KANSAS WHEAT BREEDING: AN ECONOMIC ANALYSIS

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Abstract

The increase in wheat production due to Kansas semidwarf varieties is quantified, and the costs and benefits of the wheat research program are evaluated using a two-region model of the world wheat market. The economic rate of return of the wheat breeding program is calculated, and policy implications are derived.

KANSAS WHEAT BREEDING: AN ECONOMIC ANALYSIS.

Public research in wheat breeding has resulted in higher yields for Kansas wheat producers over the past several decades. Wheat breeding research at the Kansas Agricultural Experiment Station (KAES) is currently funded at approximately $4 million dollars per year. The sources of this large research investment include the federal government, the State of Kansas, and grants from organizations such as the Kansas Wheat Commission. This research addresses the question, “What are the economic impacts of this research effort?” More specifically, empirical evidence is presented to address the question as to whether the public investment in Kansas wheat breeding has resulted in a socially worthwhile use of public funds, and how the economic benefits of the research program are distributed across consumers and producers in Kansas and other regions. The results of this research are particularly important in an era of declining taxpayer support for public agricultural research (Fuglie et al., USDA Cooperative Research Service). Careful measurement of the economic rate of return of the investment in wheat breeding research provides crucial information to administrators and policy makers, whose decisions on the allocation of research funding will determine the future size and scope of publicly-funded agricultural research.

The agronomic contribution of genetic wheat research is measured by quantifying the increase in wheat yields attributable to genetic enhancements in wheat from the Kansas wheat breeding research program for the period 1979 to 1994. Yield gains are measured for all semi-dwarf varieties released by KAES, beginning with the release of Newton in 1977. This increase in wheat yields represents an increase in the supply of wheat produced in Kansas, and is the foundation of the economic impacts of the wheat breeding program.

An economic model of the world wheat market is developed and used to measure the impact of the KAES wheat breeding program on: (1) Kansas wheat producers, (2) Kansas consumers of wheat (flour millers), (3) wheat producers outside of Kansas, including foreign producers such as Argentina and Australia, and (4) all wheat consumers outside of Kansas, including importers such as China and Japan. Annual benefits to each group resulting from the increased wheat yields are measured and analyzed. Several measures of the outcome of the investment in wheat breeding are calculated and assessed, and policy implications for the future of Kansas wheat breeding are presented.

Funding of Kansas Wheat Breeding Research

Research in wheat genetics is funded by a variety of sources, as can be seen in Figure One. All nominal dollar values were deflated by the Personal Consumption Expenditure (PCE) index (US Department of Commerce); therefore, all dollar values reported are in constant 1995 dollars. The major source of funds for public wheat breeding in Kansas is the State of Kansas and other nonfederal sources, such as grants from the Kansas Wheat Commission (Figure One). The federal component of funding is relatively small, averaging approximately $250,000 per year from 1970 to 1995. Public wheat breeding in Kansas is a cooperative effort between the KAES and the USDA Agricultural Research Service (USDA/ARS), as can be seen by the ARS funds (which include overhead) in Figure One. Funds from ARS averaged $740,000 per year.

Annual state-level appropriations and other nonfederal sources resulted in an increase in total research funding from $1.8 million in 1970 to over $6 million in 1988. Since 1988, however, state and other nonfederal funds have declined, causing total funding to decline to approximately $3.2 million in 1995. The importance of state-level funding, coupled with the current political climate of decreasing public sector support (Acker 1993), result in a situation where continuation of public funding of the wheat breeding research program is dependent on how well the program is serving the public. Empirical evidence on the economic consequences of the breeding program provides evaluation of the program, together with assessment of the likely consequences of changes in the level of funding of public wheat breeding in Kansas.

Measurement of the Social Benefits of Kansas Wheat Breeding

The methodology used to calculate the economic consequences of the Kansas wheat breeding program follow a rich literature in the welfare economics of agricultural research, initiated by Schultz (1953), and further developed by Ayer and Schuh (1972) and Akino and Hayami (1975). More recently, the economic evaluation of agricultural research has been summarized by Huffman and Evenson (1993) and Alston, Norton, and Pardey (1995). The present study follows previous evaluations of wheat breeding programs conducted by Blakeslee and Sargent (1982), Zentner and Peterson (1984), Brennan (1984, 1989a, and 1989b), and Byerlee and Traxler (1995).

The first step in evaluating the economic impact of the Kansas wheat breeding program is to measure the increase in yields due to the genetic improvement of wheat, holding all other production parameters constant. This was accomplished by applying the methodology of Feyerharm et al. (1984) to calculate the relative yields for each variety with data from KAES wheat variety performance tests (KAES). By using relative yield performance data from nurseries, we implicitly assume that actual producer yields are equivalent to test plot yields in KAES experiments. While a gap between experimental and actual yields may exist, Brennan (1984) reports, "The only reliable sources of relative yields are variety trials" (p. 182).

Salmon (1951) reported that tests over many location-years are necessary to detect differences in cultivar yields. Yield data were aggregated over all locations and years to develop a yield ratio for each variety. Following Feyerharm et al. (1984), relative yield ratios were derived by calculating the mean yield ratio over all location-years where the ith variety was grown together with the control. The ratio of the ith variety's yield to a control variety's yield (Y_i/Y_0) was calculated for the eight semi-dwarf varieties released by KAES (Table 1). Following the recommended method of Brennan (1984) and Zentner and Peterson (1984), an index of varietal improvement was used to calculate annual shifts in the aggregate wheat production function attributable to Kansas wheat breeding research. The index (I_t) was constructed by calculating the average yield increase of the eight KAES semi-dwarf varieties relative to the control variety's yield, weighted by the percentage of Kansas acres planted to each variety (w_{it}):

(1) $I_t = S_i \, w_{it} \, (Y_i/Y_0 - 1)$, $i=1,...,8$, $t=1978,...,1994$.

Note that there are two sources of change in the productivity index: higher yields and changes in the percentage of acres planted to a variety. The annual increase in Kansas wheat production, J_t, is the first difference of the index of varietal improvement: $J_t = I_t - I_{t-1}$.

The index of varietal improvement, I_t, and the annual shift in Kansas wheat production, J_t, are reported in table 2, together with the percentage of acres planted to each of the KAES semi-dwarf varieties.

The annual shift in wheat production (J_t) is the foundation for the analysis of the economic impacts of wheat breeding research. Previous work by Echeverria et al. (1989) used a similar methodology of using experimental yields to measure research-induced industry supply curve shifts for rice in Uruguay. Alston, Norton, and Pardey (1995) demonstrated how to convert an annual shift in the quantity of wheat produced (J_t) into a percentage shift in cost savings (K_t): the formula is simply $K_t=J_t/e$, where e is the elasticity of supply of wheat (page 339).

An Economic Model of Kansas Wheat Breeding Research Impacts

Edwards and Freebairn (1984) pioneered an economic model to measure the impact of productivity gains from research into a tradable commodity such as wheat. The model was applied to Australian wool research by Alston and Mullen (1992). This simple two-country model of supply and demand is adopted here to estimate the impact of the research-induced supply shift on producer and consumer surpluses in (1) Kansas, and (2) the rest of the world (ROW, defined as all areas outside of Kansas). Alston, Norton, and Pardey (1995) report explicit formulas for the calculation of changes in economic surplus to producers and consumers in two countries, and their model is modified below to the case of Kansas wheat research. The supply (Q^s) and demand (Q^d) of wheat in Kansas (K) and the ROW (R) are assumed to be linear functions of the world price of wheat (P), as in equations (2)-(5), where k is the percentage downward shift in supply (k = KP). Time subscripts have been omitted for notational simplicity.

(2) $Q^s_K = a_K + b_K(P + k)$
(3) $Q^d_K = g_K + d_K P$
(4) $Q^s_R = a_R + b_R P$
(5) $Q^d_R = g_R + d_R P$
(6) $Q^s_K + Q^s_R = Q^d_K + Q^d_R$ (market-clearing).

To simplify, we assume no transportation costs, resulting in a constant price in both regions, and a system of five equations (2 through 6) to solve for five unknowns: P, Q^s_K, Q^s_R, Q^d_K, and Q^d_R. The solution to this system of equations results in the welfare changes for producers and consumers in Kansas and ROW, as in equations (7) and (8):

(7) $DP = -kb_K/(b_K + b_R - d_K - d_R) < 0$
(8) $DQ^s_K = b_K(P + Dk)$; $DQ^d_K = d_K DP$; $DQ^s_R = b_R DP$; $DQ^d_R = d_R DP$.

The welfare changes for producers and consumers in Kansas and ROW are given in equations (9) through (13), where PS is producer surplus, CS is consumer surplus, and TS is total surplus:

(9) $DPS_K = (k + DP)(Q^s_K + 0.5DQ^s_K)$
(10) $DCS_K = -DP(Q^d_K + 0.5DQ^d_K)$
(11) $DPS_R = DP(Q^s_R + 0.5DQ^s_R)$
(12) $DCS_R = -DP(Q^d_R + 0.5DQ^d_r)$
(13) $DTS = DPS_K + DCS_K + DPS_R + DCS_R$

To solve this simple model, price and quantity data, together with elasticity estimates of supply and demand, and a measure of research-induced productivity change (k) are necessary. A recent study of Kansas crop acreage response resulted in an estimate of the supply elasticity of wheat in Kansas (e_K) of 0.4 (Lin and Barkley). For simplicity, we assume that this elasticity holds for both Kansas and ROW: ($e_K = e_R = 0.4$). The demand elasticity is taken from Huang: $h_K = h_R = -0.1$. The price of wheat (P) is the season average price received by farmers (USDA *Agricultural Outlook*), deflated by the PCE (US Department of Commerce). The quantity of wheat supplied in Kansas (Q^s_K) is taken from the Kansas Department of Agriculture, and the Kansas quantity demanded (Q^d_K) is the number of bushels of wheat ground into flour and feed (Kansas Department of Agriculture). Wheat production in ROW (Q^s_R) is found by subtracting Kansas production from world wheat production, reported in USDA *Agricultural Outlook*. The market-clearing equation (6) is used to calculate ROW demand (Q^d_R).

Model Results: Research-Induced Changes in Economic Surplus

The results of the model appear in table 3: Kansas wheat producers gained an average of $52.7 million dollars per year from 1979 to 1994 due to growing wheat varieties developed and released by KAES. Not all producers benefit: only those producers who adopt the high-yielding varieties earn higher levels of economic surplus. Although the economic benefits to Kansas producers are large, they are volatile: the benefits fluctuated from a low of -$84.9 million in 1984 to a high of +$280.7 million in 1993. Consumers of wheat in Kansas benefit by $190,000 per year. This relatively small benefit results from the research-induced shift in the world supply of wheat being quite small, since Kansas produced only about two percent of the world's wheat. This fact allows for large producer gains, with only a limited drop in the world price of wheat.

Wheat producers who reside outside of Kansas are made worse off due to the decrease in the price of wheat, with an average annual loss of $40.7 million. There is a degree of research benefit spillover of KAES varieties into neighboring states, particularly Oklahoma, but these spillovers are not accounted for in this analysis. Non-Kansas consumers benefit from the research-induced shift in the supply of wheat by an annual average of $41.4 million. The ROW producer losses are approximately equal to the ROW consumer gains. This result, together with large gains to Kansas wheat producers and small Kansas consumer losses, results in a change in total economic surplus (DTS) equal to an annual average of $53.6 million. These annual benefits are large relative to the annual average costs of the research program of roughly $4 million.

The final step in the evaluation of the impacts of the Kansas wheat breeding program is to calculate the rate of return to the public investment in the genetic improvement of wheat varieties. Proper measurement of the rate of returns requires careful consideration of the timing of varietal development and the discounting procedure. Input from KAES Agronomists led to the assumption of the time required to develop a variety of 17 years from the initial variety cross to the release date. Since the economic benefits of KAES semi-dwarf varieties began in 1979, all research costs from the period of 1962 to 1994 are included in the analysis (1962 is 17 years prior to 1979). Cost data are not available from KAES records prior to 1970, resulting in the assumption of annual costs of $2 million for the period 1962 to 1969. The economic benefits (DTS) reported in table 3 were used for the period 1979 to 1994. After 1994, the five-year average benefit level from 1990 to 1994 ($69.0 million) was assumed to decrease at ten percent per year, until all research program benefits are depleted in year 2005.

The benefit-cost ratio (BCR) is calculated as a measure of gross research benefits: $BCR_t = [B_t/(1+r)^t]/[C_t/(1+r)^t]$, where B_t is the DTS from table 3, and C_t are program costs. The BCR_t for KAES semi-dwarf wheat varieties equals 11.96: for each dollar of public funds invested in wheat breeding research, almost 12 dollars of benefits result, most of which accrue to Kansas wheat producers. The Net Present Value (NPV_t) of the program is given by: $NPV_t = S_t[(B_t - C_t)/(1+r)^t]$, where r is the discount rate. The NPV_t of the program for the period 1962 to 2004, with an assumed discount rate of 5 percent equals $446.3 million (1995 dollars). A third measure of economic performance is the Internal Rate of Return (IRR_t), computed as the discount rate that results in a value of zero for the NPV_t:

$0 = S_t[(B_t - C_t)/(1+IRR)^t]$. The IRR_t for the wheat breeding program equals 39 percent. The BCR_t, NPV_t, and IRR_t provide evidence that the economic rate of return to Kansas wheat breeding is high, although it is difficult to assess these measures further without comparable values for other public investments (the opportunity cost of funds).

Policy Implications and Conclusions

Results of the two-region economic model of research-induced increases in the supply of wheat in Kansas provide empirical evidence that wheat producers who adopt the new varieties are the major beneficiaries of the technological advance. Kansas consumers (wheat millers) are made better off, but by only a small percentage (0.04%) of the value of wheat purchased. A transfer of economic surplus from non-Kansas producers to ROW consumers of approximately $41 million occurs annually, due to the decrease in the world price of wheat induced by the enhanced yields of KAES wheat varieties.

The traditional sources of research funding for the wheat program are the State of Kansas and the federal government. If, due to political realities, these sources reduce their support of the program, society would lose the economic benefits of the research. Two alternative funding procedures are possible. First, a one-cent per bushel "tax," or "check-off program" would raise roughly $3.8 million each year (on average, 380 million bushels of wheat are produced in Kansas), which would allow continuation of the research at approximately the current size and scope. One attribute of this funding method is that the major beneficiaries of the program, the Kansas wheat producers would also be the funding source of the program. One difficulty with this approach is that the economic benefits may not be obvious to all wheat producers, resulting in problems raising the funds. A second possibility is to raise the price of the released foundation wheat seed to a level high enough to cover the costs of research and development. This strategy would "internalize" the large, positive externality associated with public wheat breeding. The higher price could also lead to increased competition from private breeders, who have difficulty competing with the currently subsidized KAES varieties.

One implication for wheat breeders derived from this research is that any decrease in the long development time (17 years) of a variety would result in large economic benefits to society. An example of this is greenhouse breeding, which allows for two generations of winter wheat to be grown in one year. The major implication of this research is that more resources could be advantageously allocated to the wheat breeding program. The major tenet of economics is to "allocate resources to the highest return." Given the large economic benefits of the Kansas wheat breeding program, an increase in funding is an appropriate use of scarce resources, since the economic rate of return to the investment is high, although there are also distributional consequences of the program.

Table 1. Yield Advantages of KAES Semi-Dwarf Wheat Varieties.

KAES Variety	Year Released	Yield Ratio[a]
Newton	1977	1.253
Cheney	1978	1.134
Arkan	1982	1.315
Norkan	1986	1.297
Karl	1988	1.609
Karl92	1992	1.712
Ike	1993	1.646
Jagger	1994	2.345

[a]Yield Ratio is defined as the mean value of (Y_i/Y_0), where Y_i is the yield of variety i and Y_0 is yield of the control variety (Newton) for all location-years.

Table 2. Percent Acres Planted and Production Increase of KAES Semi-Dwarf Varieties.

Year	Newton	Cheney	Arkan	Norkan	Karl	Karl92	Ike	Jagger	I_t	J_t
	(%)									
1978	0.1	0	0	0	0	0	0	0	0.0003	0
1979	2.8	0	0	0	0	0	0	0	0.007	0.007
1980	17.5	0	0	0	0	0	0	0	0.044	0.037
1981	34.2	0	0	0	0	0	0	0	0.087	0.042
1982	41.1	0.1	0	0	0	0	0	0	0.104	0.018
1983	38.5	0	0	0	0	0	0	0	0.097	-0.007
1984	30.9	0	0.9	0	0	0	0	0	0.081	-0.016
1985	25.7	0	6.3	0	0	0	0	0	0.085	0.004
1986	21.1	0	10.1	0	0	0	0	0	0.085	0.0003
1987[a]	17.3	0	12.5	0.4	0	0	0	0	0.084	-0.001
1988	13.4	0	14.9	0.8	0	0	0	0	0.083	-0.001
1989	11.6	0	11.9	1.3	0	0	0	0	0.071	-0.013
1990	8.3	0	6.8	0.8	0.7	0	0	0	0.049	-0.022
1991	7.6	0	3.2	0.2	5.9	0	0	0	0.066	0.017
1992	5.8	0	2.2	0	11.5	0	0	0	0.092	0.026
1993	3.1	0	0.8	0	0	23.0	0	0	0.174	0.083
1994	2.5	0	0.4	0	0	23.6	0	0	0.176	0.002
1995	1.6	0	0.1	0	0	22.4	0.9	0	0.170	-0.006
1996	1.3	0	0	0	0	20.9	7.2	0.1	0.212	0.042

[a]Data on acres planted to each variety were not collected in 1987 (KAES); therefore values for 1987 are the mean of 1986 and 1988.

Source: Percentage acres planted (KAES). Indices are from author's calculations.

Table 3. Research-Induced Changes in Economic Surplus, 1979 to 1994.

	Wheat Production		Wheat	Kansas			ROW		
Year	Kansas	ROW	Price[a]	k_t	DPS_K	DCS_K	DPS_R	DCS_R	DTS
	---(million bushels)-----		($/bu)	(%)	---------(million 1995 dollars)--------				
1979	410.4	15,535	7.66	0.13	52.8	0.22	-41.8	42.8	53.9
1980	420.0	16,266	7.06	0.66	274.8	0.98	-214.7	219.5	280.6
1981	302.5	16,483	6.44	0.68	207.0	0.74	-161.6	163.9	210.1
1982	458.5	17,586	5.53	0.24	110.1	0.38	-86.9	88.8	112.5
1983	448.2	17,986	5.26	-0.09	-38.6	-0.14	30.9	-31.5	-39.4
1984	431.2	17,979	4.94	-0.20	-84.9	-0.27	68.2	-69.6	-86.6
1985	433.2	18,809	4.09	0.04	16.8	0.06	-13.4	13.6	17.1
1986	336.6	18,376	3.12	0.00	0.9	0.003	-0.7	0.7	0.9
1987	366.3	19,257	3.24	-0.01	-2.9	-0.01	2.3	-2.3	-2.9
1988	323.0	18,225	4.58	-0.01	-3.6	-0.02	2.9	-2.9	-3.7
1989	213.6	18,188	4.56	-0.14	-30.0	-0.12	24.1	-24.3	-30.3
1990	472.0	19,584	2.91	-0.16	-72.1	-0.28	58.1	-59.2	-73.6
1991	363.0	21,605	3.12	0.13	47.3	0.15	-37.4	37.9	48.0
1992	363.8	19,919	3.37	0.22	78.9	0.28	-62.1	62.9	80.0
1993	388.5	20,643	3.42	0.71	280.7	0.97	-214.9	218.2	285.0
1994	433.2	20,551	3.48	0.01	5.5	0.02	-4.4	4.5	5.6
Mean (1979-94)	376.9	18,562	4.55	0.14	52.7	0.19	-40.7	41.4	53.6

[a]Price is in constant 1995 dollars.

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