IMPACTS OF BREEDING AND CROP MANAGEMENT RESEARCH IN CLASSES OF WHEAT ON ECONOMIC RETURNS AND EXPORTS

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Abstract

Studies in the area of return to research investment has largely neglected the impacts of crop management research (CMR), though percentage of the annual public wheat research expenditure is higher for crop management research than the breeding research (BR). The CMR includes all crop-related research not aimed at varietal improvement. Thus, the CMR includes research on crop husbandry, pest and disease management, and resource management.

Also, studies in this area largely neglected the economic analysis of research investment in various classes of a crop. This oversight is somewhat surprising particularly in the case of wheat which includes distinct classes (hard red winter wheat, hard red spring wheat, soft red winter wheat, white wheat, and durum wheat) that are very different in their supply and demand attributes. On the supply side, each class requires unique agroclimatic conditions and crop management practices. On the demand side, end uses of theses classes of wheat are different ranging from feed use to bread mix. Because these classes of wheat are used for different purposes, export demand for wheat favors some classes against others.

The objectives of this study are (i) to examine the impact of both the CMR and BR on various classes of wheat with emphasis on quality improvement research, (ii) to evaluate the size and distribution of the economic benefits from research on various classes of wheat, and (iii) to analyze the impacts of research on the various classes of wheat exports.

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Introduction

Agricultural research has been the principal source of new knowledge and emerging technologies. It has contributed significantly to the productivity and the growth of the agricultural industry in the United States and other countries. Investment in agricultural research is generally directed toward achieving two objectives: (1) improving productivity per unit of fixed input and thus increasing supply, and (2) improving product quality and thus increasing demand. The impact of research on improving agricultural productivity and the resulting benefits to producers, as well as domestic and foreign consumers of agricultural products, has been empirically analyzed by many studies (Araji, 1980; Norton and Davis, 1981; Ruttan, 1982; Edwards and Freebairn, 1982, 1984; White, 1986, 1987; Araji, 1989, 1990; Araji and White, 1990).

The impact of agricultural research on improving product quality, and thus increasing demand has received little attention. There are two principal ways of improving product qualities: (1) genetic and varietal improvement research, and (2) management practice research directed toward fertilizer application, irrigation, pest control, and adequate rotation system that includes nitrogen fixing legumes. Generally, newly developed varieties are associated with specific agronomic practices.

The objectives of this study are: (1) to analyze the impact of breeding and management practice research on quality improvements of five classes of wheat, and (2) to analyze the impact of demand shifting and supply shifting research on welfare gains and exports of five classes of wheat. The five classes of wheat are Hard Red Winter (HRW), Hard Red Spring (HRS), Soft red, White, and Durum. The quality characteristics considered in this study are protein, kernel weight, sedimentation, falling number, flour yield, and loaf volume.

Review of Literature

Technological change in agriculture has direct and indirect impact on demand. The direct effect of technological change on demand is through quality improvement of a given product. The indirect effect occurs because the technological change associated with the production of one commodity can affect the production and price of that commodity and related commodities. Hence, the impact of technological change can spill over into other markets through price effects on inputs and outputs of complementary and substitute goods. For most goods, a shift in supply resulting from technological change will affect quantity demanded by reducing the price of the commodity along a given demand curve. The resulting change in the equilibrium price may affect demands for substitute

and complementary goods, which in turn affect demand for the commodity being considered.

The indirect impact of technological change on demand was analyzed by White and Araji (1991) in a multimarket equilibrium model. A multimarket supply-demand model, which includes technological variables in the specification of supply function, was developed for two substitute products--pork and beef. The model explicitly accounts for the fact that technological change in one market influences demand for related products. The results show that cross-market effects of technological change and the resulting impact on demands for pork and beef are important and should be taken into account in evaluating the welfare impact of technological change.

The direct impact of technological change on improving product quality and shifting the demand for a given product was evaluated in recent years. Varietal improvement and management practice researches will alter quality characteristics for a given product. Ladd and Savannunt (1976) have shown that this type of innovation will change the quantity consumed. Thus, the impact of research on quality improvement will lead to a rightward shift in the ordinary demand curve for the product being considered. Unnevehr (1986), utilizing the model of consumer goods characteristics developed by Ladd and Savannunt (1976), estimated the

research gain from rice quality improvement in Southeast Asia. The price of rice was expressed as a direct function of quality characteristics, quantity consumed, and income. Unnevehr concludes that the development of new rice variety through research will alter one or more of the quality characteristics. The estimated returns to investment in quality improvement rice research with direct impact on demand ranged from a low of 29 percent for the development of a rice variety with less Amylase to a high of 61 percent for the development of a variety with better head rice recovery.

Lemieux and Wohlgenant (1989) used an ex-ante approach to evaluate the impact of a new growth hormone (PST) on the increase in meat yield and in meat quality of the U.S. pork industry. The effects of PST on prices, quantity, and economic surplus were estimated for a one year adjustment, a five year adjustment, and when the supply elasticity of hogs is infinite. For each time length, the effect of PST on hog prices from shifts in supply and/or demand was estimated. The results show that price and quantity changes are quite sensitive to adoption rates and length of time for adjustment. The approach used also accounts for market interrelationships between the raw material and final product, interrelationships between the domestic and international market, and the change in product quality induced by adoption of PST.

Voon and Edwards (1991) estimated the distribution of research benefits resulting from a reduction of backfat depth in pigs in Australia. Their results show that under the assumptions of perfectly elastic supply of non-farm inputs and of marketing services the gross annual research benefits from a 10 percent reduction of fat depth in pigs amounts to $7 million. Approximately 80 percent of the economic benefits accrue to producers. When the assumption of perfectly elastic supply of non-farm inputs and marketing services is relaxed, producers' and consumers' benefits from reduction in fat depth in pork are lower, and some of the benefit from demand shifting research is passed to marketers and input suppliers. Aggregate benefits are identical to the two cases, also under the assumption of non-linear supply and demand, perfectly elastic supply of non-farm inputs and marketing services, and substitution between farm product and marketing services.

Voon (1991) evaluated the research gain from demand shift resulting from a reduction of Pale, Soft, Exudative (PSE) syndrome in Australian pork. The results show that a one percent reduction in PSE due to research will benefit the Australian pig industry by about $7 million per year. About 85 percent of the benefits accrue to pork producers, indicating a high price elasticity of demand relative to that of supply. This implies

that producers can increase their profit by increased investment in research that would reduce PSE syndrome.

Voon and Edwards (1992) examined the impact of research on improving the quality of Australian wheat. They considered a single quality characteristic--protein content. They assumed that the increase in the amount of protein in wheat occurs in all Australian production and that Australian wheat is a homogeneous product. A comparative static trade model that allows for different shifts in the domestic and export demands and the supply function in response to quality improvements was used to estimate the size and distribution of benefits from quality improvement research. The results show that the expected net benefit from a one percent increase in the level of protein in Australian wheat is about $53 million per year with producers capturing 99 percent of this benefit.

Five major classes of wheat are produced in the U.S. About 57 percent of all U.S. wheat is exported. Over 86 percent of the soft white wheat produced in the U.S. is exported. High protein content is a positive quality characteristic for the hard and durum wheat classes. A premium price is generally paid for these classes of wheat with a protein content of 14 percent and higher. Lower protein content, on the other hand, is preferred quality characteristic for soft white wheat. Foreign buyers of U. S. soft white offer a premium price for protein content of 9.5 percent and

below. In this study, the Voon and Edwards approach of analyzing the impact of demand-shifting quality improvement research will be extended to include the impact of breeding and agronomic research on different quality characteristics for five classes of wheat.

Theoretical Framework

Figure 1. depicts domestic market, export market and equilibrium condition. The domestic demand, export demand, total demand, and domestic supply under the 'without the research' scenario are denoted by D_{dd}, E_{dd}, D_{td}, and S. These schedules are represented by the following linear functions:

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

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

$$\begin{aligned} Q_{td} &= Q_{dd} + Q_{ed} \\ &= (a + b) - (\alpha + \beta)P \\ &= c - \theta P \end{aligned} \tag{3}$$

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

where:

Q_{dd} = domestic demand for each class of wheat,

Q_{ed} = export demand for each class of wheat,

Q_{td} = total demand for each class of wheat,

Q_s = supply of each class of wheat,

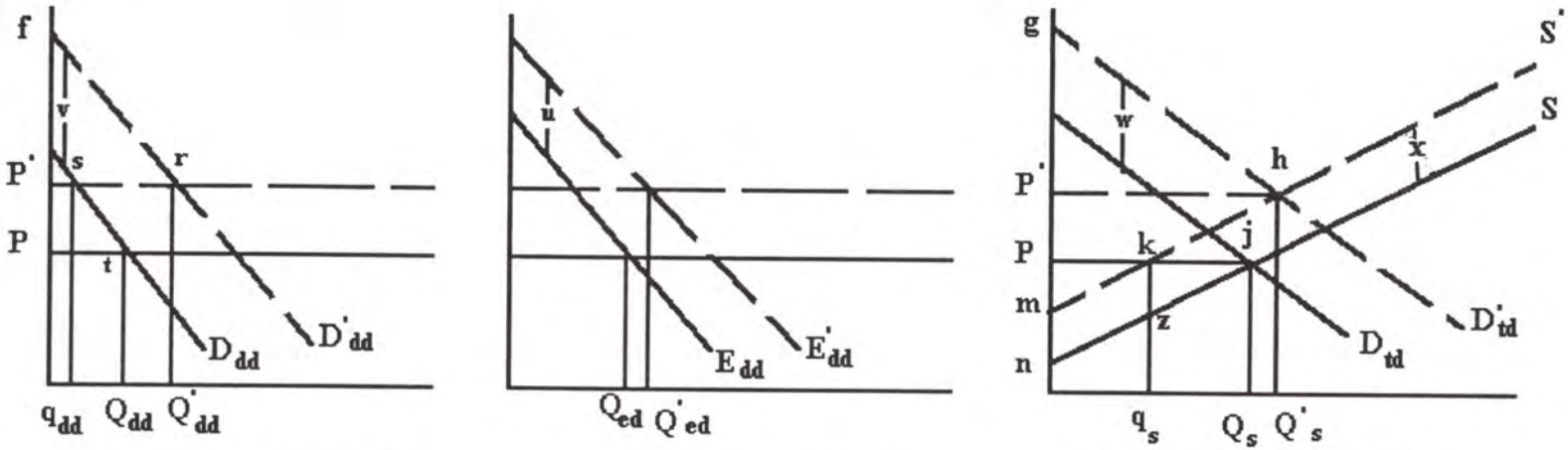

Figure 1: Welfare Gains to Producers and Consumers from Wheat Quality Improvement Research

P = price for each class of wheat, and

a,b,c,d,α,β,θ and γ are parameters, such that:

$$\alpha = e_d \frac{Q_{dd}}{P},$$

$$\beta = e_x \frac{Q_{ed}}{P},$$

$$\theta = e_t \frac{Q_{td}}{P},$$

$$\gamma = e_s \frac{Q_s}{P},$$

e_d = domestic elasticity of demand for each class of wheat,

e_x = export elasticity of demand for each class of wheat,

e_t = total elasticity of demand for each class of wheat, and

e_s = supply elasticity for each class of wheat.

Equations (1) through (4) can be solved simultaneously to obtain the equilibrium price, quantity demanded, exports, and supply. Graphically, the market equilibrium under the 'without research' scenario is at point j (Figure 1). At this equilibrium point, the quantity demanded is Q_{dd}, quantity exported is Q_{ed}, and quantity supplied is Q_s, which is also equal to total demand.

The breeding and management practices research alters the quality and supply of wheat. In particular, quality characteristics such as protein, 1000 kernel weight, sedimentation, flour yield, and loaf volume are influenced by varietal improvements and agronomic practices.

Management practices associated with changes in these quality characteristics will effect the cost of production. Specifically, it is assumed that improvement of these quality characteristics would likely increase the cost of production, which would shift the supply function to the left. On the demand side, consumers would be willing to pay more per unit as wheat contains more of these desired quality characteristics, which would shift the demand curves upward. This scenario, termed 'with research,' is analyzed as follows. First, the impact on the quality improvements are captured mathematically. Second, graphical analysis of the effect of quality improvements is provided. Finally, the changes in producers' and consumers' surplus resulting from the quality changes are illustrated.

The basic approach presented above is modified to incorporate the research impacts of different quality characteristics in different classes of wheat. The mathematical model is outlined below.

$$Q_{dd} = a + \alpha v - \alpha P' \tag{5}$$

$$Q_{ed} = b + \beta u - \beta P' \tag{6}$$

$$Q_{td} = c + \theta w - \theta P' \tag{7}$$

$$Q_{s} = d - \gamma x + \gamma P' \tag{8}$$

where:

v = additional price domestic consumers willing to pay for the desired quality improvement,

u = additional price exporter willing to pay for the desired quality improvement,

w = weighted average of V and W and defined as:

$$(v.Q_{dd} + u.Q_{ed})/Q_{td}.$$

x = increase in production

Because the taste and end-use preference may vary between domestic and foreign consumers, the value assigned to v and u may differ. As elaborated in the foregoing discussion, the quality improvements may increase the cost of production. This is captured in the supply function (Eq. 8) as $x increase in per unit of production.

The new equilibrium solution for domestic demand, exports, and supply can be solved using equations (5) through (8). Graphical solutions under the "with research" scenario are such that the equilibrium point is at h, and price, quantity demanded, exports and supply are respectively, P', Q'_{dd}, Q'_{ed}, and Q'_s (Figure 1). In addition, we can also solve for the reference points q_s and q_{dd}, which will be useful in obtaining the numerical values for changes in producers' and consumers' surplus.

Changes in consumers' and producers' surplus are illustrated in Figure 1. The change in producers' surplus is the area P'hkP minus mkjn. The area P'hkP represents the gain from the price increase and the area mkjn represents the loss from the cost of production increase. The area mkjn is of two parts: mkzn and kjz. Thus, changes in producers' surplus brought by the research investment is:

$$\begin{aligned} G_p &= \frac{1}{2}(q_s + Q_s)(P' - P) - [xq_s + \frac{1}{2}x(Q_s - q_s)] \\ &= \frac{1}{2}[(q_s + Q_s)(P' - P) - x(Q_s + q_s)] \end{aligned} \tag{9}$$

where:

G_p = change in producers' surplus attributed to research investment in each class of wheat,

$P' = P+(w\theta+\gamma x)/(\theta+\gamma)$,

$Q_s' = Q_s+\theta\gamma(w-x)/(\theta+\gamma)$, and

$q_s = Q_s - \gamma x$

Changes in consumers' surplus is the area efrs minus the area P'stP as shown in Figure 1. The area efrs represents the gain from the increase in consumption of improved quality of class of wheat. The area P'stP represents the loss in consumption due to price increase. Thus changes in consumer surplus attributed to the investments in different classes of wheat is estimated by Equation 10.

$$G_c = \frac{1}{2}v(q_{dd} + Q'_{dd}) - \frac{1}{2}(q_{dd} + Q_{dd})(P' - P)$$
$$= \frac{1}{2}[v(q_{dd} + Q'_{dd}) - (q_{dd} + Q_{dd})(P' - P)] \quad (10)$$

where:

G_s = changes in consumer surplus attributed to research investment in each class of wheat,

$Q'_{dd} = Q_{dd} + [\alpha\theta(v-w) + \alpha\gamma(v-x)]/(\theta+\gamma)$

$q_{dd} = Q_{dd} - \alpha[(w\theta + \gamma x)/(\theta+\gamma)]$

The total change in Surplus (G_t) attributed to research investment in different classes of wheat is the sum of consumers' surplus and producers' surplus and expressed in Equation 11.

$$G_t = G_p + G_c. \quad (11)$$

Data

To numerically measure the changes in exports, producers' surplus and consumers' surplus as mathematically captured in equations (10) and (11), data are required for equilibrium price (P), quantity of domestic demand (Q_{dd}), exports (Q_{ed}) and supply (Q_s) under the "without research scenario," and for the parameters θ, γ, α, v, w, and x.

The values for price, domestic demand, exports, and production by classes of wheat, reported in Table 1, are averages over the period

1978-1992. For each class of wheat, several quality characteristics were also obtained. The quality characteristics included in this study are: protein, kernel weight, sedimentation, falling number, flour yield, and loaf volume. Data on premium paid and discount (dockage) associated with each quality characteristic was also collected. Data on production, prices, and exports was from USDA Grain and Feed Market News and U.S. Export Sales published by Foreign Agricultural Service. Data on research expenditures by class of wheat was from the CRIS System. Data on quality characteristics, premium paid and dockage were from U. S. Wheat Quality Report published by U. S. Wheat Associates in cooperation with the Foreign Agricultural Service.

The parameter values for θ, γ, β and α, are derived from the elasticity coefficients, the price variable, domestic demand, export demand, total demand, and supply of each class of wheat as discussed in the theoretical section. The supply and demand elasticity estimates for the five different classes of wheat obtained from past studies are reported in Table 1. The supply elasticities coefficients were obtained from Hennings (1986) and Tweeten (1979). The estimated values of export demand elasticity for aggregate wheat varied from a low of -0.21 (Gadson, Price, and Salathe, 1982) to a high of -6.72 (Johnson, 1977). In this study, three

Table 1. Parameter and Variable Values for Estimating Research Gains from Wheat Grain Quality Improvements in the United States

Variables and Parameters [b]	Values				
	HRW [a]	HRS [a]	SOFT RED [a]	WHITE [a]	DURUM [a]
Q_s (MMT)	29.23	11.01	12.20	8.33	2.96
Q_{dd} (MMT)	13.62	5.40	5.85	2.75	1.40
Q_{ed} (MMT)	15.66	5.62	6.35	5.58	1.57
P ($/MT)	136.12	140.13	129.42	142.34	165.96
e_s	0.18	0.4	0.3	0.3	0.47
e_d	-1.28	-1.67	-1.32	-1.34	-0.92
e_x	-0.5,-3.0,6.0	-0.5,-3.0,6.0	-0.5,-3.0,6.0	-0.5,-3.0,6.0	-0.5,3.0,-6.0
v ($/MT)	3.0	2.90	2.85	2.7	2.75

[a] HRW is hard red winter wheat, HRS is hard red spring wheat, SOFT RED is soft red winter wheat, and white is soft and club white wheat.

[b] The supply elasticities for HRW, HRS, and Durum are taken from Hennings (1986), and for Soft red and White wheat are assumed. The domestic demand elasticities are average of the values reported by Hennings (1986) and Chai (1967). The export demand elasticities are assumed to represent the range of values reported in the literature. The value for v is imputed by consulting with port managers, agronomists, elevator managers, and economists.

different export demand elasticity of -0.5, -3.0,and -6.0, were used to examine the sensitivity of the results of these values.

Analysis of Results

The general results for all five classes of wheat are discussed first, followed by discussion of results specific to each class of wheat. Three factors are important in determining the impact of wheat quality improvement on exports and on the distribution of benefit between consumers and producers. These factors are: (1) the relative shift in domestic and export demand (v/u). (2) the relative shift in domestic supply and total demand (x/w), and (3) the export demand elasticity. The significance of these factors on exports and the gains from quality improvements research for all classes of wheat are discussed in the following section.

Keeping the other parameters constant, as the ratio of (v/u) increases, consumers' gain (loss) increases (decreases). This result occurs because increase in the (v/u) ratio implies that domestic consumers value the quality improvements more than foreign consumers, and that the additional gain from quality improvements exceeds the additional loss from increase in price caused by the upward shift in demand. Also, as the (v/u) rate rises, shifts in export demand gets smaller and, thus, lower exports.

The second crucial parameter is the (x/w) ratio. An increase in this ratio implies that cost of production rises faster than the value of quality improvements to both domestic and foreign consumers. Thus, as the (x/w) ratio increases, ceteris paribus, both producers' and consumers' gains decline. Producers' gain declines because additional loss from higher cost of production outweighs the additional gain from the price increase. Consumers' gain declines because additional loss from higher price, resulting from higher production cost, exceeds the additional gain from the consumption of wheat with improved quality. Producers' gain and total gain are greater if the ratio (x/w) is zero, i.e., quality improvements come without additional production expenses.

The third important parameter is export demand elasticity (e_x). Producers' gain increases if the export demand becomes more elastic and if the ratio (x/w) is less than one. This result occurs because the additional gain from price increase outweighs the additional loss caused by increase in cost of production. In contrast, if the (x/w) ratio is more than one, then producers gain (loss) decreases (increases) as the export demand becomes more elastic because additional loss from increase in production cost exceeds the additional gain from price increase. Consumers' gain (loss) increases (decreases) if the export demand becomes more elastic and if the ratio (x/w) is less than one. This result occurs because the additional loss

from price increase outweighs the additional gain from the quality improvements. In contrast, if the ratio (x/w) is more than one, then consumers' gain (loss) increases (decreases) as the export demand becomes more elastic because additional gain from increase in quality improvements exceeds the additional loss from price increase.

The impact of quality improvement research on exports and the benefits to consumers and producers is analyzed by classes of wheat in the following subsections.

Hard Red Winter (HRW) Wheat

Almost all of the HRW wheat is grown in the seven central high plains states: Texas, Oklahoma, Kansas, Colorado, Nebraska, South Dakota, and Montana. The primary end-use of HRW wheat is in bread making. The important characteristics considered for the hard red winter wheat are protein, 1000 kernel weight, sedimentation, flour yield, and loaf volume. Wheat flour used for high-quality bread should be rich in protein so that the bread dough made from the flour can be sticky and elastic. The protein content in dry HRW wheat ranges from 13.5 to 14.6 percent. The imputed value for protein contents and other quality characteristics is $3.0 per metric ton, as shown in Table 1.

Table 2. Estimated Welfare Gains of Producers and Consumers and Impacts on Exports Resulting from Quality Improvement Research on Hard Red Winter Wheat

e_x							−0.50					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports (MMT)	15.79	15.78	15.76	15.70	15.69	15.69	15.68	15.63	15.64	15.64	15.63	15.60
Cha. Exports	0.13	0.12	0.10	0.03	0.03	0.03	0.01	−0.03	−0.02	−0.02	−0.03	−0.06
Gp ($Mil)	111.78	100.57	55.82	−111.22	72.76	65.47	36.35	−72.52	53.28	47.94	26.62	−53.15
Gc ($Mil)	−24.48	−25.54	−29.80	−45.64	−6.60	−7.30	−10.11	−20.60	2.42	1.91	−0.17	−7.91
Gt ($Mil)	87.30	75.03	26.02	−156.86	66.16	58.17	26.24	−93.12	55.70	49.85	26.46	−61.06
Gp/Gt	1.28	1.34	2.15	0.71	1.10	1.13	1.39	0.78	0.96	0.96	1.01	0.87
e_x							−3.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	16.26	16.25	16.20	16.02	15.74	15.73	15.70	15.58	15.48	15.47	15.45	15.36
Cha. exports	0.60	0.59	0.54	0.36	0.08	0.07	0.04	−0.08	−0.18	−0.19	−0.21	−0.30
Gp ($Mil)	124.96	112.44	62.39	−124.26	81.34	73.19	40.63	−81.04	59.55	53.59	29.76	−59.39
Gc ($Mil)	−30.46	−30.93	−32.78	−39.72	−10.55	−10.86	−12.08	−16.68	−0.49	−0.72	−1.62	−5.01
Gt ($Mil)	94.50	81.51	29.61	−163.99	70.79	62.33	28.55	−97.72	59.06	52.87	28.13	−64.40
Gp/Gt	1.32	1.38	2.11	0.76	1.15	1.17	1.42	0.83	1.01	1.01	1.06	0.92
e_x							−6.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	16.77	16.75	16.70	16.48	15.76	15.75	15.71	15.57	15.25	15.24	15.21	15.11
Cha. exports	1.11	1.09	1.04	0.82	0.09	0.08	0.05	−0.09	−0.41	−0.42	−0.45	−0.55
Gp($Mil)	129.10	116.16	64.46	−128.35	84.02	75.61	41.97	−83.71	61.52	55.36	30.74	−61.35
Gc($Mil)	−32.33	−32.61	−33.72	−37.86	−11.79	−11.97	−12.70	−15.45	−1.40	−1.54	−2.08	−4.10
Gt($Mil)	96.77	83.55	30.74	−166.21	72.24	63.64	29.27	−99.15	60.12	53.82	28.66	−65.45
Gp/Gt	1.33	1.39	2.10	0.77	1.16	1.19	1.43	0.84	1.02	1.03	1.07	0.94

Note: e_x is export demand elasticity, v/u is relative shift in domestic and foreign demand, x/w is relative shift in domestic supply and total demand, and G_p, G_c, and G_t are changes in producer, domestic consumer, and total surpluses respectively.

The impact of quality improvement in HRW on welfare gains and exports for different export demand elasticity coefficients is shown in Table 2. The largest welfare gain occurs for parameter values of (v/u) = 0.5, (x/w) = 0.0, and e_x = -6.0. For these sets of parameters, producers' gain is about $129.1 million, consumers' loss is $32.3 million, and total gain is $96.2 million. Producers gain because the quality improvements do not cost the producers and the wind-fall profit accrues from higher price resulting from the increased demand. Consumers lose because gain from quality improvements is outweighed by the loss from price increase caused large increases in foreign demand. The parameter values of (v/u) at 0.5 and (x/w) at 0.0 might be at the lower extremes. Also, recent studies have indicated that the export demand is inelastic because of the widely prevalent restrictive trade policies in the world wheat trade (Devadoss and Meyers, 1990). Thus, a realistic set of parameters would be (v/u) = 1.0, (x/w) = 0.1, and e_x = -0.5. Under this set of parameters, the gain accrued to producers is $65.5 million, and the total gain is $58.2 million. Consumers' loss is about $7.3 million. Exports, under this set of parameters increase by 0.03 million metric ton annually (MMT).

Hard Red Spring (HRS) Wheat

About 90 percent of the HRS wheat is grown in four states: Minnesota, Montana, North Dakota, and South Dakota. Major importers of HRW wheat are Russia, Japan, China, the European Community, Taiwan, other East Asian countries, African countries, and Central and South American countries. Since HRS wheat is primarily used for bread making, high protein content and good flour and dough properties are important quality factors. The characteristics considered for the soft red winter wheat are protein, 1000 kernel weight, sedimentation, flour yield, dough properties, and loaf volume. The protein content of dry HRS wheat ranges from 15.0 to 15.9 percent. The imputed value for these quality characteristics is $2.95 per metric ton (Table 1).

The impact of quality improvement in HRS class of wheat on welfare gains and export for different export demand elasticity is presented in Table 3. Again, the most realistic set of parameters would be $(v/u) = 1.0$, $(x/w) = 0.1$, and $e_x = -0.5$. Under this set of parameters, the gain accrued to producers is $21.4 million per year, while consumers' loss is $1.4 million. Exports under this set of parameters increase by 0.01 MMT annually.

Soft Red Winter Wheat

Major states that produce soft red winter wheat are Missouri, Illinois, Indiana, Ohio, Arkansas, Mississippi, and Georgia. Major importers of soft red winter wheat include Russia, China, African countries, and Africa. Soft red winter wheat is used for making bread and cookies. The protein content of dry soft red winter wheat varies from 11.1 to 11.9 percent. The important characteristics considered for the soft red winter wheat are protein, 1000 kernel weight, sedimentation, flour yield, and loaf volume. The imputed value for these quality characteristics is 2.85 (Table 1). The impact of quality improvements for this class of wheat on welfare gains and exports for different export demand elasticity is reported in Table 4. Again, the most realistic set of parameters would be $(v/u) = 1.0$, $(x/w) = 0.1$, and $e_x = -0.5$. Under this set of parameters, the gain accrued to producers is $23.48 million per year and consumers' loss is $1.7 million. Exports under this set of parameters increase by 0.02 MMT.

White Wheat

White wheat is primarily produced in the Pacific Northwest states of Idaho, Oregon, and Washington. Primary importers of white wheat are East Asian Countries (Japan, S. Korea, Taiwan, Thailand, Singapore, and Hong Kong), Middle East countries (Egypt, Israel, Jordan, and Saudi

Table 3. Estimated Welfare Gains of Producers and Consumers and Impacts on Exports Resulting from Quality Improvement Research on Hard Red Spring Wheat

e_x							−0.50					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	5.67	5.67	5.66	5.62	5.63	5.63	5.62	5.60	5.61	5.61	5.61	5.59
Cha. Exports	0.05	0.05	0.04	0.00	0.02	0.01	0.01	−0.02	−0.00	−0.00	−0.01	−0.03
Gp($Mil)	35.91	32.30	17.91	−35.57	23.74	21.36	11.85	−23.60	17.67	15.90	8.83	−17.59
Gc($Mil)	−6.83	−7.48	−10.04	−19.50	−0.97	−1.40	−3.12	−9.51	1.99	1.67	0.38	−4.43
Gt($Mil)	29.07	24.82	7.88	−55.08	22.77	19.96	8.73	−33.11	19.67	17.57	9.20	−22.03
Gp/Gt	1.24	1.30	2.27	0.65	1.04	1.07	1.36	0.71	0.90	0.91	0.96	0.80
e_x							−3.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	5.87	5.86	5.83	5.71	5.67	5.66	5.64	5.57	5.57	5.56	5.55	5.49
Cha. exports	0.25	0.24	0.21	0.10	0.05	0.05	0.03	−0.05	−0.05	−0.05	−0.07	−0.13
Gp($Mil)	42.15	37.91	21.02	−41.69	27.86	25.07	13.91	−27.66	20.74	18.66	10.36	−20.63
Gc($Mil)	−9.81	−10.15	−11.51	−16.60	−2.97	−3.20	−4.12	−7.55	0.49	0.32	−0.37	−2.95
Gt($Mil)	32.34	27.76	9.50	−58.29	24.90	21.87	9.79	−35.21	21.23	18.98	9.99	−23.58
Gp/Gt	1.30	1.37	2.21	0.72	1.12	1.15	1.42	0.79	0.98	0.98	1.04	0.87
e_x							−6.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	6.06	6.05	6.01	5.86	5.68	5.68	5.65	5.55	5.49	5.49	5.47	5.39
Cha. exports	0.45	0.44	0.40	0.25	0.07	0.06	0.03	−0.07	−0.12	−0.13	−0.15	−0.22
Gp($Mil)	44.73	40.23	22.30	−44.22	29.57	26.60	14.75	−29.34	22.01	19.80	10.99	−21.88
Gc($Mil)	−11.03	−11.25	−12.12	−15.39	−3.79	−3.94	−4.53	−6.73	−0.12	−0.23	−0.68	−2.34
Gt($Mil)	33.70	28.99	10.18	−59.61	25.78	22.66	10.23	−36.07	21.88	19.56	10.31	−24.22
Gp/Gt	1.33	1.39	2.19	0.74	1.15	1.17	1.44	0.81	1.01	1.01	1.07	0.90

Note: e_x is export demand elasticity, v/u is relative shift in domestic and foreign demand, x/w is relative shift in domestic supply and total demand, and G_p, G_c, and G_t are changes in producer, domestic consumer, and total surpluses respectively.

Arabia), and Pakistan. The export market is important for the white wheat grown in the Northwest. About 84 percent of the soft white wheat is grown in the Pacific Northwest. An estimated 86 percent of the soft white wheat grown in the United States is exported. White wheat is mostly used to make noodles, pasta, and confectionery products such as cake, cookies, and crackers. The average protein level of white wheat ranges from 9.0 percent to 11.5 percent (U.S. Wheat Associates). The protein content of white wheat grown in the Pacific Northwest has increased in recent years because of the prolonged seven-year drought. Thus, protein content in white wheat is highly responsive to moisture and fertility and may be influenced by management practices.

The end-use products of white wheat require low gluten strength which is available only at the low protein white wheat. Consequently, many importers have set maximum protein contents for this class of wheat and are willing to pay a premium for white wheat with less protein. For example, in the spring of 1993 South Korea was willing to pay a premium of 8 to 13 cents per bushel of white wheat with protein content below 9.5 percent. The imputed value for the desired quality characteristics for white wheat is $2.7 per metric ton, as shown in Table 1.

The impact of quality improvements for this class of wheat on welfare gains and exports for different export demand elasticity is reported

Table 4. Estimated Welfare Gains of Producers and Consumers and Impacts on Exports Resulting from Quality Improvement Research on Soft Red Winter Wheat

e_x							−0.50					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	6.41	6.40	6.39	6.35	6.36	6.36	6.35	6.33	6.34	6.34	6.34	6.32
Cha. exports	0.06	0.06	0.05	0.01	0.02	0.02	0.01	−0.02	−0.00	−0.01	−0.01	−0.03
Gp($Mil)	39.72	35.73	19.82	−39.42	26.10	23.48	13.03	−25.97	19.30	17.36	9.64	−19.23
Gc($Mil)	−7.69	−8.32	−10.83	−20.13	−1.25	−1.66	−3.33	−9.55	2.01	1.69	0.45	−4.19
Gt($Mil)	32.03	27.41	8.99	−59.55	24.85	21.82	9.70	−35.52	21.30	19.06	10.09	−23.42
Gp/Gt	1.24	1.30	2.20	0.66	1.05	1.08	1.34	0.73	0.91	0.91	0.96	0.82
e_x							−3.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	6.62	6.62	6.59	6.47	6.40	6.39	6.37	6.30	6.28	6.28	6.26	6.21
Cha. exports	0.28	0.27	0.24	0.12	0.05	0.05	0.03	−0.05	−0.06	−0.07	−0.08	−0.14
Gp($Mil)	46.70	42.02	23.30	−46.29	30.68	27.60	15.32	−30.50	22.68	20.41	11.33	−22.58
Gc($Mil)	−10.96	−11.26	−12.46	−16.91	−3.42	−3.62	−4.42	−7.40	0.38	0.24	−0.36	−2.58
Gt($Mil)	35.74	30.75	10.84	−63.21	27.25	23.98	10.90	−37.90	23.07	20.64	10.97	−25.17
Gp/Gt	1.31	1.37	2.15	0.73	1.13	1.15	1.41	0.80	0.98	0.99	1.03	0.90
e_x							−6.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	6.84	6.83	6.80	6.65	6.41	6.40	6.38	6.28	6.19	6.19	6.17	6.10
Cha. exports	0.50	0.49	0.45	0.31	0.06	0.06	0.03	−0.06	−0.16	−0.16	−0.18	−0.25
Gp($Mil)	49.17	44.24	24.53	−48.72	32.30	29.06	16.12	−32.10	23.88	21.49	11.93	−23.77
Gc($Mil)	−12.11	−12.30	−13.03	−15.77	−4.19	−4.31	−4.80	−6.64	−0.19	−0.28	−0.64	−2.01
Gt($Mil)	37.06	31.94	11.50	−64.49	28.11	24.74	11.32	−38.74	23.69	21.21	11.28	−25.78
Gp/Gt	1.33	1.38	2.13	0.76	1.15	1.17	1.42	0.83	1.01	1.01	1.06	0.92

Note: e_x is export demand elasticity, v/u is relative shift in domestic and foreign demand, x/w is relative shift in domestic supply and total demand, and G_p, G_c, and G_t are changes in producer, domestic consumer, and total surpluses respectively.

in Table 5. The most realistic set of parameters would be (v/u) = 1.0, (x/w) = 0.1, and e_x = - 0.5. Under this set of parameters, the gain accrued to producers is $14.6 million per year. Domestic consumers' loss is estimated at $0.5 million annually. Exports of white wheat under this set of parameters increases by 5.5 MMT annually.

Durum Wheat

More than 90 percent of durum wheat is produced in North Dakota, South Dakota, Montana, and Minnesota. North Dakota is the leading producer of durum wheat. Importers of durum wheat are African countries, central and South American countries. Primary end-uses of durum wheat are for bread, cookies, and spaghetti. The protein content of durum wheat varies from 11.1 to 11.9 percent. The important quality characteristics considered for durum wheat are protein, 1000 kernel weight, sedimentation, flour yield, and loaf volume. The imputed value for these quality characteristics is $1.7 per metric ton, as shown in Table 1.

The impact of quality improvement for this class of wheat on welfare gains and exports for different export demand elasticity is shown in Table 6. Again, the most realistic set of parameters would be (v/u) = 1.0, (x/w) = 0.1, and e_x = -0.5. Under this set of parameters, the gain accrued to producers is $4.4 million per year. Unlike in other classes of wheat,

Table 5. Estimated Welfare Gains of Producers and Consumers and Impacts on Exports Resulting from Quality Improvement Research on White Wheat

e_x							−0.50					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	5.62	5.62	5.61	5.57	5.59	5.59	5.59	5.56	5.58	5.58	5.57	5.56
Cha. Exports	0.04	0.04	0.03	−0.01	0.01	0.01	0.01	−0.01	0.00	0.00	−0.00	−0.02
Gp($Mil)	27.19	24.46	13.57	−27.00	16.26	14.63	8.12	−16.19	10.81	9.73	5.40	−10.78
Gc($Mil)	−3.84	−4.18	−5.54	−10.58	−0.28	−0.49	−1.31	−4.38	1.52	1.38	0.83	−1.23
Gt($Mil)	23.34	20.27	8.03	−37.58	15.98	14.14	6.81	−20.58	12.33	11.11	6.23	−12.01
Gp/Gt	1.16	1.21	1.69	0.72	1.02	1.03	1.19	0.79	0.88	0.88	0.87	0.90
e_x							−3.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	5.74	5.73	5.71	5.62	5.61	5.61	5.60	5.54	5.55	5.55	5.54	5.50
Cha. Exports	0.16	0.16	0.13	0.05	0.03	0.03	0.02	−0.03	−0.03	−0.03	−0.04	−0.08
Gp($Mil)	33.60	30.22	16.76	−33.31	20.09	18.07	10.03	−19.99	13.35	12.01	6.67	−13.30
Gc($Mil)	−5.91	−6.04	−6.57	−8.55	−1.53	−1.61	−1.94	−3.14	0.68	0.63	0.41	−0.40
Gt($Mil)	27.69	24.18	10.19	−41.86	18.55	16.46	8.09	−23.13	14.03	12.64	7.08	−13.70
Gp/Gt	1.21	1.25	1.64	0.80	1.08	1.10	1.24	0.86	0.95	0.95	0.94	0.97
e_x							−6.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	5.85	5.85	5.82	5.72	5.62	5.61	5.60	5.54	5.50	5.50	5.49	5.45
Cha. Exports	0.28	0.27	0.24	0.14	0.04	0.04	0.02	−0.04	−0.08	−0.08	−0.09	−0.13
Gp($Mil)	35.34	31.79	17.63	−35.03	21.13	19.01	10.55	−21.02	14.04	12.63	7.01	−13.99
Gc($Mil)	−6.47	−6.54	−6.85	−7.99	−1.87	−1.92	−2.11	−2.80	0.45	0.42	0.30	−0.17
Gt($Mil)	28.87	25.25	10.78	−43.02	19.25	17.09	8.44	−23.82	14.49	13.05	7.31	−14.16
Gp/Gt	1.22	1.26	1.64	0.81	1.10	1.11	1.25	0.88	0.97	0.97	0.96	0.99

Note: e_x is export demand elasticity, v/u is relative shift in domestic and foreign demand, x/w is relative shift in domestic supply and total demand, and G_p, G_c, and G_t are changes in producer, domestic consumer, and total surpluses respectively.

consumers gain but by the small amount of $0.2 million annually. Exports of this class of wheat under this set of parameters increased by 1.52 MMT annually.

Conclusions

This study extends the Voon and Edwards' approach in evaluating the welfare impact of quality improvement research for five classes of wheat. The results show that for all five classes of wheat producers capture all the benefits resulting from improved wheat quality. The most realistic estimates indicate that producers' gain ranges from $4.4 million for durum wheat to $65.5 million for Hard Red Winter Wheat. Except for durum wheat, consumers' surplus is negative. Their annual losses range from $0.5 million for white wheat to $7.3 million for Hard Red Winter Wheat. Since producers gain is significantly larger than the consumers loss, the net welfare gain is positive and quite high.

The estimated returns to research imply that significant gains can be achieved by investing in breeding and management practice research to improve the quality characteristics in five classes of wheat. Particularly, for the four classes of wheat, HRW, HRS, soft red wheat, and durum wheat, quality factors such as protein, sedimentation, flour yield, and kernel weight need to be improved. On the other hand, breeding and

Table 6. Estimated Welfare Gains of Producers and Consumers and Impacts on Exports Resulting from Quality Improvement Research on Durum Wheat

e_x							−0.50					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	1.58	1.58	1.58	1.56	1.57	1.57	1.57	1.56	1.57	1.57	1.56	1.56
Cha. Exports	0.01	0.01	0.01	−0.00	0.01	0.00	0.00	−0.01	0.00	0.00	−0.00	−0.01
Gp($Mil)	7.47	6.72	3.73	−7.42	4.88	4.39	2.44	−4.86	3.59	3.23	1.79	−3.58
Gc($Mil)	−0.89	−1.13	−2.07	−5.56	0.32	0.17	−0.45	−2.76	0.93	0.82	0.36	−1.35
Gt($Mil)	6.58	5.59	1.66	−12.98	5.20	4.56	1.99	−7.62	4.52	4.05	2.15	−4.93
Gp/Gt	1.14	1.20	2.24	0.57	0.94	0.96	1.23	0.64	0.79	0.80	0.83	0.73
e_x							−3.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	1.62	1.62	1.61	1.58	1.58	1.58	1.57	1.55	1.56	1.56	1.55	1.54
Cha. Exports	0.06	0.06	0.05	0.01	0.01	0.01	0.01	−0.01	−0.01	−0.01	−0.01	−0.03
Gp($Mil)	10.15	9.13	5.06	−10.05	6.63	5.97	3.31	−6.59	4.88	4.39	2.44	−4.85
Gc($Mil)	−2.14	−2.25	−2.69	−4.33	−0.50	−0.57	−0.86	−1.95	0.32	0.27	0.06	−0.74
Gt($Mil)	8.01	6.88	2.38	−14.39	6.13	5.39	2.45	−8.54	5.20	4.66	2.49	−5.60
Gp/Gt	1.27	1.33	2.13	0.70	1.08	1.11	1.35	0.77	0.94	0.94	0.98	0.87
e_x							−6.00					
v/u			0.50				1.00				2.00	
x/w	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00	0.00	0.10	0.50	2.00
Exports(MMT)	1.67	1.66	1.65	1.61	1.58	1.58	1.57	1.55	1.54	1.54	1.54	1.52
Cha. Exports	0.10	0.10	0.09	0.05	0.02	0.02	0.01	−0.02	−0.02	−0.02	−0.03	−0.05
Gp($Mil)	11.08	9.96	5.52	−10.96	7.24	6.51	3.61	−7.19	5.32	4.79	2.66	−5.29
Gc($Mil)	−2.57	−2.63	−2.90	−3.91	−0.78	−0.83	−1.00	−1.67	0.12	0.08	−0.05	−0.54
Gt($Mil)	8.51	7.33	2.62	−14.87	6.45	5.68	2.61	−8.85	5.44	4.87	2.61	−5.83
Gp/Gt	1.30	1.36	2.11	0.74	1.12	1.15	1.38	0.81	0.98	0.98	1.02	0.91

Note: e_x is export demand elasticity, v/u is relative shift in domestic and foreign demand, x/w is relative shift in domestic supply and total demand, and G_p, G_c, and G_t are changes in producer, domestic consumer, and total surpluses respectively.

management practice research should be directed toward reducing the protein content in white wheat from the present average of 11 percent to less than 9.5 percent.

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