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ECONOMIC RETURNS FROM ADAPTIVE RESEARCH ON WHEAT: A CASE STUDY OF THE ARSSI REGIONAL DEVELOPMENT UNIT

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ABSTRACT. The study has attempted to quantify the economic rate of return (IRR) on adaptive research on HYV wheat in Arssi region. The findings show an IRR of 40 percent. The sensitivity of this estimated IRR to different demand and supply price elasticity and supply shift factor assumptions has been tested. Under all assumptions the IRR is high and relatively stable. The conclusion of the study is, therefore, that the adaptive research on wheat carried out in Arssi region has been quite profitable.

1. INTRODUCTION

The Arssi Regional Development Unit (formerly the Chilalo Agricultural Development Unit) was established pursuant to a dialogue on development assistance that was initiated in March 1966, between the governments of Ethiopia and Sweden. The dialogue culminated in the signature of an agreement by the two governments on September 8, 1967 to jointly finance and establish the Chilalo Agricultural Development Unit (CADU) [16]. CADU was located in Chilalo *awraja* in Arssi administrative region.[1] Starting 1977, the project expanded to cover the other two *awrajas* of Arssi, Arbagugu and Ticho, and was appropriately renamed, the Arssi Regional Development Unit (ARDU) [3].

The overall objective of CADU/ARDU has been to bring about an economic and social development in the project area. A significant amount of literature addresses the quantitative and qualitative achievements of this objective.[2]

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Agricultural research and extension figure prominently among activities of ARDU. Though some breeding work had been attem in the earlier phases of the project the research at ARDU has essentially adaptive in nature. That is, the research effort is dire to the testing and screening of varieties with the ultimate objectiv identifying and recommending suitable varieties for Arssi region.

Wheat and barley being the leading crops in Arssi region the search effort at CADU/ARDU was focused on these two crops. F the period 1967 — 1983, fourteen different varieties of wheat ha been released. But most have been abandoned as their yield stabili has broken down due to their susceptibility to rust and other disease In the early eighties only four of the fourteen were being cultivated viable commercial varieties.[3]

Survey data intermittently collected by CADU/ARDU suggest th the yield advantage of the released improved varieties of wheat ov the traditional varieties of wheat on the average is about 15 percent. However, yield levels of wheat at farm level in Arssi region seem t have peaked in the mid-seventies and have been declining since.

The research achievement in barley as compared to that of whe is more modest. The project has been unable to come up with varieti of convincing yield advantage over the traditional varieties. Moreov the released barley varieties were found to be susceptible to attack by barley fly and as a consequence their adoption rate among farmer is negligible. Of the seven varieties released between 1970 — 1979 only one, "Beka", appears to have been cultivated by farmers to any significant degree [6, 11].

In addition to wheat and barley the research programme at CADU/ARDU was also directed at maize, oil crops, forage crops and other cereals. But only the research on wheat has met with some success.

CADU/ARDU has incurred substantial cost on research, extension work and in the multiplication of seeds of the high yielding varieties (HYV) of wheat. The objective of this article is to examine the effectiveness of these costs by estimating an economic rate of return.

2. THEORY AND METHODOLOGY

One contribution of improved agricultural technology is growth in technical efficiency which expresses itself through increased crop production per hectare either by increasing yield potential or reducing the maturity date thus making multiple cropping possible. This has been the operational goal of much agricultural research in developing countries.

The most significant research products of the past quarter of a century in terms of increasing output have been the high yielding varieties (HYVs) of wheat and rice. Since their introduction into developing countries in the early sixties more than a third of the area under these two cereals has been sown with the HYVs, "making the HYVs the most widely and rapidly adopted technology in agricultural history" [21].

The long standing belief that the return to investment in agricultural research is very high began to be empirically validated starting the late 1950's. Since then numerous studies, undertaken in both developed and developing countries, show very high internal rates of return on investment in agricultural research. Anderson in his review of 50 research programmes found the average annual rates of return slightly less than 50 percent, only four showing returns of less than 20 percent [2]. The indications are that agricultural research is an attractive area for public investment.

Different methodologies have been developed to evaluate the returns to investment in agricultural research.[5] Probably the most

widely used ex-post method for evaluating output increasing or input saving agricultural research programmes to date, is the Index-Number Approach based on the theory of consumers' and producers' surplus. The path breaking study using this methodology was the one by Grilches on hybrid corn research in U.S.A. [10]. He estimated the internal rate of return (IRR) on investments to be 35—40 percent. His study was followed by that of Peterson on poultry research [18]. His estimate of IRR was 20—30 percent. These high rates of return at a time when a 10 percent IRR was taken as acceptable aroused sufficient interest for similar studies to be undertaken in different countries. Studies were conducted in developing countries also and confirmed that high rates of return from agricultural research do obtain in developing countries as well [2, 5, 12, 16, 20].

2.1 The Theory of Consumers' and Producers' Surplus

The theory of Consumers' and Producers' surplus was popularized by Alfred Marshall [14]. The theory, despite controversies surrounding it, has become an important analytical tool for empirical economic studies [8]. One area of application is the ex-post evaluation of the IRR of agricultural research programmes.

The basic analytical framework is illustrated in Figure 1 below.

The shift in the supply function from S to S' is induced by increased productivity due to the utilization of improved technology. The shift factor of the supply function is designated as K. This shift in supply produces changes in consumers and producers surplus. The area POA plus ABR represents the change in consumers surplus. This is a flow of benefits by virtue of the fact that consumers are able to purchase more of the product and at a lower price (in the general case). Producers' surplus changes by the area BRO minus the area POA. In the case where the area POA is greater than the area BRO producers will sustain a loss. The total change in economic surplus (producers

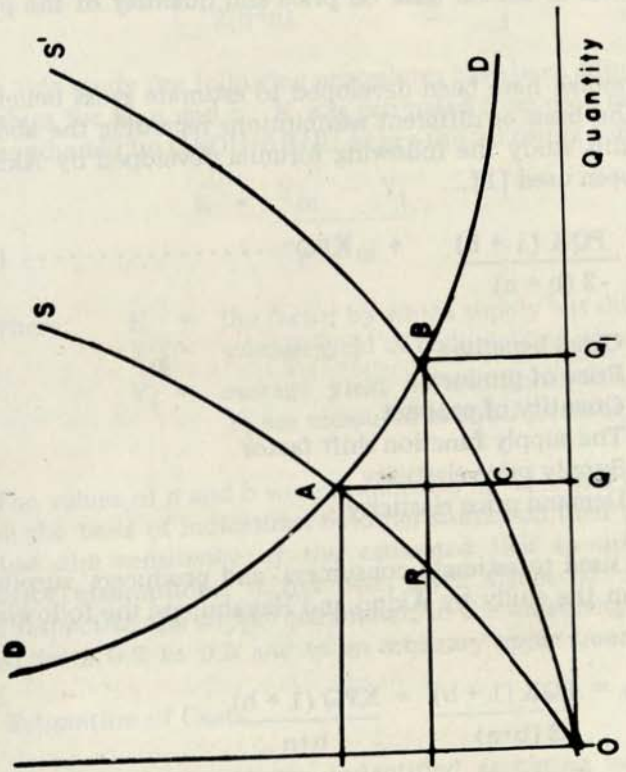

Figure. 1. ANALYTICAL FRAMEWORK BASED ON THE THEORY OF CONSUMERS AND PRODUCERS SURPLUS

plus consumers) will be the area AOB. In this framework the estimation of gross benefits amounts to the calculation of the area AOB.

The data required to calculate the area AOB include: the supply function shift factor (K), the demand and supply elasticities, n and b respectively, as well as annual data on price and quantity of the product.

Different formulae have been developed to estimate gross benefits (area AOB) on the basis of different assumptions regarding the above parameters. In this study the following formula developed by Akino and Hayami has been used [1].

$$B = \frac{PQK\,(1 + b)}{2\,(b + n)} + KPQ \quad \text{---------- (1)}$$

Where: B = Gross benefits
P = Price of product
Q = Quantity of product
K = The supply function shift factor
b = Supply price elasticity
n = Demand price elasticity

The formulae used to estimate consumers' and producers' surplus, again adopted from the study by Akino and Hayami, are the following [1].

$$\text{Consumers surplus} = \frac{PQK\,(1 + b)}{2\,(b+n)} + \frac{KPQ\,(1 + b)}{b+n} \left[\frac{1-K\,(1 + b)}{b+n} - \frac{K\,(1 + b)}{2}\right] \quad \text{---------- (2)}$$

$$\text{Producers surplus} = KPQ - \frac{KPQ(1+b)}{b+n} - \left[\frac{1-K(1+b)}{2(b+n)} - \frac{K(1+b)}{2}\right] \quad \text{----------} (3)$$

In this study the following procedures have been adopted in obtaining values for K, n and b. K was estimated from crop sampling survey data conducted by CADU/ARDU as per the following formula [1].

$$K = \frac{Y_m - Y_t}{Y_m} \quad \text{----------} (4)$$

Where: K = the factor by which supply has shifted
Y_m = average yield of high yielding wheat varieties
Y_t = average yield of traditional varieties; Y_m and Y_t are measured at equal levels of inputs

The values of n and b were assumed to be −1.0 and 0.35 respectively, on the basis of indications by other studies on their probable level.[6] To test the sensitivity of the estimated IRR to different demand elasticity assumptions, n has been given values of −0.3 and −0.5. With respect to the supply parameter, in the sensitivity test b has been varied from 0.2 to 0.5 and to an arbitrary upper bound value of 1.0.

2.2 Estimation of Costs

The following costs are indentified as having been incurred to generate the gross benefits as defined above.

1) Research costs
2) Agricultural extension costs
3) The cost of additional resources used in the multiplication of improved seeds

Research costs at CADU/ARDU are not reported disaggregated by commodity groups. Therefore, to isolate the research costs on wheat a rough coefficient was developed using the number of different wheat trials in the total for all crops.

Similarly, extension costs at CADU/ARDU are reported as aggregates. For the isolation of extension costs on wheat we had to rely on the estimates given by the chairman of the extension department at ARDU regarding budget disbursement among the different extension activities.

With respect to the estimation of the cost of additional resources used in the multiplication of improved seeds, it is assumed that they are reflected by the price differential between improved seeds and traditional varieties.

2.3 Estimation of a Rate of Return

The internal rate of return (IRR) is defined as the discount rate that makes the net present value of the projects net benefits equal to zero. The decision rule employed with the IRR criterion is to invest in all projects that show a $P \geqslant r$, where P is the IRR and r is the centrally determined discount rate reflecting the opportunity cost of capital. The centrally determined discount rate (r) in Ethiopia at present is 10 percent [9]. The higher the value of P relative to r the more profitable the project is.

The IRR may be expressed thus:

$$\sum_{t=1}^{T} \frac{B_t - C_t}{(1+P)^t} = 0 \quad \text{---------- (5)}$$

Where: B_t = estimated gross benefits in year t
C_t = estimated costs in year t
P = the internal rate of return
t = year
T = the year costs and benefits are assumed to end

The beginning of the project life, 1967/68, would be t = 1. The determination of T, the finite time horizon for which the calculations are made requires additional assumptions, as the project is an ongoing one with no definite cut off period. Studies at CADU/ARDU have shown that improved varieties sustain their yield stability on the average for four years, after which they will have to be replaced by newly developed varieties [11]. On the basis of this evidence it was decided to make the fourth year after the last year for which cost data are available, to be the terminal year of the time horizon for which IRR is calculated. For this study the last year for which cost data were available is 1982/83. Therefore, no productivity gains were assumed for the following four years and stable costs and benefits at the level of 1982/83 were used for upto 1986/87.

3. RESULTS

3.1 Estimates of Gross Benefits

To arrive at an estimate of gross benefits data on the quantity of output from HYV wheat is necessary. And this requires data on acreage under HYV wheat, as well as, yield data. The crop sampling

surveys carried out by CADU/ARDU provide data on yield but not on acreage under HYV. Therefore, the acreage data had to be generated indirectly by estimating adoption levels of the improved varieties of wheat in Arssi Region. The adoption levels were estimated by fitting a logistic curve.[7]

Due to lack of complete data an average farm household number of 203,784 was used for all the years. Likewise an average allocation of 0.45 hectares for wheat per farm household was used for all the years under consideration. The estimated adoption levels in conjunction with the number of farm households, the average allocation of land for wheat per farm household, and yield data helped generate data of output from HYV wheat in Arssi region. The estimated output from HYV wheat ranges from 16,414 quintals in 1967/68 to 864,211 quintals in 1982/83 (Table 1).

In calculating the value of wheat produced from HYV's the following procedure was used: Initially the value of the output was calculated using current producer prices at Asella. Then the values obtained were adjusted using the Addis Ababa Cereals Price Index (1981 = 100). This index had to be used as a proxy for the wholesale price index of commodities which is not available. 1981 was used as the shifted base year for the index because the prices for wheat, maize and sorghum for the year were reasonably consistent with estimated import parities and thus were considered efficient [22]. The adjusted annual value of the estimated produce from HYV wheat is presented in Table 2 below.

TABLE 1

ESTIMATES OF ADOPTION LEVEL, ACREAGE AND OF PRODUCTION HYV WHEAT IN ARSSI REGION (1967/68 – 1982/83)

Year	Adoption Level %	Acreage Under HYV Wheat (Ha)	Yield (Qt/Ha)*	Production from HYV (Qts)
1967/68	1	917	17.9	16,414
1968/69	2	1,834	"	32,829
1969/70	3	2,751	"	49,243
1970/71	4	3,668	"	65,657
1971/72	6	5,502	"	98,486
1972/73	9	8,253	"	147,729
1973/74	14	12,838	"	229,800
1974/75	20	18,341	"	328,304
1975/76	27	24,760	"	443,204
1976/77	34	31,179	15.2	473,921
1977/78	42	38,515	"	585,428
1978/79	48	44,017	"	669,058
1979/80	53	48,602	"	738,750
1980/81	57	52,271	"	794,519
1981/82	60	55,022	"	836,334
1982/83	62	56,856	"	864,211

Notes: * Due to lack of completeness in the time series data it was preferred to use two separate averages. Otherwise the yield data for 1967 – 1982/83 would have been overestimated. Note too that Ha is the short form for hectares and Qt for quintals.

TABLE 2

ESTIMATED VALUE OF WHEAT PRODUCED FROM HYV WHEAT IN ARSSI REGION (1967/68 – 1982/83)

Year	HYV Wheat Output (Qts)	Wheat Producer Prices (1) (Br/Qt)	Value at Current Producers Prices (Br)	Addis Ababa Cereals Price Index (2) (1981=100)	Adjusted value (1981=100)
1967/68	16,414	21.65	355,363	31.9	1,113,991
1968/69	32,829	22.10	725,521	32.2	2,253,171
1969/70	49,243	20.50	1,009,482	34.0	2,969,065
1970/71	65,657	21.40	1,405,060	45.1	3,115,432
1971/72	98,486	19.19	1,889,946	41.2	4,587,248
1972/73	147,729	13.13	1,939,682	32.2	6,023,857
1973/74	229,800	19.00	4,366,200	35.6	12,264,607
1974/75	328,304	19.00	6,237,776	36.3	17,183,956
1975/76	443,204	20.50	9,085,682	36.2	25,098,569
1976/77	473,921	22.00	10,426,262	56.0	18,618,325
1977/78	585,428	22.00	12,879,416	72.4	17,789,249
1978/79	669,058	26.39	17,656,441	87.6	20,155,755
1979/80	738,750	22.75	16,806,563	101.9	16,493,192
1980/81	794,519	31.00	24,630,089	98.7	24,954,497
1981/82	836,334	31.00	25,926,354	100.0	25,926,354
1982/83	864,211	31.00	26,790,541	116.9	22,917,486

Notes: (1) Price data for 1967/68 – 1975/76 were obtained from the documents of the Credit and Sales Section of CADU/ARDU. The prices for 1967/77 – 1982/83 were obtained from AMC – branch office at Asella. Br is the short form for Birr, the Ethiopian Currency which at this time exchange in the bank at the rate of 2.07 for one U.S. Dollar (seller's price) and at 2.4 for the dollar (buyer's price).

(2) Calculated from: CSO, *Statistical Report*, various issues.

The supply shift factor (K) due to the cultivation of HYV wheat in Arssi calculated as per the formula given in the previous section is 0.15 or 15 percent. Price elasticity of demand (n) is unitary and supply price elasticity (b) is 0.35 (see preceding section). The estimates of gross benefits i.e. the value of incremental output due to HYV wheat when the parameters K, n, and b have the above values are given in Table 3 below. The gross benefits have also been separated into consumers' surplus and producers' surplus (Table 3). It should be noted, however, that in developing economies in general the distribution of benefits between "producers" and "consumers" does not coincide with the distribution between "producer households" and "consumer households" as the producers consume a substantial proportion of their own produce. In such a case, producers' households capture a portion of "consumers' gain". Therefore, the benefits that accrue to producers are likely to be larger than what the figures in Table 3 suggest. Hence from our calculations it appears that the greater proportion of benefits from the adaptive research on wheat at CADU/ARDU has been captured by producers.

3.2 Estimates of Costs

Research and extension costs have been isolated from the aggregate data in accordance with the procedure outlined in the methodology section (see appendix I and II for details). No consistent pattern or trend emerges from the cost estimates obtained. From the experiences of many third world countries, it is noted that the extension expenditures are larger than the expenditures on research.

The cost of additional resources used in the multiplication of improved seeds is estimated through the price differential charged for improved seeds as compared to traditional varieties (appendix III).

TABLE 3

ESTIMATES OF GROSS BENEFITS, CONSUMERS SURPLUS AND PRODUCERS SURPLUS FROM HYV WHEAT IN ARSSI REGION
(1967/68 – 1982/83)
(Br.)

Year	Gross Benefits	Consumers' Surplus	Producers' Surplus
1967/68	250,648	115,987	134,661
68/69	506,963	234,596	272,368
69/70	668,040	309,133	358,906
70/71	700,972	324,373	376,599
71/72	1, 032,131	477,615	554,515
72/73	1, 355,368	627,192	728,176
73/74	2, 759,537	1, 276,967	1, 482,570
74/75	3, 866,390	1, 789,160	2, 077,230
75/76	5, 647,178	2, 613,214	3, 033,964
76/77	4, 189,123	1, 938,504	2, 250,619
77/78	4, 002,581	1, 852,182	2, 150,619
78/79	4, 535,045	2, 098,578	2, 436,467
79/80	3, 710,968	1, 717,239	1, 993,729
80/81	5, 614,762	2, 598,214	3, 016,548
81/82	5, 833,430	2, 699,402	3, 134,028
82/83	5, 156,434	2, 386,124	2, 770,310

The different types of costs incurred to realize the gross benefits considered above are summarized in Table 4 below. In the studies reviewed the total costs stream is adjusted by deflating it by the index of wholesale prices of commodities. This was not possible in this study due to the absence of such an index in Ethiopia. Therefore, the adjustment was attempted by the use of two indices. The value of benefits and the additional cost of producing HYV seeds have been adjusted using the Cereals Price Index for Addis Ababa. The sum of costs on research and extension was adjusted by the Retail Price Index for Addis Ababa as labour cost is the dominant component. The limitations of using the Retail Price Index as a proxy for an Index of Wholesale Prices of Commodities are recognized. Nevertheless, it has been used, in the absence of the latter, to achieve a degree of consistency. In both indices 1981 has been used as the shifted base year.

3.3 Estimates of IRR

The IRR under the assumptions of unitary price elasticity of demand, 0.35 price elasticity of supply and the estimated value of the supply shift factor, K, of 15 percent was found to be about 40 percent. The sensitivity of this estimated IRR to different price elasticity assumptions has been tested. The supply price elasticity parameter, as indicated above, was varied from 0.2, the typical lower bound value for cereals in developing countries, to 0.5 and to an arbitrary upper bound value of 1.0. The calculations carried out show that the estimated IRR is completely insensitive to these different assumptions of the supply parameter when the assumption of unitary price elasticity of demand is maintained.

The sensitivity of the estimated IRR to different demand price elasticity (n) and supply shift factor (K) assumptions has also been tested. Calculations have been carried out by assuming the values of 0.3 and 0.5 for n, and 0.165 and 0.135 for K, i.e. 10 percent above and below the estimated K value of 0.15. The estimates of IRR under these various assumptions are summarized in Table 5 below.

TABLE 4

SUMMARY OF COSTS INCURRED AT CADU/ARDU IN THE GENERATION OF BENEFITS FROM HYV WHEAT (1967/68 – 1982/83)

Item	67/68	68/69	69/70	70/71
1. Research Costs	96,151	178,004	115,769	147,740
2. Extension Costs	54,396	121,700	184,593	253,540
Sub-total	150,547	299,704	300,362	401,280
3. Sub-total adjusted by Retail Price Index For A.A. (1981=100)	442,785	878,897	868,098	1,053,228
4. Additional Cost on HYV Seed Production	29,241	46,255	96,832	291,295
5. Total Cost	472,026	925,152	964,930	1,344,523

	71/72	72/73	73/74	74/75
1. Research Costs	158,930	142,929	34,014	256,473
2. Extension Costs	217,895	316,312	403,320	508,645
Sub-total	376,825	459,241	437,334	765.118
3. Sub-total Adjusted by Retail Price Index For A.A. (1981=100)	983,877	1,275,669	1,115,648	1,796,052
4. Additional Cost on HYV Seed Production	707,646	793,450	416,073	474,303
5. Total Cost	1,691,523	2,069,119	1,531,721	2,270,355

TABLE 4 (Continued)

Item	75/76	76/77	77/78	78/79
1. Research Costs	260,418	215,974	44,341	159,076
2. Extension Costs	184,793	264,992	309,198	351,352
Sub-total	445,211	480,966	353,539	510,428
3. Sub-total Adjusted by Retail Price Index For A.A. (1981 = 100)	982,806	824,985	519,910	656,921
4. Additional Cost on HYV Seed Production	385,826	103,521	185,732	199,862
5. Total Cost	1,368,632	928,506	705,642	856,783

	79/80	80/81	81/82	82/83
1. Research Costs	128,551	83,726	322,788	250,002
2. Extension Costs	228,149	320,938	365,311	448,085
Sub-total	356,700	404,664	688,099	698,087
3. Sub-total Adjusted by Retail Price Index for A.A. (1981 = 100)	395,455	429,580	688,099	661,067
4. Additional Cost on HYV Seed Production	508,132	407,300	334,888	328,668
5. Total Cost	903,587	836,880	1,022,987	989,735

TABLE 5

SUMMARY OF IRR ESTIMATES UNDER DIFFERENT ASSUMPTIONS OF SUPPLY SHIFT FACTOR (K) SUPPLY (b) AND DEMAND (n) PRICE ELASTICITIES

K, b, n	Assumptions		Estimated IRR (%)
K = 0.15	b = 0.35	n = 1.0	40
K = 0.15	b = 0. 2	n = 1.0	40
K = 0.15	b = 0. 5	n = 1.0	40
K = 0.15	b = 1. 0	n = 1.0	40
K = 0.15	b = 0. 5	n = 0.5	50
K = 0.15	b = 1. 0	n = 0.3	51
K = 0.15	b = 1. 0	n = 0.5	47
K = 0.165	b = 0.35	n = 1.0	46
K = 0.135	b = 0.35	n = 1.0	34

4. CONCLUSION

The findings of the study show an IRR of 40 percent for the adaptive research on HYV wheat at CADU/ARDU. This estimated IRR is quite high and compares favourably with results reported in other developing countries.

Needless to say the study suffers from data limitations and as a result several indirect estimation methods have been used to generate some data. Therefore, no claim is placed on the estimated IRR of being accurate to the degree of having hit the "bulls eye." However, the sensitivity test shows the IRR under various assumptions to be high and relatively stable. Hence, the indications are that the estimated IRR of 40 percent does faithfully represent the general magnitude of the rate of return.

Thus, the conclusion with regard to the adaptive research on HYV wheat at CADU/ARDU is that it has been quite profitable for the period of the study. The society at large has benefited from increased output of wheat and it appears that producing households which also consume a substantial share of their output have captured the larger share of the benefits.

NOTES

1. Until recently the Ethiopian state consisted of 16 Administrative Regions each sub-divided into *Awrajas.*

2. See for instance: [6], [7], [13].

3. The four viable varieties were identified as "Enkoy", "Romany BC", "K6290–Bulk" and "K6295–4A." [11].

4. CADU publications Nos. 24, 49, 64, 108 and ARDU publications Nos. 8, 27.

5. For brief but comprehensive review of the different methodologies see [19].

6. A study conducted in Arssi by ARDU [4] estimated the income elasticity of demand for cereals in Arssi to be 0.82. Economic literature suggests that the price elasticity is bound to be slightly higher, hence the assumption of n = 1.0 [15].

Studies reviewed indicate price supply elasticities between 0.2 and 0.5 to be characteristic for foodgrains in developing countries [12, 15, 19]. Based on this an average value of 0.35 was assumed as the price elasticity of supply for wheat in Arssi.

7. The logistic curve fitted to estimate the annual adoption levels of HYV wheat in Arssi is of the type:

$$Y_c = \frac{P}{1+10^{a+bt}}$$

Where: Y_c = the estimated level of adoption of HYV wheat in year t.

P = an upper asymptote of adoption level

a = the parameter that gives the intercept value at $t = 0$

b = the slope parameter

t = year

On the basis of available data and an assumed value for P = 65% for the year 1986/87 (actual adoption level for 1981/82 was 60%) the following estimating formula was arrived at:

$$Y_c = \frac{65}{1+10^{(1.806179974 - 0.20609723t)}}$$

REFERENCES

[1] Akino, M. and Hayami, Y., "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development", *American Journal of Agricultural Economics*, Vol. 57, Feb. 1975, pp. 1-10.

[2] Andersen, Pinstrup, *Agricultural Research and Technology in Economic Development*, (New York: Longman Inc., 1982).

[3] ARDU, "Plan for 1976–80", (Asella: ARDU Pub. No. 1, February, 1976).

[4] ARDU, "Impact of the Agrarian Reform on Peasants Income and Expenditure Patterns", (Asella: ARDU Pub. No. 18, October, 1981).

[5] Ayer, H. A. and G. E. Schuh, "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in Sao Paulo, Brazil", *American Journal of Agricultural Economics*, Vol. 54, Nov. 1972, pp. 557-579.

[6] Bengtsson, Bo. M.I., *Rural Development Research and Agricultural Innovations*, (Uppsala: Swedish University of Agricultural Sciences, 1983).

[7] Cohen, M.M., "Rural Change in Ethiopia: The Chilalo Agricultural Development Unit", *Economic Development and Cultural Change*, Vol. 22, (1974), pp. 580-614.

[8] Currie, J.M., J.A. Murphy, and A. Schmitz, "The Concept of Economic Surplus and Its Use in Economic Analysis", *Economic Journal*, Vol. 81, Dec., 1971, pp. 741-799.

[9] Development Projects Study Agency, "Guidelines to Project Planning in Ethiopia", (Addis Ababa: 1981).

[10] Grilches, Zvi, "Research Costs and Social Returns, Hybrid Cron and Related Innovations", *Journal of Political Economy*, Vol. 66, August, 1958, pp. 419-431.

[11] Haile, Betru, " On the Activities of the Plant Husbandry Department", (Asella: ARDU Pub., No. 24, November, 1983).

[12] Hertford., et. al "Productivity of Agricultural Research in Colombia", in *Resource Allocation and Productivity in National and International Agricultural Research*, eds. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan, (minneapolis: University of Minnesota Press, 1977, pp. 86-123).

[13] Kifle, Henock, "Investigation on Mechanized Farming and Its Effects On Peasant Agriculture", (Asella: CADU Pub. No. 74, 1972).

[14] Marshall, Alfred, *Principles of Economics*, (London, 1930).

[15] Mellor, John W., *The Economics of Agricultural Development*, (Ithaca: Cornell University Press, 1971, pp. 59-60).

[16] Moya, P. F., R. E. Evenson, and Y. Hayami, "Social Returns to Rice Research in the Philipines: Domestic Benefits and Foreign Spillover", *Economic Development and Cultural Change*, Vol. 26, April, 1978, pp. 591-607.

[17] Nekby, B., CADU: *An Ethiopian Experiment in Developing Peasant Farming*, (Stockholm: Prisma Publishers, 1971).

[18] Peterson, W. L., "Return to Poultry Research in the United States", *Journal of Farm Economics*, Vol. 49, August, 1967, pp. 656-669.

[19] Schuh, Edward and Helio Tollini, *Costs and Benefits of Agricultural Research: The State of the Arts*, (Washington D. C. World Bank Staff Working Paper No. 360, 1979).

[20] Scobie, G. M., and P. T. Rafael, "The Impact of Technical Change on Income Distribution: The Case of Rice in Colombia", *American Journal of Agricultural Economics*, Vol. 60, Feb. 1978, pp. 85-91.

[21] World Bank, "Agricultural Research Sector Policy Paper", (Washington D. C., June, 1981).

[22] World Bank, "Ethiop . Recent Economic Developments and Future Prospects", (World B nk Report No. 4683 a-Et., 1984).

APPENDIX I

ESTIMATES OF ANNUAL RESEARCH EXPENDITURES ON WHEAT AT CADU/ARDU (1967/68 – 1982/83)

Year	Total Expenditure of Plant Husbandry Dept. (Br.)	Proportion of Wheat Trials of Total	Research Expenditure on Wheat (Br.)
1967/68	331,624.72	0.29	92,171.17
68/69	556,262.66	0.32	178,004.05
69/70	551,280.20	0.21	115,768.84
70/71	527,645.35	0.28	147,740.70
71/72	429,541.74	0.37	158,930.44
72/73	492,858.62	0.29	142,929.00
73/74	147,887.00	0.23	34,014.01
74/75	625,542.86	0.31	256,472.57
75/76	635,167.04	0.41	260,418.49
76/77	1,028,449.54	0.21	215,974.40
77/78	184,754.54	0.24	44,341.09
78/79	232,235.12	0.68	159.076.00
79/80	194,773.63	0.66	128,550.60
80/81	209,315.25	0.40	83,726.10
81/82	1,075,961.63	0.30	322,788.49
82/83	1,000,008.00	0.25	250,002.00

APPENDIX II

ESTIMATES OF AGRICULTURAL EXTENSION EXPENDITURES ON WHEAT AT CADU/ARDU (1967/68 – 1982/83) (Br.)

Year	Total Expenditure of the Extension Department	Extension Expenditure on Wheat[a]
1967/68	120,880.56	54,396
68/69	270,444.95	121,700
69/70	410,206.60	184,593
70/71	563,422.28	253,540
71/72	484,212.16	217,895
72/73	702,915.00	316,312
73/74	896,266.83	403,320
74/75	1,130,321.99	508,645
75/76	923,967.32	184,793
76/77	1,324,960.00	264,992
77/78	1,545,992.13	309,198
78/79	1,756,757.99	351,352
79/80	1,140,743.26	228,149
80/81	1,604,688.24	320,938
81/82	1,826,554.15	365,311
82/83	2,240,426.00	448,085

[a]Upto 1974/75, 45% of total and for 1975/76 – 1982/83 20% of total.

APPENDIX III

ESTIMATES OF COSTS OF ADDITIONAL RESOURCES USED IN THE PRODUCTION OF HYV SEEDS OF WHEAT (1967/68 – 1982/83)

Year	HYV Seeds Distributed (Qts.)	Price of HYV Seeds (Br/Qt)	Value of HYV Seeds (Br)	Price of Local Varieties (Br/Qt)
1	2	3	4	5
1967/68	1,796	26	46,696	21.65
68/69	3,819	26	99,294	22.10
69/70	5,986	26	155,636	20.50
70/71	17,286	29	501,294	21.40
71/72	19,686	34	669,324	19.19
72/73	12,242	34	416,228	13.13
73/74	11,394	32	364,608	19.00
74/75	13,244	32	423,808	19.00
75/76	14,702	30	441,060	20.50
76/77	9,662	28	270,536	22.00
77/78	13,447	32	430,304	22.00
78/79	12,864	40	514,560	26.39
79/80	18,010	51.50	927.515	22.75
80/81	19,610	51.50	1, 009,915	31.00
81/82	16,336	51.50	841,304	31.00
82/83	18,742	51.50	965,215	31.00

APPENDIX III (Continued)

Year	Value of Seeds at Local Variety Prices (Br)	Additional Cost on Seed Production	Additional Cost Adjusted by A.A. Cereals (1981 = 100)
	6	7 (4–6)	8
1967/68	37,368	9,328	29,241
68/69	84,400	14,894	46,255
69/70	122,713	32,923	96,832
70/71	369,920	131,374	291,295
71/72	377,774	291,550	707,646
72/73	160,737	255,491	793,450
73/74	216,486	148,122	416,073
74/75	251,636	172,172	474,303
75/76	301,391	139,669	385,732
76/77	212,564	57,972	103,521
77/78	295,834	134,470	185,732
78/79	339,481	175,079	199,862
79/80	409,728	517,787	508,132
80/81	607,910	402,005	407,300
81/82	506,416	334,888	334,888
82/83	581,002	384,213	328,668

Source: HYV Seeds Distributed: Farm Management Section ARDU
Prices: Sales and Credit Section Ardu.