34th Annual Conference of the Australian Agricultural Economics Society,
University of Queensland, Brisbane, 12-15 February 1990.

RESEARCH PAYOFF FROM QUALITY IMPROVEMENT: THE CASE OF PROTEIN CONTENT IN AUSTRALIAN WHEAT

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ABSTRACT

This paper focusses on developing a partial equilibrium model for assessing research payoffs from quality improvement for tradable commodities. The model allows for effects on world prices via an excess demand function. Welfare changes from research are determined in country A (Australia) only.

The model is used to evaluate the economic benefits from an improvement in the quality characteristic 'protein' in wheat. Quality-improving research for wheat has the potential to provide substantial economic gains to Australia. Research which lifts the average protein level in wheat by one percentage point confers gross annual domestic benefits of about $530 million in present values over 30 years. The majority of this gain accrues to producers. It is of interest that, despite the welfare gains accruing to consumers from a rise in the demand curve, the distribution of benefits from demand-shifting research is similar to that obtained in studies of supply-shifting research. The analysis also showed that the aggregate gains to Australia are larger the larger the export elasticities of demand. This reflects larger producer gains net of smaller gains to consumers. Where the implied world demand for Australian wheat is extremely price elastic, the economic benefits are little affected by elasticities of supply and demand.

An implication of the analysis is that the Australian wheat industry could invest large sums in research in order to raise the protein content in wheat. Another implication is that policy makers involved in resource allocation should consider investing in demand-shifting research as well as in cost-reducing research.

Research Payoff from Quality Improvement: The Case of Protein Content in Australian Wheat

Introduction

Agricultural research can be broadly classified into two main categories: supply-shifting (i.e. cost-reducing or yield-raising) research and demand-lifting research.[1] For research in the first category, the per unit cost reduction or the increased yield per unit farm input is caused by technological improvements in production. This makes possible a downward shift of the commodity supply curve. Issues concerning the supply-shifting innovation have received much attention, and models have been developed for both nontradable and tradable commodities (see, for example, Lindner and Jarrett, 1978; Norton and Davis, 1981; Edwards and Freebairn, 1981, 1982, 1984).

The demand-raising innovation, on the other hand, has received relatively little attention. It is recognised that a rise in demand may be accomplished, for instance, by research into improving quality characteristics of a product, and by promotion. The paucity of studies of demand-shifting research relative to those of cost-reducing research may lead to misallocation of resources[2]: for instance, it is possible that policy makers may direct excessive research funds into cost-reducing research due to a lack of knowledge of the significance and the likely payoff from demand-raising research.

An instance of the evaluation of research benefits for quality improvement is found in Unnevehr (1986). It has been deduced theoretically by Unnevehr (1986) and previous workers (e.g. Ladd and Suvannunt, 1976) that quality improvement due to scientific research leads to a rise in the ordinary demand curve. In Unnevehr's paper, however, no distinction is made between the open and the closed economy situations.

In this paper, a partial equilibrium model is developed for assessing research benefit from a rise in the commodity demand curve in an open economy situation. The rise in the commodity demand curve is attributed to product quality improvement. Several theoretical issues concerning quality changes are raised. The paper aims to throw light on the size and distribution of benefit from research that raises the quality characteristics 'protein' in Australian wheat. An economic evaluation of research benefit from wheat grain quality improvement has not been attempted in Australia. In the light of the scarcity of studies of quality-improving research, this paper could also provide useful source of stimulation for further studies on this important area.

The Model

In this section, a model is developed for evaluating research benefits from quality improvement for an exporting economy. The model allows for effects on world prices via an excess demand function. An extended disaggregated commodity supply and demand model with separate sectors for the home country and the rest of the world (ROW) used for evaluating

[1] A discussion of the technical issues concerning cost-reducing and demand-lifting research is given in Edwards (1984).

[2] Industries and Governments allocate resources to research activities introduced to lower the supply curve and to raise the demand curve for commodities. The supply-shifting research and the demand-lifting research are in competition with each other and with other activities for resources.

research benefits (e.g. Edwards and Freebairn, 1984) appears to be inappropriate for evaluating research benefits from quality improvement. This is because the total ROW demand curve specified in a disaggregated model would comprise the demand curves for two heterogenous products after quality changed in one market: the ROW demand for Australian exports and the ROW demand for ROW production. The aggregation of the individual demands to form an aggregated demand is appropriate only when the product is homogenous. This problem is avoided by the use of an aggregated trade model developed in this paper. Our aggregated trade model allows welfare changes to be determined for country A (Australia) only. The model cannot be used to give estimates of economic surpluses for ROW because it excludes the demand and the supply curves in the ROW. The rationale for the use of this kind of analysis is that Australia will often be uninterested in the effects that it's quality-improving research has on welfare in ROW.

The model is also in the partial equilibrium tradition in not allowing for welfare changes in related markets in Australia. In mitigation it might be said, in addition to noting that this limitation is common to all partial equilibrium models, that an industry's producers may be little more interested in the effects which research for their industry has on other domestic markets than they are in its effects in the ROW segment of their own market. However, this will not be true if a substantial number of the producers of the commodity directly concerned (e.g. wheat) also produce the related commodities (e.g. barley and oats). There is also the point that the broader community may be interested in welfare effects to which wheat industry research gives rise beyond the wheat market. This is more likely to be so if taxpayers contribute to the funding of the research.

The model developed in this paper is used to estimate the level and the distribution of research benefits from a rise in the average protein level[3] in Australian wheat due to genetic research. The domestic and ROW consumers exhibit stronger preference for and place higher value on Australian wheat with increased protein content (AWB, pers comm.). Therefore, quality improvement, in practice, causes an upward shift in both the domestic and the ROW demand (the export demand) curves for Australian wheat.

In this paper, quality is considered to be an exogenous decision variable in producers' decision processes. Quality is a decision variable to producers if they can improve the quality composition of their harvest by incurring greater costs. In this paper, however, quality (i.e. average protein level in wheat) of the product is enhanced by adoption of an improved variety resulting from genetic research. Therefore, in such a case, quality is not an endogenous variable in the production decision. The new variety is assumed to utilise an equal amount of each input (e.g. fertilisers) as the old ones[4]. Consequently, a rise in demand is assumed to have no effect on the marginal cost curve.

[3]The average protein level of Australian standard white (ASW) wheat has declined from 11% to 10% between 1967-89 (AWB, 1989). The precise reasons for the fall in the average level of protein in Australian wheat have not been provided. However, it is clear that the fall in protein is due to variations in certain factors of production rather than changes in proportion of wheat supplied from the different states. The declining average protein level in ASW wheat (which constitutes about 80% of the total wheat production in Australia), combined with the increasingly exacting quality requirements of the overseas' customers, causes substantial problems in marketing Australian wheat (AWB, 1989).

[4]In cases where the new variety uses a greater amount of an input, or changes the proportion in the use of inputs, the analysis can be extended by incorporating a relevant supply shift into the model. In reality, however, it is uncertain in most ex-ante analysis of research benefit as to how the new variety is going to behave.

The model for assessing research benefits from quality improvement is illustrated in Figure 1. The model is a competitive, market-clearing one. Commodity supply and demand curves are assumed to be linear. In Figure 1, the supply curve is represented by S, the 'without research' domestic demand curve is D_{dd} and the 'without research' total demand curve (which is the sum of the domestic and export demand) is D_d. Thus, the horizontal differences between domestic demand (D_{dd}) and total demand (D_d) is ROW (excess) demand.

Research raises the domestic as well as the export demand curves for Australian wheat and the social benefits from research are assessed only from the Australia's perspective. The size of the demand shifts in Australia and ROW is measured vertically, and is identical in both cases[5]. Demand shifts are assumed to be parallel. The use of linear demand curves together with common price intercepts for domestic and ROW demand and vertical shifts in demand imply that a fixed proportion of Australia's production is exported[6], and that this proportion is unaffected by the quality change.

With a rise in quality, the domestic demand curve shifts up from D_{dd} to D'_{dd} and the total demand curve shifts up from D_d to D'_d. Consequently, the commodity price increases from P to P'. With this price change, the domestic consumption increases from Q_{dd} to Q'_{dd} and the quantity exported to ROW increases from $Q_s - Q_{dd}$ to $Q'_s - Q'_{dd}$. With an increase in price, the domestic consumers' surplus increases by area $fghP'$ (i.e. area $(eagk - P'jkP + jgh)$) and domestic producers' surplus increases by area $P'cdP$.

The demand and supply equations in the absence of the quality change are specified as

$$Q_{dd} = a - \alpha P \tag{1}$$

$$Q_{ed} = b - \beta P \tag{2}$$

$$Q_d = c - \theta P \tag{3}$$

$$Q_s = d + \gamma P. \tag{4}$$

The linear domestic demand curve is represented by equation 1; the excess demand curve by equation 2; the total demand curve by equation 3; the supply curve by equation 4; P represents wheat price; D_{dd} is the quantity demanded in Australia; Q_{ed} is the quantity exported to ROW; Q_d is the total (world) demand; Q_s is the quantity supplied by Australia; a, b, c and d are the intercept terms; and α, β, θ and γ are the demand and supply price slopes. Note that the total demand function (equation 3) is a horizontal summation of the domestic demand function (equation 1) and the excess demand function (equation 2). Hence, the total demand price slope, θ, is the sum of α and β. Equations 1-4 can be solved to determine the 'without research' quantities and price.

Now introduce demand shifts caused by R&D-induced technological change. The size of the demand shifts, measured vertically, is represented by w. With these changes, the 'with research' demand curves become

$$Q'_d = a + \alpha w - \alpha P' \tag{5}$$

$$Q'_{dd} = a + \gamma w - \gamma P' \tag{6}$$

[5]This is based on the assumption that both domestic and ROW consumers place similar valuations on high protein wheat (AWB, pers comm.).

[6]Wheat exports in each of the past several years represented about 80% of Australia's total production.

where all terms are defined above except that the prime superscript denotes 'with research'. Equations 1-5 can be solved for the unknown variables P', Q'_s and Q'_{dd}. These variables can be expressed in terms of initial price and quantity.

Algebraically, the gain for domestic consumers, CS, gain for domestic producers, PS, and aggregate national gain, TS, from R&D-induced demand shift can be expressed as

$$CS = 1/2[w - (P' - P)](Q_{dd} + Q'_{dd}) \quad (7)$$

$$= \frac{\gamma w}{\alpha + \beta + \gamma} Q_{dd} + \frac{\alpha\gamma^2 w^2}{2(\alpha + \beta + \gamma)^2} \quad (8)$$

$$PS = 1/2(P' - P)(Q_s + Q'_s) \quad (9)$$

$$= \frac{(\alpha + \beta)w}{\alpha + \beta + \gamma} Q_s + \frac{\gamma(\alpha + \beta)^2 w^2}{2(\alpha + \beta + \gamma)^2} \quad (10)$$

$$TS = 1/2w(Q_{dd} + Q'_{dd}) + 1/2(P' - P)(Q_{ed} + Q'_{ed}) \quad (11)$$

$$= \frac{w}{\alpha + \beta + \gamma}[\gamma Q_{dd} + (\alpha + \beta)Q_s] + \frac{\gamma w^2}{2(\alpha + \beta + \gamma)^2}[\alpha\gamma + (\alpha + \beta)^2] \quad (12)$$

The Data

The data needed for applying the formulae are tabulated in table 1. Initial equilibrium price and quantity data are simple averages of 1987-88 and 1988-89 figures.

For the empirical estimation, the crucial elasticity data are the price elasticity of demand in Australia, the price elasticity of supply, and the export demand elasticities. Data on the elasticities of supply and demand in Australia are based on findings in past econometric studies.

Previous studies (e.g. BAE, 1974; Bains, 1971; Gruen et al., 1968) indicate that the retail demand for wheat is price inelastic and that the demand for wheat grains for animal consumption is price elastic. The estimates for demand elasticities were reported to be in the range -0.5 and -2.3.

There is a sizable literature on the supply elasticity responses for wheat in Australia (e.g. Adams, 1987; Hall and Menz, 1985; Vincent, Powell and Dixon, 1982; Wicks and Dillon, 1978; Powell and Gruen, 1967). The wheat-only elasticities were reported to be higher than those of all cereals. Both shortrun and longrun estimates for wheat supply in Australia were reported to be in the range 0.2 and 1.3.

In the case of the price elasticity of export demand, significant differences in estimates were reported. For instance, Throsby and Rutledge (1977) reported a value of -4.7 whereas the IAC (1976) reported a value as high as -60.0. For illustrative purposes, a range of the export elasticity estimates is used.

The data on implicit prices for the characteristic 'protein' in wheat were obtained from the Australian Wheat Board. These are based on AWB statistics that a premium of $5.00 per tonne is offered to producers for wheat with an average protein level greater the base class by one percentage point, and that a discount of $4.50 per tonne is incurred for wheat with an average protein level lower than the base class by one percentage point. The average

Table 1: Values of Variables for Estimating Research Gains from Wheat Grain Quality Improvement in Australia

Variable	*Value*	*Description*
Q_s	12.90 Mt	Commercial wheat production in Australia
Q_{dd}	2.50 Mt	Domestic wheat consumption in Australia[a]
Q_{ed}	10.40 Mt	ROW demand for Australian export[a]
P	\$173.0/t	Average retail price of wheat[a]
e	0.2, 1.3	Average value for elasticity of farm supply of wheat [b]
η	-0.50, -2.3	Average retail elasticity of demand for wheat[c]
E_a	-4, -10, -20, -60	Assumed values for the elasticity of export demand [d]
w	\$4.75/t	Price premium for the improved quality wheat grain[e]

[a] From Australian Bureau of Statistics Quarterly Publications, Canberra; Quarterly Review of the Rural Economy, various Publications; and Commodity Statistical Bbulletin, various Publications.

[b] see text.

[c] see text.

[d] For illustrative purposes, a common range of the export demand elasticities is used.

[e] The average implicit price (retail level equivalents) obtained from the AWB (pers comm.).

implicit price for protein in wheat represents about 3% of the retail price for the Australian wheat.

Benefits to farmers, consumers and aggregate in Australia are evaluated as changes in economic surpluses[7]. Research is regarded as an investment that provides benefits over a period of 30 years. The discount rate used to express future benefits from research in present value terms is 10%. The formula used for calculating present values is represented by $PV(i) = G(i)[(1+i)^n - 1]/[i(1+i)^n]$ where $PV(i)$ denotes the present value of research benefits to group i (where i refers to farmers, consumers, and aggregate in Australia), $G(i)$ is the level of benefits to group i specified in previous equations, and the rest of terms on the RHS denote the discount factor. The values of gains/losses as a result of quality improvement are shown in table 2.

Result

Values for the level and the distribution of research benefits are shown in Table 2. Quality-improving research for wheat has the potential to provide substantial economic gains to Australia. Research which lifts the average protein level in Australian wheat by one percentage point confers gross domestic benefits over 30 years of about \$540 million in present values. This represents approximately \$18 million per year. The majority of these gains (over 90 %) accrue to producers.

It is of interest that, despite the welfare gains accruing to consumers from a rise in the demand curve, the distribution of benefits from demand-shifting research is similar to that obtained in studies of supply-shifting research (IAC, 1976; Edwards and Freebairn 1981,

[7]Economic surplus measures are appropriate for many agricultural products; income effects due to price changes are likely to be small since consumers spend a very small fraction of their income on a particular food item.

1984). In the present analysis, the consumers' share of the research benefits is small due to the small proportion of production consumed domestically and the highly price elastic export demand. Where consumption accounts for a higher share of domestic production, as it does in Australia for beef, dairy products and many fruits, it could be expected that consumers' share of the benefits from demand-increasing research would be higher.

Table 2 also shows that the aggregate gains to Australia are larger the larger the export elasticities of demand. This reflects larger producer gains net of smaller gains to consumers. Where the implied world demand for Australian wheat is extremely price elastic, the economic benefits are affected little by elasticities of supply and demand. Where the world demand is less price elastic (i.e. Australia has some importance in world market), the gains from research are more sensitive to the demand and supply elasticities.

Concluding Comments

In this paper the level and the distribution of benefits from wheat grain quality improvement research are estimated using an aggregated trade model. The model allowed welfare changes to be determined for Australia only. The major finding is that research which lifts the average protein level in wheat by a one percentage point has the potential to create large economic gains in Australia. An important implication is that it would be profitable for the Australian wheat industry to invest large sums in research in order to raise the protein content in wheat. Another implication of the finding is that policy makers involved in resource allocation should consider investing in demand-shifting research as well as in cost-reducing research.

A feature of this model is the partial equilibrium nature of the analysis. This is likely to be seen as a more significant limitation in decisions on public funding of demand-raising research for the wheat industry than in decisions by the industry on its own investment in research.

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Table 2: Estimated level and distribution of benefits from research that raises the protein content in Australian wheat (PV in millions of dollars summed over 30 years)

	Elasticities of Export Demand															
	-4.0				-10.0				-20.0				-60.0			
	Elasticities of Supply and Demand															
	0.2	0.2	1.3	1.3	0.2	0.2	1.3	1.3	0.2	0.2	1.3	1.3	0.2	0.2	1.3	1.3
	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3	-0.5	-2.3
Producers' Gain	545	548	415	426	563	564	498	501	570	571	535	536	575	575	563	563
Consumers' Gain	6	6	32	29	3	3	15	15	1	1	8	8	0	0	3	3
Aggregate Gain	551	554	447	455	566	567	513	516	571	572	543	544	575	575	566	566
Farm Share (%)	99	99	93	94	99	99	97	97	99	99	98	98	100	100	99	99

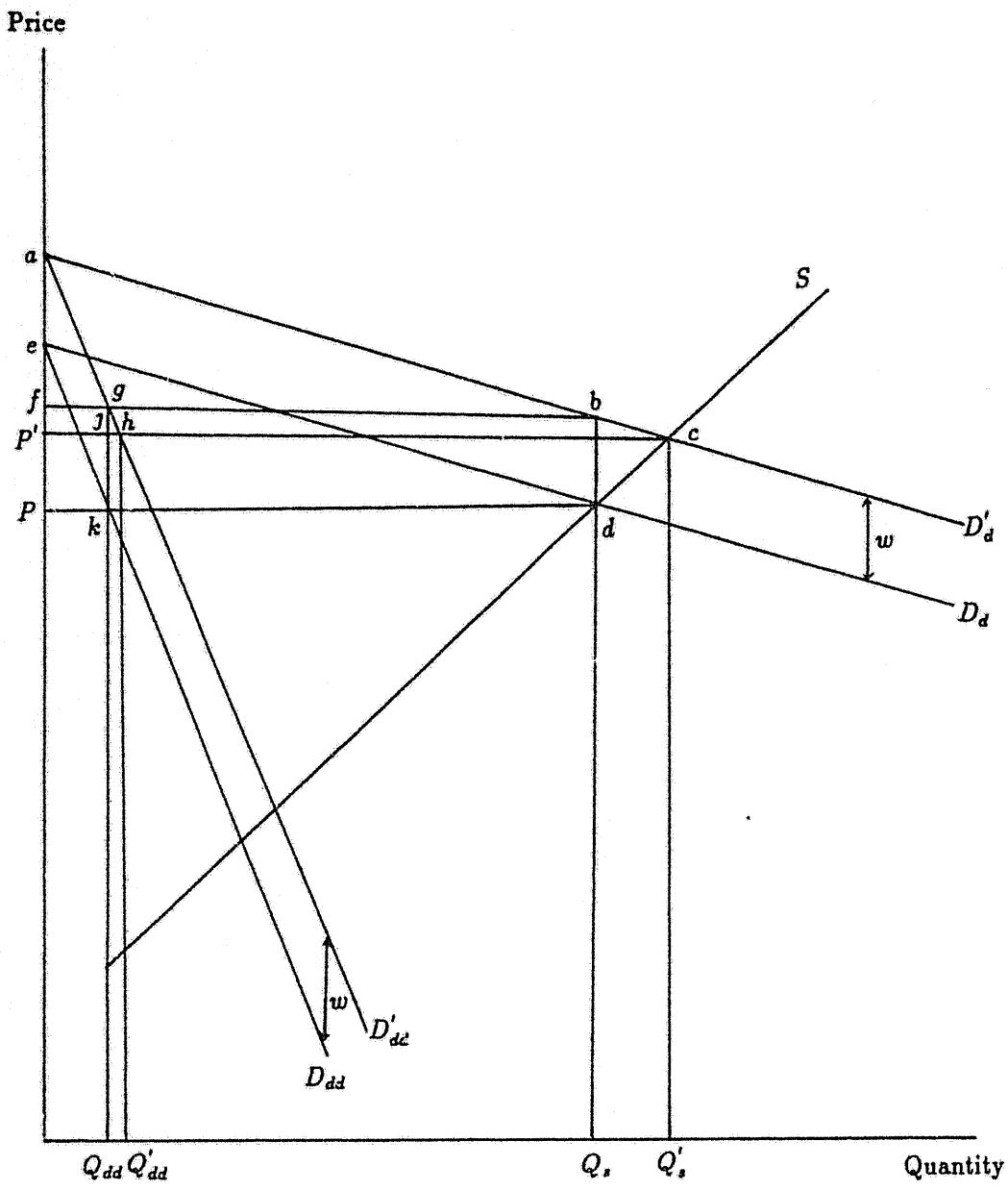

Figure 1. Welfare Gains from Wheat Grain Quality Improvement.