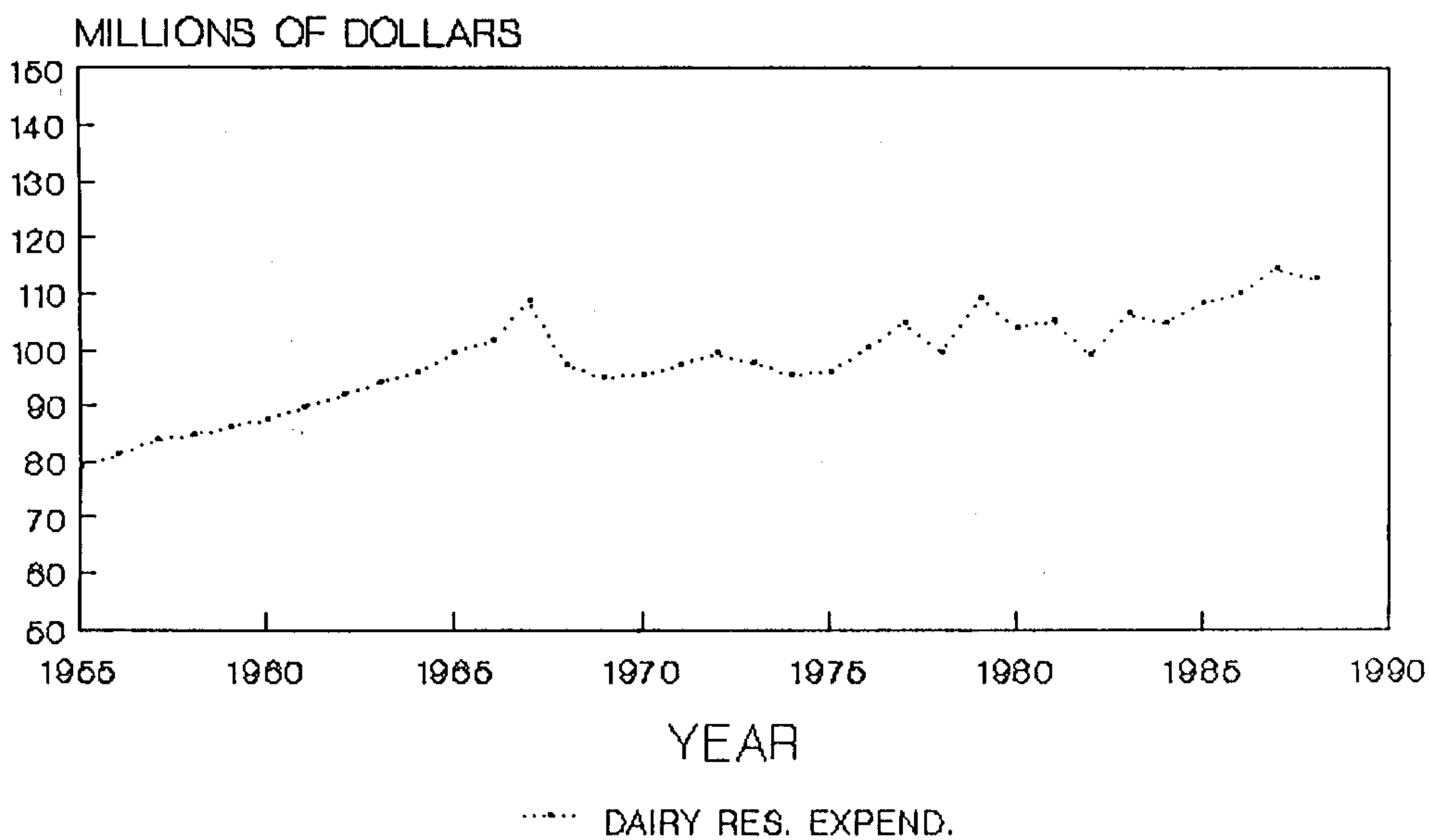

Figure 1. Public Research Expenditures on U.S. Dairying, 1955-1988

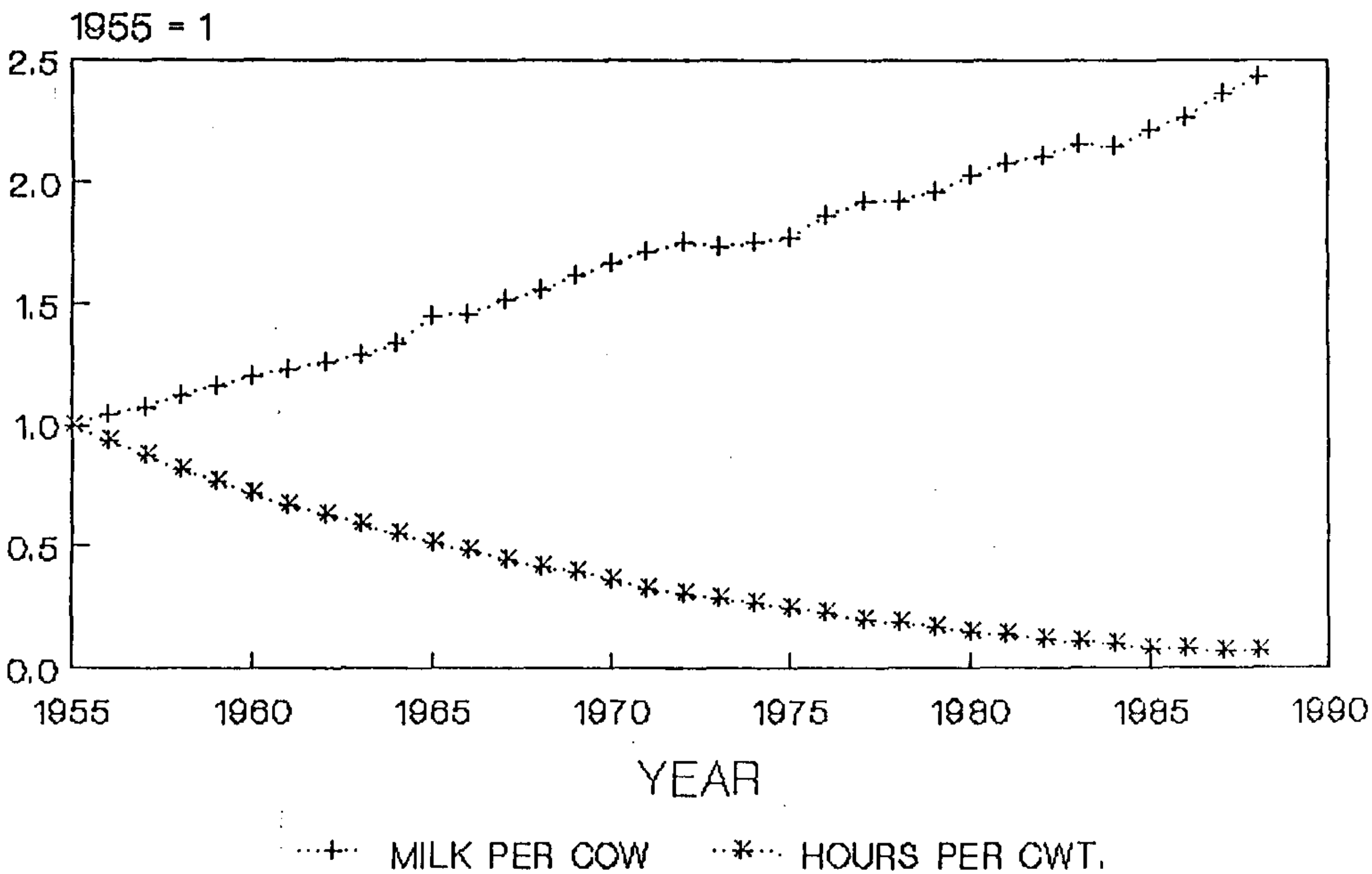

Figure 2. Productivity Improvements in U.S. Dairying, 1955-1988