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EVALUATING THE LEVEL AND DISTRIBUTION OF BENEFITS FROM DAIRY INDUSTRY RESEARCH

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A model and associated formulae are developed to estimate the size and distribution of benefits generated by different types of research for the Australian dairy industry. Particular attention is given to the influence of policy interventions on the estimates. The estimates of aggregate research benefits differ for free market assumptions versus current policy assumptions, but quantitatively the differences are small. By contrast, estimates of the distribution of benefits between different groups of consumers and farmers are significantly altered by the policy interventions.

Introduction

Assessment of who gains from research, and how much, requires that attention be given to the nature of the research advance, and to the large influence of government policy distortions. Research can be directed to new product development and shifts of demand, to reducing off-farm production costs, to reducing farm production costs, and to improving the institutional arrangements and the flow of market information. Australian dairy products are sold to three broad market categories, fresh milk, manufactured dairy products for domestic sales, and export sales of manufactured products. For each product, off-farm storage, transport, processing and distribution activities are at least as important a contributor to total consumer prices as are farm costs. Hence, research to reduce costs at both farm and off-farm levels is of interest. Regulated prices for fresh milk, the all milk levy, export subsidies financed by the levy, and the payment of pool prices to farmers are important aspects of dairy industry policy influencing prices paid and received and quantities bought and produced. Each of these considerations, among others, are expected to influence the national benefits of alternative research options and also the distribution of the benefits to consumers of fresh milk, to consumers of manufactured dairy products, and to producers.

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The objectives of this paper are to present a framework for evaluating the benefits of research for the Australian dairy industry, and to illustrate the use of the model, in quantifying national social benefits and benefits perceived by consumers of fresh milk and of manufactured dairy product and by farmers. The model is based on changes in economic surplus caused by research-induced shifts in supply and demand curves. It builds on related studies by Freebairn, Davis and Edwards (1982), Mullen, Alston and Wohlgenaut (1989) and Alston, Edwards and Freebairn (1988). Particular attention is given to the effects of dairy industry price policy distortions on measured benefits. The policy arrangements refer to current circumstances as described in Industry Commission (1991). Using data for 1989-90 prices and quantities, together with estimates of key elasticities reported in the literature, the framework is used to estimate the gross annual benefits of research, and their distribution, for research that results in increases in demand for fresh milk and for manufactured dairy products, lower off-farm production costs for fresh milk, manufactured dairy products sold domestically and for export, and lower on-farm production costs.

Model Context

Behaviour of the Australian dairy industry is represented by a partial equilibrium model of supply and demand functions, with government policy altering price signals in specified ways, and with prices and quantities adjusting to clear markets. The dairy industry is disaggregated in two directions. First, the final product market is separated into domestic fluid milk sales (about a quarter of current milk production), domestic manufactured dairy product sales (about a half) and export sales of manufactured dairy products (about a quarter). This breakdown captures quite distinct markets and it enables a good representation of dairy industry policy.

A multistage production process is represented in a simplified way. Each final buyer product is represented as a combination of farm production of a homogeneous product, milk, and the three off-farm activities of converting farm milk to fresh milk, domestic manufactured dairy products and export manufactured dairy products. The off-farm activities represent about a half of the retail price of fresh milk and of the price of export products and about two-thirds of the retail price of domestic manufactured dairy products. This multistage production process enables assessment of the benefits of an array of categories of research directed to the on-farm, off-farm and demand expansion areas.

In order to simplify the model, special assumptions, and in some cases perhaps unduly restrictive assumptions, will be placed on the off-farm activities and the way in which research affects these activities. First, a constant input-output relationship is assumed between farm milk and each of the three final products. Alternatively, the elasticity of substitution between farm milk and other inputs in produc-

ing fresh milk and manufactured dairy products is assumed to be zero. Models relaxing this assumption are described in Alston and Scobie (1983) and Freebairn, Davis and Edwards (1983). Second and allied, off-farm research is assumed to lower costs by reducing the level of inputs other than farm milk, that is, the farm milk to retail product ratio remains unchanged. For some forms of research this assumption may be inappropriate. These assumptions simplify both graphical and algebraic presentations used below, and they may be a reasonable approximation for a large number of potential applications.

To simplify the analysis, it is assumed that the supply of non-farm inputs such as labour and capital to the industry is perfectly elastic and that the off-farm activities only generate normal profits. Together, these assumptions mean no surplus is earned by the off-farm segments of the dairy industry, both before and after research, and that cost reductions induced by research are fully passed on to consumers and to farmers. A constant mark-up of final product prices over the farm milk price is used to reflect the cost of the various off-farm activities using the familiar model described in Tomek and Robinson (1981), Campbell and Fisher (1982) and others.

A perfectly elastic export demand curve is assumed. In the context of the long run, this seems a reasonable approximation. Currently, Australia provides about 6% of world trade of manufactured dairy products. However, the effects of national and trade policies may mean that Australia has some market power. Presumably such distortions underlie the position taken by the Industry Commission (1991) and others who use a less than perfectly elastic curve, but still a highly elastic one (with an assumed elasticity of −20). The perfectly elastic assumption simplifies the calculation of changes of economic surplus because the world price establishes a constant opportunity return.[1]

Australian dairy industry policy exhibits important variations between the different States. The key arrangements applying to the dominant producing States of Victoria, Tasmania and South Australia, which collectively account for over 70% of national production, are assumed to apply to all of Australia. Policy significantly influences market outcomes in three main ways. First, prices for fresh milk, both at the farm and retail levels, are regulated at prices substantially above free market levels, with farm prices about double that received for milk used for export manufactured products. Various quota arrangements ensure that these prices are not undercut. Relative to a free market,

[1] Where the export demand curve is less than perfectly elastic, a marginal export return curve, which itself is downward sloping, becomes the reference point. The situation raises the opportunity for Australia to raise national welfare by restricting exports, the so-called "optimal tax". Given the diverse pattern of different effective tax rates and subsidies on different Australian exports and imports, we then enter difficult unchartered waters of the theory of the second best. Also, as noted in Alston, Edwards and Freebairn (1988), many analytical results become ambiguous with the large country case.

fresh milk prices are higher, consumption is lower, there is a large transfer from consumers to producers, and there is a small deadweight loss from too little consumption.

Second, a levy collected on all milk produced is used to fund a subsidy on exports. This has the effect of raising domestic prices for manufactured dairy products above the export price by the amount of the export subsidy. Import restrictions and large transport costs ensure that the domestic price is not undermined by imports. Algebraically, the relationships between the levy of t on all production $\bar{Q}$, the export subsidy s, the farm-level export return P_f^e and the farm-level return on the sale of domestic manufactured products $\bar{P}_f^m$ is

$$s = t\bar{Q}/\bar{Q}^e \tag{1}$$

$$\bar{P}_f^m = P_f^e + s \tag{2}$$

where $\bar{Q}^e$ is export sales. In 1989-90, the levy t was nearly two cents a litre, giving an export subsidy s of eight cents a litre, resulting in a price for milk used for domestic sales of manufactured products of about 28 cents a litre or 40% above the export parity price of 20 cents a litre. Relative to a free market outcome, the levy and export subsidy arrangements result in higher prices for domestic manufactured product sales, lower manufactured domestic product sales, a transfer from consumers to producers, and a deadweight loss from too little consumption.

Third, producers are paid a weighted average, or pool, return. In the case of Victoria, Tasmania and South Australia, returns from fresh milk, domestic manufactured products and export sales are pooled; but only returns from domestic manufactured product sales and exports are pooled for the other States.[2] To simplify the analysis, the dominant method is assumed to apply to all producers. Algebraically, the pool price, $\bar{P}^p$, is measured as

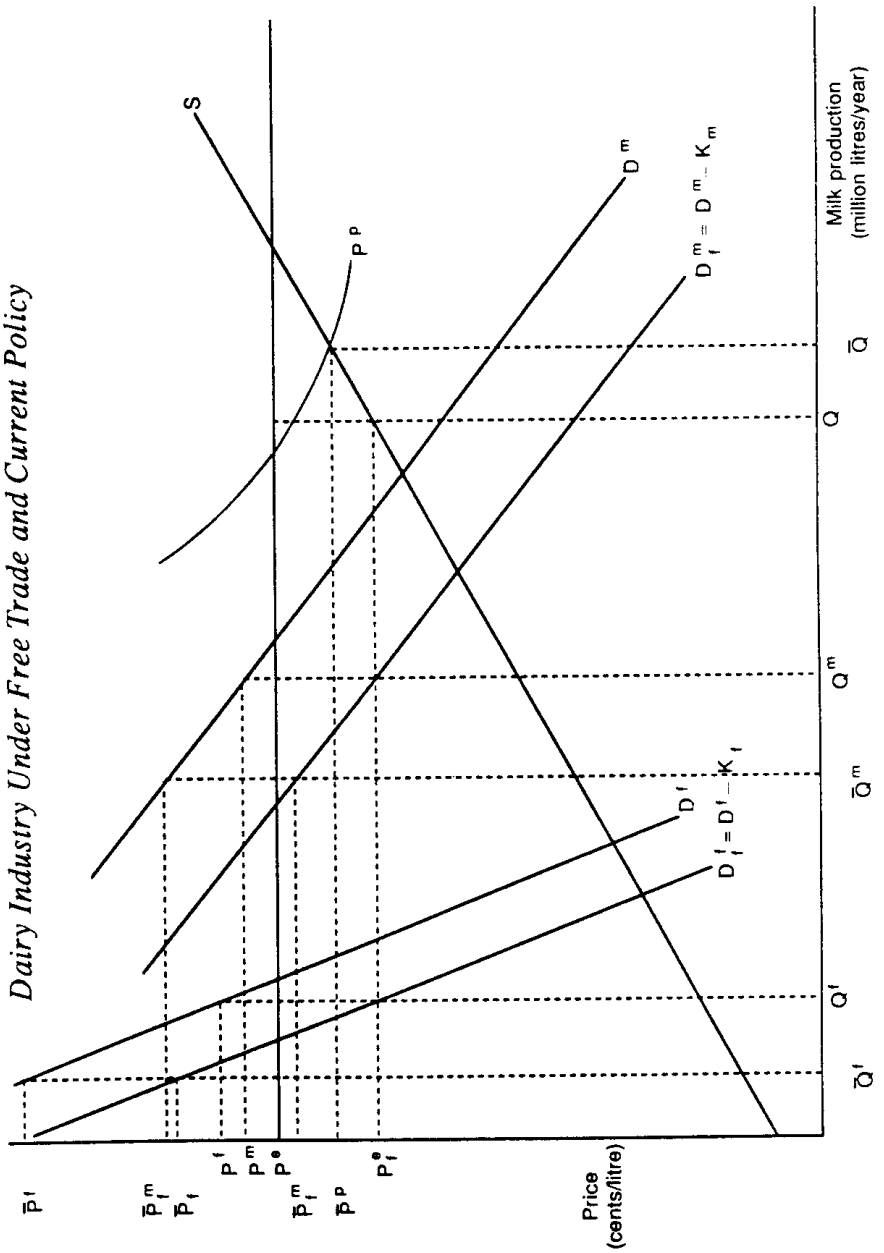
$$\bar{P}^p = (\bar{P}_f^f\bar{Q}^f + \bar{P}_f^m\,\bar{Q}^m + P_f^e\bar{Q}^e)/(\bar{Q}^f + \bar{Q}^m + \bar{Q}^e) \tag{3}$$

$$= P_f^e + (\bar{P}_f^f - P_f^e)\,\bar{Q}^f/\bar{Q} + (\bar{P}_f^m - P_f^e)\,\bar{Q}^m/\bar{Q} \tag{3'}$$

where $\bar{P}_f^f$ and $\bar{Q}^f$ are the farm-level fluid milk price and quantity, $\bar{P}_f^m$ and $\bar{Q}^m$ are the domestic farm-level manufactured price and quantity, with $\bar{P}_f^m$ as defined in (2), and P_f^e and $\bar{Q}^e$ are the farm-level export price and quantity, and $\bar{Q} = \bar{Q}^f + \bar{Q}^m + \bar{Q}^e$ is total production. This pool price is a more complicated version of that described in Parish (1962). In general, it is above the export return P_f^e and it falls with increased output. For 1989-90 circumstances, the pool price, assuming $\bar{P}_f^f = 35$, $\bar{P}_f^m = 28$, $P_f^e = 20$, $\bar{Q}^f = .25\bar{Q}$, $\bar{Q}^m = .5\bar{Q}$, $\bar{Q}^e = .25\bar{Q}$ and $t = 2$, would be

[2] A quota arrangement for fluid milk sales applies in NSW, Western Australia and Queensland.

FIGURE 1
Dairy Industry Under Free Trade and Current Policy



27.75 cents per litre or 39% above the export price. Relative to a free market outcome, the pool price arrangement results in returns for marginal farm production exceeding export returns (and also the return on marginal sales), for increased production and exports, and a deadweight loss due to too much production.

Diagrammatically, the dairy industry in free market mode and under current policy arrangements is described in Figure 1. The farm milk supply curve is given by S; the export demand is given by the perfectly elastic curve at export price P^e, with farm level export demand returns given by P_f^e, where $P_f^e = P^e - K_e$, in which K_e is the off-farm cost of converting farm milk into manufactured products for export; D^f is the fluid milk demand at retail and D_f^f is the derived fluid milk demand at farm level with K_f being the margin to convert farm milk into fresh milk at retail; and D^m is domestic retail demand for manufactured products and D_f^m is the derived demand for milk used to produce domestic manufactured products with K_m being the off-farm marketing margin.

Under free market conditions of Figure 1, the export farm return P_f^e is the key price which is equated for all milk uses, that is, $P_f^e = P_f^f = P_f^m$. The various marketing margins then determine the retail prices of fresh milk, P^f, and domestic manufactured products, P^m. Exports are given by production less domestic consumption, that is, $Q^e = Q - Q^f - Q^m$.

Outcomes under current dairy policy are illustrated also in Figure 1. A superscript bar is used to distinguish price and quantity outcomes under the policy scenario. Prices for fluid milk, both at the retail and farm levels, are policy determined at above free market levels, and quantity adjusts to the predetermined price. The export subsidy arrangements of equations (1) and (2) determine the prices for domestic manufactured products at levels above those of free trade, with $\bar{P}_f^m = P_f^e + s$. The curve P^p is the locus of weighted average prices paid to farmers as described in equation (3). Its intersection with the supply curve determines production at $\bar{Q}$. Exports are given as $\bar{Q}^e = \bar{Q} - \bar{Q}^f - \bar{Q}^m$.

Comparison of the outcomes of a free market with the outcomes under current dairy policy confirm the effects of policy on prices and quantities noted above. In turn, these outcomes can be used to compute deadweight losses of too little domestic consumption and too much production.

Evaluation of Effects of Research

Research, when adopted, is assumed to shift one or more of the supply and demand curves shown in Figure 1. The following types of research can be identified:

- farm production productivity gains shift the supply curve outwards. This could take the form of increased output per unit input (a horizontal shift)

or lower cost per unit output (a vertical shift), with both interrelated by the slope of the supply curve.[3]

- off-farm productivity gain for export products. This would be represented as a reduction in the term K_e and as an upward shift of the curve P_f^e.
- off-farm productivity gain for domestic manufactured products. This would be represented as a reduction in the term K_m, and as an upward shift of the curve D_f^m.
- off-farm productivity gain for fluid milk. This would be represented as a reduction in the term K_f and as an upward shift of the curve D_f^f.
- product development for fluid milk, represented as an upward shift of the D^f curve, and in turn of the D_f^f curve.
- product development for domestic manufactured products, represented as an upward shift of the D^m curve, and in turn of the D_f^m curve.

Because of the infinite export demand elasticity assumption, shifts in export demand are not relevant. The simplifying assumption of a constant off-farm mark-up and no economic surpluses in the off-farm sector means that no purpose is served in distinguishing between the demand shift and off-farm productivity gains for domestic sales. Both result in equal upward shifts of the farm-level demand curve.

The research-inspired shift of supply or demand will lead to a new equilibrium pattern of prices and quantities. Clearly, the response under current Australian dairy policy will be different from that occurring under a free market. Such differences will be important in measuring and interpreting the gains from research.

Gross annual benefits[4] of research are measured with reference to comparisons of consumer and producer surpluses achieved in the before-research and after-research comparative static outcomes. Consideration will be given to changes in:

- consumer surplus for domestic consumers of fluid milk;
- consumer surplus for domestic consumers of manufactured dairy products;
- producer surplus or quasi-rents for farmers;
- national benefits measured as the difference in social valuations of what is sold (measured off domestic demand curves for local sales and off the export demand curve for exports) less the social costs of production (measured as areas under the farm and off-farm supply curves).

Note that, by assumption, no change in economic surplus is modelled for off-farm producers or for foreign consumers.

[3] Formally if dQ/dP is the slope of the supply curve, a horizontal shift ΔQ is related to a vertical shift ΔP as $\Delta Q = dQ/dP\ \Delta P$.

[4] A full evaluation would need to consider the time profile of gross annual benefits, costs of the research and its extension, and application of a present value method to reach an overall investment assessment.

The usual and well-known qualifications on changes in economic surplus as measures of welfare gains applies here as in related evaluations of the benefits of research. Important strong assumptions include the absence of a significant role for other distortions and second-best considerations, and that a dollar is a dollar regardless of its distribution.

Research Benefits With a Free Market

An assessment of the benefits of research and the distribution of the benefits under free market assumptions provides a point of reference for the later assessment under current dairy policy conditions.

Research leading to a reduction in on-farm costs is shown in Figure 2[5] as an outward shift of the supply curve[6] from S to S' with a per unit cost reduction of k_s. Under free market conditions and an infinitely elastic export demand curve at price P^e there are no price changes, no change in domestic consumption, and no change in consumer surplus. All the benefits of on-farm research go to producers as area $ACEB$ equal to $\frac{1}{2}\, k_s\,(Q + Q')$, where k_s is the per unit cost reduction, Q the original free market supply and Q' the after-research free market supply.

The effects of research which reduce off-farm costs of transporting, processing, storage and distribution dairy products for the domestic market are shown in Figure 3. The particular case shown is a reduction of off-farm costs for fluid milk of k_f. Initially the cost reduction leads to an upward shift of the farm-level demand for milk for the fluid milk market from D_f^f to $D_f'^f$. Because of the assumed infinitely elastic export demand, farm price remains at its initial level of P_f^e, total production remains unchanged at Q, and prices and quantity for domestic sales of manufactured dairy products remain at pre-research levels P^m (and P_f^m not shown) and Q^m. The research-induced off-farm cost reduction for fluid milk is passed forward in full to consumers of fluid milk as a retail price drop of $k_f = P^f - P'^f$. In turn, domestic consumption of fluid milk rises from Q^f to Q'^f, with an offsetting fall in exports. Domestic consumers of fluid milk gain $P'^f P^f AB = DEFG = \frac{1}{2}\, k_f\,(Q^f + Q'^f)$. This gain also is the aggregate social gain.

Similar reasoning can be used to evaluate the benefits of research which reduces the off-farm costs for manufactured products sold on the domestic market. A cost reduction of k_m per unit generates a surplus

[5] In order to simplify the diagram, Figure 2 does not include the demand curves for fluid milk or the farm-level demand curve for domestic manufactured dairy products shown in Figure 1.

[6] A parallel shift is assumed for simplicity and in view of the discussion by Rose (1980). Other shifts will not affect measures of consumer benefits if the shift is measured at the new equilibrium point. Producer and social benefits will be greater (smaller) if the supply curve shift is convergent (divergent) than estimated in the paper for a parallel shift.

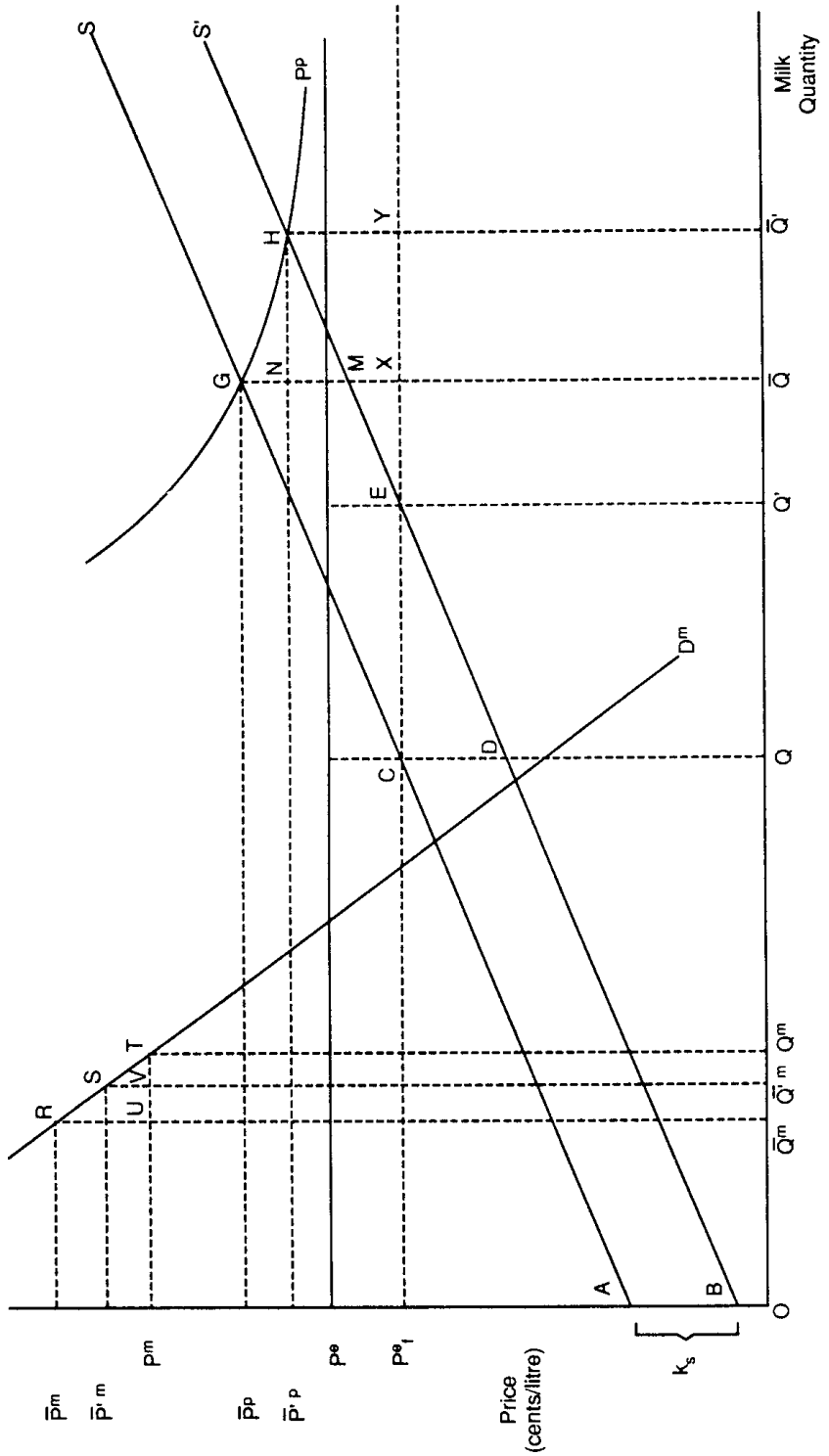


FIGURE 2
Research Shifts Farm Supply from S to S'

FIGURE 3
Research Reduces Off-farm Fluid Milk Costs by k_f

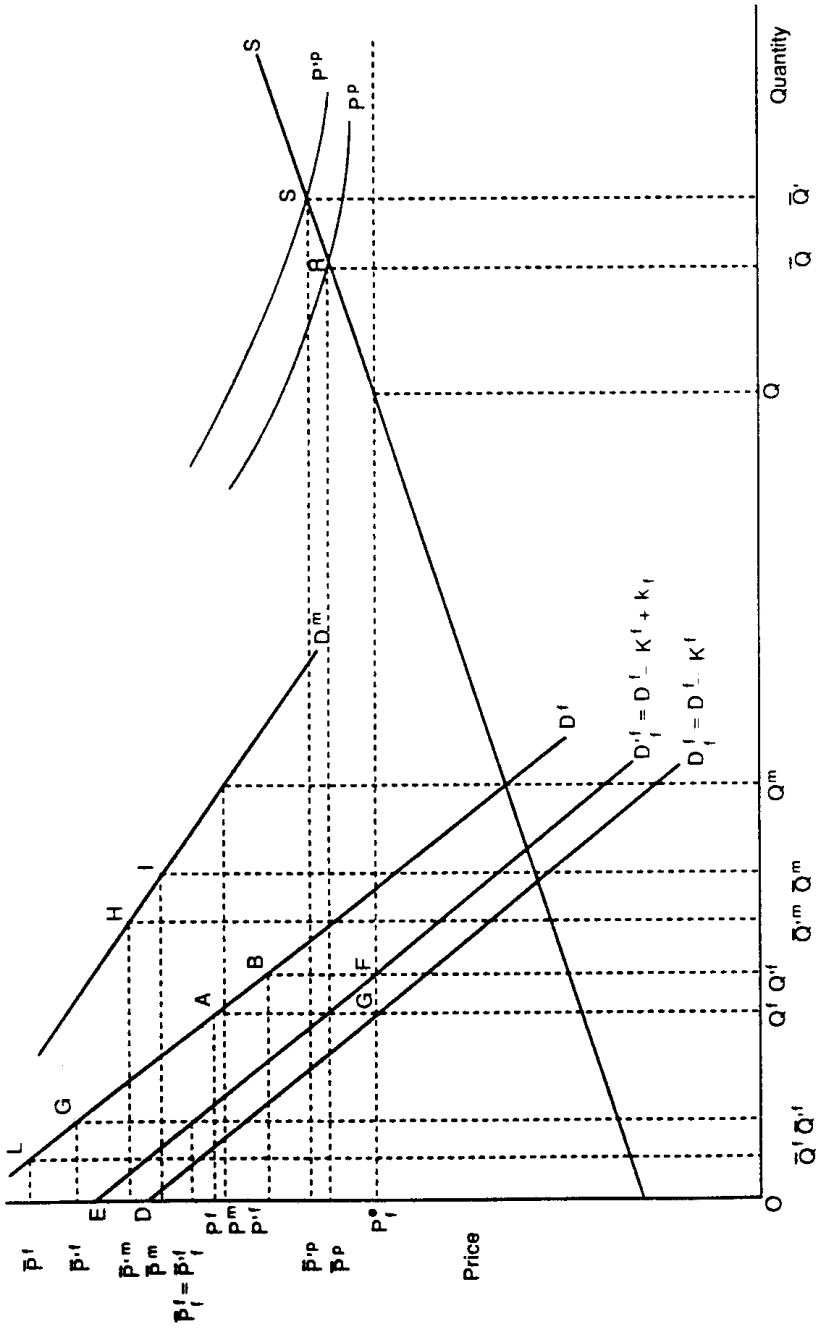
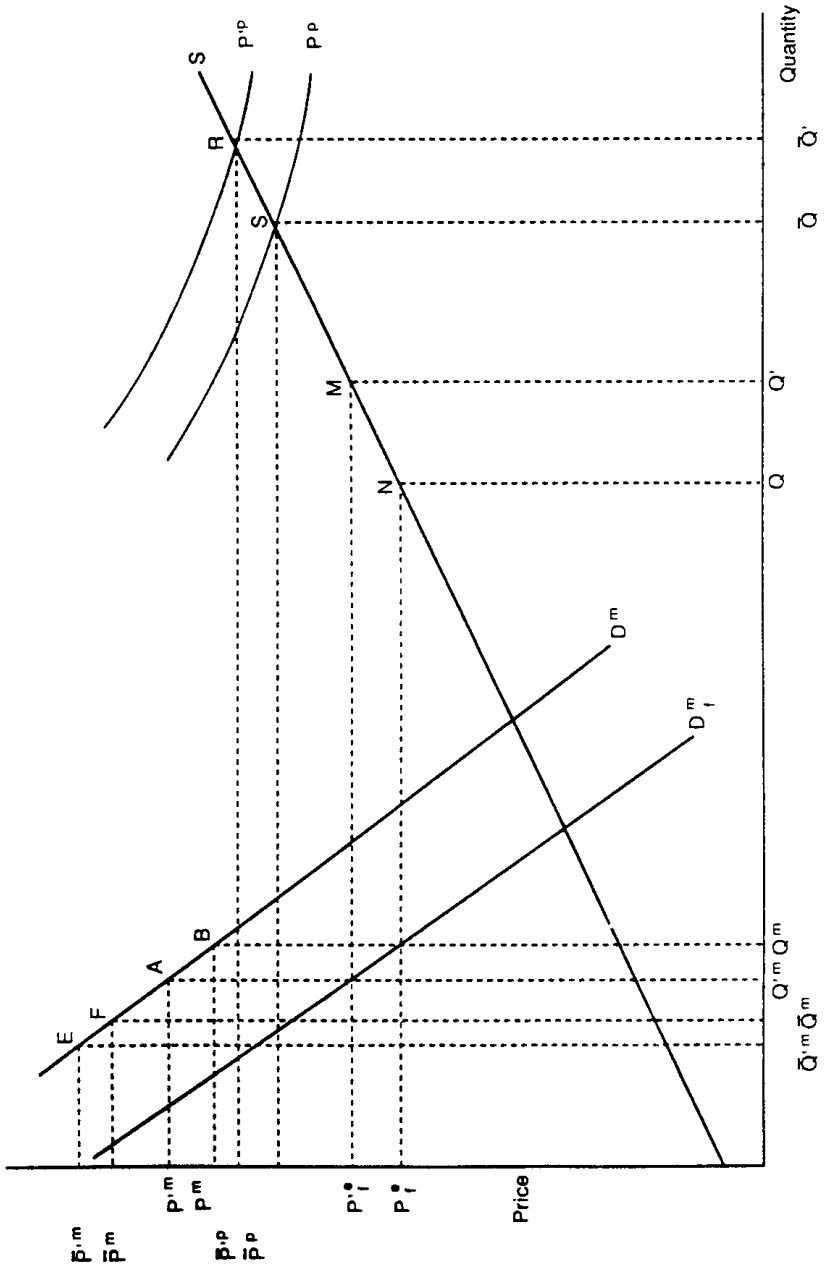


FIGURE 4
Research Reduces Off-farm Export Product Costs by k_e



gain for domestic consumers of manufactured dairy products of $\frac{1}{2} k_m (Q^m + Q'^m)$, where Q^m and Q'^m are the before-research and after-research quantities consumed, and this also is the national benefit. Consumers of fluid milk and producers are not affected.

The effects of research which generates lower off-farm costs of producing export dairy products are shown in Figure 4. The cost saving of k_e per litre, given a perfectly elastic export demand curve at export price P^e (not shown in Figure), shifts the farm-level export demand curve upwards from $P_f^e (= P^e - K_e)$ to $P'^e_f (= P^e - K_e + k_e)$. The higher opportunity return on milk for export sales in turn raises the farm-level price of milk used for domestic consumption. In fact, domestic prices rise by the cost saving k_e at both the retail product and farm levels. That is, for manufactured products, the farm-price (not shown in Figure 4) rises from $P_f^m = P_f^e$ to $P'^m_f = P'^e_f$ and the retail price rises (shown in Figure 4) by k_e from $P^m (= P_f^e + K_m)$ to $P'^m (= P'^e_f + K_m = P_f^e + k_e + K_m)$. The same price rises occur for fluid milk, but these are not shown in Figure 4. The price changes induce lower domestic consumption of fluid milk and manufactured dairy products, increased total milk production (from Q to Q') and increased exports. Domestic consumers lose because of the higher price, by $P^m P'^m AB = \frac{1}{2} k_e (Q^m + Q'^m)$ in the case of manufactured products (shown in Figure 4) and by $\frac{1}{2} k_e (Q^f + Q'^f)$ in the case of fluid milk (not shown). Farmers gain from the higher farm-level price for all sales by $P_f^e P'^e_f MN = \frac{1}{2} k_e (Q + Q')$. Aggregating the surpluses, society has a net gain of $\frac{1}{2} k_e (Q^e + Q'^e)$, where $Q^e (= Q - Q^m - Q^f)$ and Q'^e are quantities exported before research and after research, respectively.

Formulae summarising the gains to fluid milk consumers, to manufactured product consumers, to farmers and to society are reported in the first half of Table 1.

Research Benefits with Current Dairy Policy

Consider next the benefits of research for current dairy industry policy assumptions. Research leading to a reduction in on-farm costs of k_s is shown in Figure 2 as an outward shift of the supply curve from S to S'. Because fluid milk prices are regulated, there are no changes in prices, quantity or consumer surplus for fluid milk (and so the fluid milk story is not shown in Figure 2). Inspection of equations (1) and (2) indicates that the subsidy on exports fall, because the extra production and exports dilute the all-milk levy. In turn, prices of domestic manufactured products fall, from $\bar{P}^m$ to $\bar{P}'^m$, and domestic consumption rises. Consumer surplus increases by $\bar{P}'^m \bar{P}^m RS = \frac{1}{2} (\bar{P}^m - \bar{P}'^m) \ (\bar{Q}^m + \bar{Q}'^m)$. The supply shift raises output and also lowers the pool price from $\bar{P}^p$ to $\bar{P}'^p$ through the mechanism of equation (3). Perceived producer benefits are given by the cost savings on existing production less the

pool price fall, $BAGM - \bar{P}^p \bar{P}'^p GN$, plus the surplus on extra production, NHM. In aggregate, producer gains can be represented as

$\frac{1}{2}(k_s - (\bar{P}^p - \bar{P}'^p))(\bar{Q} + \bar{Q}')$.

The social benefits of supply-increasing research stem from two sources, the reduction in costs of the research and indirectly via reductions in the deadweight costs of current dairy policy. In Figure 2, suppose P^m is the free market retail price of manufactured dairy products, a price which is not altered by the supply research. Then, the deadweight loss from too little consumption of manufactured dairy products is URT in the before-research situation with price $\bar{P}^m$, and it is reduced to VST in the after-research situation with price $\bar{P}'^m$. The net gain URSV is the social value of additional consumption (of $\bar{Q}^m \bar{Q}'^m$) less the social cost (opportunity return on export sales and off-farm manufacturing costs) of producing the extra domestic manufactured dairy products. From the supply-side perspective, the economic surplus is given by the difference between the national value of production measured as the area under the P_f^e curve and the opportunity cost of production measured as the area under the supply curve. These are the areas $OP_f^e X \bar{Q}$ less $OAG\bar{Q}$ before research, and $OP_f^e Y \bar{Q}'$ less $OBH\bar{Q}'$ after research. With some manipulation, the net gain of surplus from research can be derived as $BACE$ plus CGX less $EHY = \frac{1}{2} k_s(Q + Q')$ plus production deadweight loss before research minus production deadweight loss after research. The first term, $\frac{1}{2} k_s (Q + Q')$, where Q and Q' refer to the free market before-research and after-research quantities, is the estimated social benefit under free market conditions derived above. Because the pool price falls, research reduces the production deadweight loss. Thus, social benefits of supply research are greater in the current dairy policy scenario than they are under a free market scenario, a result derived in Alston, Edwards and Freebairn (1988).

The effect of research reducing the off-farm costs of producing fluid milk is shown in Figure 3. The per unit cost reduction of k_f shifts the farm-level demand for fluid milk upwards from D_f to D'_f. It is assumed that government policy maintains a constant and artificially high farm price of $\bar{P}^f_f$. Initially, the retail price of fluid milk also falls by the cost saving from $\bar{P}^f$ to $\bar{P}'^f$ with fluid milk consumer surplus rising by $\bar{P}'^f \bar{P}^f LG = \frac{1}{2} k_f (\bar{Q}^f + \bar{Q}'^f)$. The increase in farm milk allocated to the fresh market reduces exports and in turn influences the export subsidy, the price of manufactured products and the pool price paid to farmers. By equations (1) and (2), the export subsidy rises, because of less dilution, and the price of milk used for manufactured products rise, from $\bar{P}^m$ to $\bar{P}'^m$. Consumers of manufactured products lose consumer surplus $\bar{P}^m \bar{P}'^m HI = \frac{1}{2}(\bar{P}^m - \bar{P}'^m)(\bar{Q}^m + \bar{Q}'^m)$. From equation (3) it can be argued that the pool price locus is shifted upwards because of larger contributions of the relatively more profitable sales of fluid milk and

domestic manufactured product, relative to export sales. This shift, shown as a move from P^p to P'^p in Figure 3, results in a higher pool price and extra production. Farmer surplus then increases by $\bar{P}^p \bar{P}'^p SR = \frac{1}{2}(\bar{P}'^p - \bar{P}^p)(\bar{Q} + \bar{Q}')$.

Assessment of the social benefits of the off-farm fresh milk research requires consideration of the cost savings and of changes in the deadweight costs of the policy distortions. The social benefits associated with reduced production costs for fluid milk sales owing to research is given by $\frac{1}{2} k_f (Q^f + Q'^f)$, where Q^f and Q'^f are the free market quantities consumed before and after research, respectively. This sum is derived from the measure that economic surplus equals free market surplus less the change in the deadweight loss of too little consumption, and because of the linear demand curve assumption the deadweight loss is the same before and after research.[7] Deadweight costs of too little consumption of manufactured products increase, because of the price rise, and the deadweight costs of excess production also increase.

A similar analysis gives estimates of the benefits of research, and their distribution, when research reduces the off-farm costs of domestic sales of manufactured dairy products. Current policy means the research will not alter prices, quantity or consumer surplus for fresh milk. Initially the research induced cost reduction of k_m causes an upward shift of the derived demand curve for farm-level milk for the production of manufactured dairy products. Because of the policy arrangements, two other changes will follow. With exports as a share of production falling, the export subsidy will rise by equation (1) and, in turn, the farm price of milk used for manufacturing will rise from $\bar{P}^m_f$ to $\bar{P}'^m_f$. This price increase will be less than the cost reducing effect of the research. Then, in net, the manufactured product retail price falls from $\bar{P}^m$ to $\bar{P}'^m$, but by less than the research-induced cost reduction k_m as occurs with free market assumptions. Consumer surplus for domestic manufacured products rises by $\frac{1}{2}(\bar{P}^m - \bar{P}'^m)(\bar{Q}^m + \bar{Q}'^m) = \frac{1}{2}(k_m - (\bar{P}'^m_f - \bar{P}^m_f))(\bar{Q}^m + \bar{Q}'m)$, where $\bar{Q}^m$ and $\bar{Q}'^m$ refer to domestic consumption of manufactured products before-research and after-research. Second, increased returns from domestic sales, by equation (3), shift the pool price locus upwards. In turn, this means the off-farm research induces a rise in the pool price, from $\bar{P}^p$ to $\bar{P}'^p$, and an increase in production, from $\bar{Q}$ to $\bar{Q}'$. These price and quantity changes generate an increase in producer surplus of $\frac{1}{2}(\bar{P}'^p - \bar{P}^p)(\bar{Q} + \bar{Q}')$.

Aggregate social gains to society of the off-farm manufacturing products cost-reducing research are given by $\frac{1}{2} k_m (Q_m + Q'_m)$ plus the deadweight cost of distortions before-research less the deadweight costs of distortions after-research. The first term is the measure of

[7] A result demonstrated and used in Alston, Edwards and Freebairn (1988) for the analogous case of a per unit tax. Here that tax is the difference $\bar{P}^f_f - P^f_f$.

society benefits under free market assumptions. The deadweight costs of too little consumption of manufactured dairy products and of too much farm production are increased in moving from the before-research to the after-research situations. That is, research reducing off-farm costs of manufactured products aggravates policy distortions, and the social gain from such research under current policy is less than achievable with a free market scenario.

The final research category leads to reductions in the off-farm costs of transporting, processing, storing and distributing export manufactured dairy products. In Figure 4 the cost-reducing research of k_e per litre equivalent of export product shifts the farm level return for exports up from P_f^e $(= P^e - K_e)$ to P'^e_f $(= P^e - K_e + k_e)$. With the farm price of milk for domestic fluid consumption fixed, and also the retail fluid price, there are no changes for the fluid milk market segment (which is not shown in Figure 4). Manipulation of equations (1) and (2) indicates that the prices for domestic manufactured dairy products, both the retail price and the derived farm milk price, will rise, but by less than the reduction in costs k_e, or in the opportunity return of diverting milk to export sales.[8] Thus, domestic consumers of manufactured dairy products lose consumer surplus given by and $(\bar{Q}^m + \bar{Q}'^m) < (Q^m + Q'^m)$, the loss is smaller than occurs under the free market scenario.

The locus of pool price returns in Figure 4 is pushed upward by the increased farm level return from exports associated with reduced off-farm costs of export production as shown in the shift from P^p to P'^p. The net increase in farm returns per unit output will be less than the cost reduction k_e for three reasons. First, returns from fluid milk remain constant, since $\bar{P}_f^f$ remains policy fixed. Second, as argued above, the increased price on domestic manufactured product sales is less than the cost reduction. Third, the output expansion and the downward slope of the pool price locus results in a fall in the pool price. In net terms, farmer returns increase by $\bar{P}^p\,\bar{P}'^p\,RS = \frac{1}{2}\,(\bar{P}'^p - \bar{P}^p)\,(\bar{Q} + \bar{Q}')$, and this increase is less than the free market increase in surplus.

Social benefits of the off-farm export cost-saving research derive from the cost savings and from reduced domestic consumption and production distortions. In effect, the research has similar effects to an increase in export prices. This, in turn, reduces the gap between policy-fixed fresh milk prices and the opportunity return of milk exports; manufactured product prices rise by less than the increase in

[8] Algebraically, taking the difference between the before-research farm price, $\bar{P}_f^m = P^e - K_e + t\,S/D^e$, and the after-research farm price, $\bar{P}'^m_f = P^e - K_e + k_e + t\,(S'/D'^e - S/D^e)$, gives $\bar{P}'^m_f - \bar{P}^m_f = K_e + t\,(S'/D'^e - S/D^e)$, in which the last term is negative because exports rise more than supply since fluid milk sales are unchanged and domestic manufactured product sales fall.

TABLE 1

Summary Formulae for the Gross Annual Benefits of Research in the Dairy Industry

		Free Market Scenario	Current Dairy Policy Scenario
1	Farm cost saving, k_s :		
	fluid consumers	$GC^f = 0$	$\overline{GC^f} = 0$
	manufactured prod. cons.	$GC^m = 0$	$\overline{GC^m} = \frac{1}{2}(\bar{P}^m - \bar{P}'^m)(\bar{Q}^m + \bar{Q}'^m) > 0$
	farmers	$GF = \frac{1}{2} k_s (Q + Q')$	$\overline{GF} = \frac{1}{2}(k_s - (\bar{P}^p - \bar{P}'^p)(\bar{Q} + \bar{Q}') < GF$
	society	$G = \frac{1}{2} k_s (Q + Q')$	$\overline{G} = \frac{1}{2} k_s (Q + Q') + \frac{1}{2}[(\bar{P}^m - P^m)^2 - (\bar{P}'^m - P^m)^2]\, dQ^m/dP^m$ $+ \frac{1}{2}[(\bar{P}^p - P_f^e)^2 - (\bar{P}'^p - P_f^e)^2]\, dS/dP^p > G$
			$\overline{GA} = \overline{GC^f} + \overline{GC^m} + \overline{GF}$
2	Off-farm fluid milk cost cost saving, k_f :		
	fluid consumers	$GC^f = \frac{1}{2} k_f (Q^f + Q'^f)$	$\overline{GC^f} = \frac{1}{2} k_f (\bar{Q}^f + \bar{Q}'^f) < GC^f$
	manufact. prod. cons.	$GC^m = 0$	$\overline{GC^m} = \frac{1}{2}(\bar{P}^m - \bar{P}'^m)(\bar{Q}^m + \bar{Q}'^m) < 0$
	farmers	$GF = 0$	$\overline{GF} = \frac{1}{2}(P'^p - \bar{P}^p)(\bar{Q} + \bar{Q}') > 0$
	society	$G = \frac{1}{2} k_f (Q^f + Q'^f)$	$\overline{G} = \frac{1}{2} k_f (Q^f + Q'^f) + \frac{1}{2}[(\bar{P}^m - P^m)^2 - (\bar{P}'^m - P^m)^2]\, dQ^m/dP^m$ $+ \frac{1}{2}[(P^p - P_f^e)^2 - (\bar{P}'^p - P_f^e)^2]\, dS/dP^p < G$
			$\overline{GA} = \overline{GC^f} + \overline{GC^m} + \overline{GF}$
3	Off-farm manufactured product cost saving, k_m :		
	fluid consumers	$GC^f = 0$	$\overline{GC^f} = 0$
	manufactured prod. cons.	$GC^m = \frac{1}{2} k_m (Q^m + Q'^m)$	$\overline{GC^m} = \frac{1}{2}(\bar{P}^m - \bar{P}'^m)(\bar{Q}^m + \bar{Q}'^m) < GC^m$
	farmers	$GF = 0$	$\overline{GF} = \frac{1}{2}(\bar{P}'^p - \bar{P}'^p)(\bar{Q} + \bar{Q}') > 0$
	society	$G = \frac{1}{2} k_f (Q^m + Q'^m)$	$\overline{G} = \frac{1}{2} k_m (Q^m + Q'^m) + \frac{1}{2}[(\bar{P}_f^m - P_f^m)^2 - (\bar{P}'^m_f - P_f^m)^2]\, dQ^m/dP^m$ $+ \frac{1}{2}[(P^p - P_f^e)^2 - (\bar{P}'^p - P_f^e)^2]\, dS/dP^p < G$
			$\overline{GA} = \overline{GC^f} + \overline{GC^m} + \overline{GF}$

4	Off-farm export product cost saving, k_e:			
	fluid consumers	$GC^f = -\frac{1}{2} k_e (Q^f + Q'^f)$	$\overline{GC^f}$	$= 0 > GC^f$
	manufactured prod. cons.	$GC^m = -\frac{1}{2} k_e (Q^m + Q'^m)$	$\overline{GC^m}$	$= \frac{1}{2} (\bar{P}'^m - \bar{P}^m)(\bar{Q} + \bar{Q}'^m) > GC^m$
	farmers	$GF = \frac{1}{2} k_e (Q + Q')$	$\overline{GF}$	$= \frac{1}{2} (\bar{P}'^p - \bar{P}^p)(\bar{Q}' + \bar{Q}) < GF$
	society	$G = \frac{1}{2} k_e (Q^e + Q'^e)$	$\overline{G}$	$= \frac{1}{2} k_e (Q^e + Q'^e) + \frac{1}{2} [(\bar{P}^f_f - P^e_f)^2 - (\bar{P}'^f_f - P'^e_f)^2] \, dQ^f/dP^f$
				$+ \frac{1}{2} [(\bar{P}^m_f - P^e_f)^2 - (\bar{P}'^m_f - P'^e_f)^2] \, dQ^m/dP^m$
				$+ \frac{1}{2} [(\bar{P}^p - P^e_f)^2 - (\bar{P}'^p - P'^e_f)^2] \, dS/dP^p > G$
			$\overline{GA}$	$= \overline{GC^f} + \overline{GC^m} + \overline{GF}$

GC^f is gross annual benefit for fluid milk consumers, GC^m is gross annual benefit for domestic manufactured product consumers, GF is gross annual benefit to farmers, and G is national gross annual benefits, all computed for a free trade scenario. These terms with a bar superscript refer to the current dairy policy scenario; and $\overline{GA}$ is the apparent national gain.

k_s is the reduction in farm production cost, k_f is the reduction in off-farm fluid milk production cost, k_m is the reduction in off-farm manufactured product sold domestically cost, and k_e is the reduction in off-farm export production cost.

P^f is fluid milk retail price, P_m is manufactured product retail price, P^e_f is farm level derived export price, P^p is pool price paid to farmer, all for a free market scenario. These terms with a bar superscript refer to the current dairy policy scenario.

Q^f is fluid milk quantity, Q^m is domestic manufactured product quantity, Q^e is export quantity and Q is supply, all for a free market scenario. Terms with a bar superscript refer to the current dairy policy scenario.

Price and quantity terms with a " ′ " superscript refer to after research variables

export opportunity returns; and the resulting production and export stimulus dilutes the production distorting effects of the pool pricing arrangements. Net social benefits are given by the cost reduction for free market level exports, plus reductions in the deadweight costs of too little domestic consumption of both fresh milk and manufactured products and the deadweight costs of too much production. Because of the reduced policy distortions, the social benefits of this type of research exceed those obtainable under a free market scenario.

Formulae for calculating the benefits of research under the current dairy policy scenario are collated in the second column of Table 1. Assumed linear supply and demand curves enable the various deadweight costs of too little consumption and too much production to be specified as areas of triangles. For example, for the case of a farm cost reduction shown in Figure 2 and the formulae for $\bar{G}$ in Table 1: the before-research excess production deadweight cost is area $CGX = \frac{1}{2}(\bar{P}^p - P_f^e)\,\Delta Q = \frac{1}{2}\,(\bar{P}^p - P_f^e)\,(dS/dP^p)\,(\bar{P}^p - P_f^e) = \frac{1}{2}\,(\bar{P}^p - P_f^e)^2\,dS/dP^p$, where $(\bar{P}^p - P_f^e)$ is the pool price distortion, ΔQ is the change in quantity and dS/dP^p is the slope of the supply curve: and the reduction in the production deadweight loss in moving from pool price $\bar{P}^p$ to $\bar{P}'^p$ is given by $CGX - EHY = \frac{1}{2}\,[(\bar{P}^p - P_f^e)^2 - (\bar{P}'^p - P_f^e)^2]\,dS/dP^p$, the last term for $\bar{G}$ in Table 1.

Other measures of the aggregate benefits of research might be considered as well as the $\bar{G}$ measure of social benefits. One option is to add the surplus changes to consumers and farmers. This measure is termed the apparent national gain, $\overline{GA} = \overline{GC}^f + \overline{GC}^m + \overline{GF}$, where the right hand terms are estimated gains to consumers of fluid milk, consumers of manufactured products and farmers, respectively. Because of the various distorting deadweight costs of dairy policy, it is clear that the apparent national gain, $\overline{GA}$, will differ from the social gain under free market conditions, G, and the social gain under current policy, $\bar{G}$. It has not been possible to use analytical methods to evaluate either the direction of differences or the magnitude of differences of $\overline{GA}$ relative to G and $\bar{G}$. The following empirical illustration provides some insights.

An Illustrative Example

A model of the Australian dairy industry for 1989-90 circumstances is employed to gain a perspective on the magnitude of effects of current policy on estimates of the benefits of research and their distribution.

The characterisation is illustrative in several ways. First, all States are assumed to have the same policy arrangements as the dominant producing states of Victoria and Tasmania. In fact, NSW, WA and most of Queensland, which jointly account for 18% of national production, pay their farmers the manufactured price less the levy for marginal production, a price somewhat below the pool price arrangement modelled in this paper which also includes a portion for fluid milk

sales. Second, approximate and rounded numbers on prices and quantities as reported in Table 2 are used rather than actual numbers, and the various price relationships required by equations (1), (2) and (3) are enforced. For example, in terms of the quantities, national figures for fluid milk, domestic manufactured products, exports and production in 1989-90 were 1696 million litres (rather than 1500 of Table 2) 2693 (rather than 3000), 1873 (rather than 1500) and 6262 (rather than 6000), respectively. Third, in deriving the free market scenario, and in evaluating benefits of research, estimates of the slopes of the various demand curves and the supply curve are required. Values for demand elasticities drawn from the literature and surveyed by the Industry Commission (1991) have been used in Table 2. A somewhat arbitrary low supply elasticity of 0.6, a low estimate from amongst those canvassed by the Industry Commission, was chosen to ensure a free market scenario of Australia as a continuing net exporter. Linear curves at current policy prices and quantities were computed. These curves in turn were used to compute the quantities for a free market outcome in Table 2. The various assumptions and approximations mean that the estimates of the resulting benefits must be no more than crude indicative numbers. Nevertheless, precision in estimating research benefits easily can be spurious, and the example of Table 2 is adequate to cast light on the order of magnitude of the effect of policy distortions on measures of research benefits and their distribution.

Evaluation of the benefits of research into different areas of cost reduction in the dairy industry involves two steps. First, the before-research situation depicted in Table 2 was shocked by a one cent/litre cost reduction to evaluate after-research price and quantity outcomes. For the free market situation this step involved easy solution of linear equations. For the current policy scenario, non-linearities stemming from the pool price function, equation (3), required a different procedure, namely one based on approximate linear equations in percentage changes.[9] Second, values for the before-research and after-research prices and quantities were substituted into the formulae of Table 1. Estimates of the gross annual benefits of research, and their distribu-

[9] For example, using equations (1), (2) and (3) to substitute for the pool price in the farm supply equation results in a polynomial equation of degree three which is not readily solvable analytically. Instead, equations were replaced by a system of linear approximations in percentage changes and elasticities derived from total differentials. For example, the demand equation $Q = a + bP$ is replaced by $q = E_d p$, where q is the percentage change in Q, p is the percentage change in P and E_d is the elasticity of demand, and the market clearing identity $Q = Q^d + Q^e$ is replaced by $q = W_d q^d + (1 - W_d)q^e$, where q is percentage change in quantity, with the superscripts d and e referring to domestic sales and exports, and W_d is share of domestic sales in production. Matrix manipulation is used to solve for percentage changes in the endogenous price and quantity variables as functions of percentage changes in the exogenous research-induced cost reduction variables. Details are available on request from the author.

TABLE 2
Data Used in Estimating Benefits of Research

Symbol	Description	Values	
		Current policy[1]	Derived free market[2]
Q^f	fluid milk (million l/year)	1500	1532
Q^m	domestic manuf. milk (million l/year)	3000	3171
Q^e	export milk (million l/year)	1500	292
Q	milk production (million l/year)	6000	4995
P^f	retail fluid milk price (cents/l)	70	55
P_f^f	farm fluid milk price (cents/l)	35	20
P^m	retail manuf. milk price (cents/l)	84	76
P_f^m	farm manuf. milk price (cents/l)	28	20
P^e	export price (cents/l)	40	40
P_f^e	farm export price (cents/l)	20	20
P^p	pool farm price (cents/l)	27.75	20
K^f	fluid milk off-farm margin (cents/l)	35	35
K^m	manuf. milk off-farm margin (cents/l)	56	56
K^e	export milk off-farm margin (cents/l)	20	20
t	all milk levy (cents/l)	2	0
e_f	retail fluid milk demand elasticity: assumed	–0.1	
e_m	retail manuf. milk demand elasticity: assumed	–0.6	
e_s	farm milk supply elasticity: assumed	0.6	

[1] Approximate values for 1989 circumstances drawing from data in Industry Commission (1991).
[2] Linear demand and supply curves computed for current policy prices and quantities and assumed elasticities are used to solve quantities for farm level export price of 20 cents/l.

TABLE 3
Estimated Gross Annual Benefits of Research in the Dairy Industry for Different Types of Research Under Scenarios of a Free Market and Current Dairy Policy
($ million per year)

	Type of Research and Research Beneficiary	Free Market	Current Dairy Policy
1.	Reduction in farm production cost of one cent/litre, k_s:		
	fluid milk consumers	$GC^f = 0$	$\overline{GC}^f = 0$
	manufactured product consumers	$GC^m = 0$	$\overline{GC}^m = 10.0$
	farmers	$GF = 50.6$	$\overline{GF} = 43.6$
	perceived national gain		$\overline{GA} = 53.6$
	aggregate social gain	$G = 50.6$	$\overline{G} = 53.9$
2.	Reduction in off-farm fluid milk cost of one cent/litre, k_f:		
	fluid milk consumers	$GC^f = 15.3$	$\overline{GC}^f = 15.0$
	manufactured product consumers	$GC^m = 0$	$\overline{GC}^m = -0.2$
	farmers	$GF = 0$	$\overline{GF} = 0.4$
	perceived national gain		$\overline{GA} = 15.3$
	aggregate social gain	$G = 15.3$	$\overline{G} = 15.2$
3.	Reduction in off-farm domestic manufactured cost of one cent/litre, k_m:		
	fluid milk consumers	$GC^f = 0$	$\overline{GC}^f = 0$
	manufactured product consumers	$GC^m = 31.8$	$\overline{GC}^m = 28.0$
	farmers	$GF = 0$	$\overline{GF} = 0.3$
	perceived national gain		$\overline{GA} = 28.3$
	aggregate social gain	$G = 31.8$	$\overline{G} = 31.6$
4.	Reduction in off-farm export cost of one cent/litre, k_e:		
	fluid milk consumers	$GC^f = -15.3$	$\overline{GC}^f = 0$
	manufactured product consumers	$GC^m = -31.6$	$\overline{GC}^m = -19.9$
	farmers	$GF = 50.6$	$\overline{GF} = 29.3$
	perceived national gain		$\overline{GA} = 9.4$
	aggregate social gain	$G = 3.7$	$\overline{G} = 9.6$

These numbers are computed using the formulae of Table 1 applied to data of Table 2.

tion, between fluid milk consumers, manufactured product consumers and farmers are reported in Table 3.

The estimates in Table 3 indicate that dairy policy, relative to free trade, can have marked effects on estimates of the gross annual benefits of cost-reducing research, and more so on the distribution of the benefits than on the aggregate or national benefits. Consider first estimates of aggregate benefits. Comparing the free market benefits, G, with the current dairy policy scenario benefits, $\bar{G}$, the differences are relatively small in the cases of reduced off-farm costs of fluid milk and of domestic manufactured products, 6.5% different for farm research, and 260% different for off-farm export cost-reducing research.

Especially interesting is the observation that crude estimates of aggregate research benefits made on assumptions which ignore the policy distortions, the $\overline{GA}$ estimates, differ very little (by less than 2%) from the correct estimate of national social benefits, $\bar{G}$. The results in Table 3 indicate no systematic pattern of under- or over-estimation by the crude method. Whether these results are peculiar to the particular illustrative example shown here, or of more general application, requires further evaluation in other contexts.

A general observation that national benefits of research are roughly proportional to the per unit cost reduction times the quantity of production to which it applies is not significantly altered by current dairy policy. For example, a one cent/litre reduction in farm costs applying to all production has higher aggregate benefits than a one cent/litre reduction in the cost of off-farm manufactured product production — about a half of total production — and in turn for cost-reducing research on off-farm fluid milk and off-farm export costs, each of which represent 25% or less of production.

Relative to free trade, dairy policy has a substantial effect on estimates of the perceived distribution of the benefits of research between consumers and farmers. For farm production research, for example, under a free market and the small country assumption of a fixed export price, lower farm costs and the associated output expansion, all of which is exported, benefits farmers only. By contrast, with current dairy policy, the output expansion drives down the export subsidy and domestic manufactured product prices thereby benefiting consumers, and the fall in the farmer pool price erodes some of the benefits of the research cost reduction for farmers. These types of price responses explain the quite different pattern of research benefits between the two scenarios for research-reducing costs of off-farm export production. Quantitatively, the distribution of research benefits for off-farm cost reductions in fluid milk and domestic manufactured products is little influenced by the policy scenario.

Conclusions

Policy interventions alter consumption and production decisions and the resulting pattern of prices and quantities. In the case of the Australian dairy industry these effects are large (Industry Commission, 1991, and Table 2 above). Likewise, policy can alter estimates of the benefits of research and of the distribution of these benefits. In the case of the Australian dairy industry, a comparison of estimates of benefits obtained under free market and current policy assumptions differ. However, particularly in the case of aggregate benefits, the differences are not large in the sense of likely effects on assessments of ranking different research project options or in determining the aggregate amount to devote to investment in research.

Consider first estimates of aggregate benefits. Formally, from Table 1, the benefits to society under a free market, G, differ from those estimated for current policy, $\bar{G}$. When research leads to an increase in exports as a share of production, namely, research shifting out the farm supply curve ($k_s > 0$) and research reducing off-farm costs of producing export products ($k_e > 0$), the distorting deadweight costs of dairy industry policy are reduced, and $\bar{G} > G$. By contrast, where research leads to an increase in the relative importance of domestic sales, for example through lower off-farm costs for fresh milk ($k_f > 0$) or for domestic sale of manufactured products ($k_m > 0$) or by the development of new products that increase domestic demand (not shown), the distorting deadweight costs of current policy increase, and $\bar{G} < G$.

Simplistic use of formulae for estimating aggregate research benefits based on assumptions of a competitive market to policy distorted prices will give inaccurate estimates of national social benefits. In terms of Table 1, these are the measures $\overline{GA}$, which differ from both $\bar{G}$ and G. To date, it has not been possible to assess analytically the direction or magnitude of biases. For the dairy policy example, the differences are found to be positive and negative for different research projects. But, these differences are not large.

Overall, for the example shown here, and likely more generally, estimates of aggregate benefits of research are not very sensitive to policy assumptions. The conclusion can be explained as follows. Most of the estimated aggregate research benefit is given by the area of a rectangle obtained from the poduct of the unit cost reduction times the output affected. A relatively small part of the aggregate research benefit is given by changes in a triangle representing changes in efficiency or deadweight costs of policy distortions. That is, aggregate benefits of research, and the relative ranking of different research projects, depend primarily on the contribution of research to reducing aggregate industry production costs.

It is in the area of the distribution of the benefits of research between consumers and producers, and different groups of consumers and producers, that the policy influences are of considerable importance,

both in concept and in empirical magnitudes. Different patterns of price responses occur under the alternative assumption sets of a free market and current policy. Because of the small export country assumption, under free market assumptions cost-reducing research (other than research on off-farm costs for exported milk products) does not alter market prices. As a result, research alters economic surplus only for the directly affected sector, and the gains of the sector equal social benefits. By contrast, with policy distortions, changes in research influence quantities produced and sold in different sectors. Resulting changes in the export subsidy and pool price paid farmers lead to changes in economic surplus received by all players in the Australian dairy industry.

If, as seems likely, lobbying for research funding and the setting of research priorities is partly driven by sectoral benefits, then the distribution of benefits matter and careful attention should be given to the effects of policy interventions. For example, relative to a free market situation, farmers are encouraged to lobby more strenuously for allocating research funds away from on-farm research towards off-farm research increasing domestic sales.

The model might be extended and modified in several directions. Some are straightforward and are unlikely to dramatically alter the general results. Examples include, greater spatial and temporal disaggregation, non-linear supply and demand equations, international market power, upward-sloping off-farm supply curves, and multi-market situations.[10] Others may have important implications for the conclusions. These include more general assumptions of non-zero elasticities of substitution between farm and non-farm inputs, and other policy instruments.[11] Finally, particular industry circumstances directly influence empirical outcomes.

[10] Related studies looking at these types of model variants include: Alston, Edwards and Freebairn (1988), Lindner and Jarrett (1978), Voon and Edwards (1991), Edwards and Freebairn (1984) and Alston (1991).

[11] Some related papers for developing these areas of assumption relaxation include: Holloway (1989) and Mullen, Alston and Wohlgenaut (1989).

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