



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

RESEARCH NOTES

Returns to Alternative Organisational Models of Wheat Breeding Research: Simulation Results from Ethiopia

Regassa E. Namara, and Winfried Manig*

I

INTRODUCTION

A careful review of the existing literature on the economics of crop breeding research programmes reveals two major gaps. First, the usual focus of most studies has been on the estimation of returns to past investments to provide justification for the need of increased or continued public commitments. Examples of such ex-post analyses are numerous and are documented in Alston *et al.* (2000). A more realistic but less frequently attempted type of evaluation is the ex-ante analysis of the issue of improving the economic efficiency of public crop breeding programmes usually facing a severe budget constraint in the context of developing countries. Second, while the institutional aspects involved in crop breeding research have received attention (e.g., detailing the methodological routines of participatory research), the much more pertinent issue of how alternative organisational models can improve economic returns or efficiency has not been evaluated to the extent that is needed in the present context of developing countries such as Ethiopia. Although few institutional innovations such as farmer participation and decentralisation are found to have profound implication for breeding research efficiency in developing countries (Maurya *et al.*, 1988; Salazar, 1992; Galt, 1989), the claim is based just on results derived from a limited set of case studies not on those emerging from any formal evaluation procedures such as cost-benefit analyses and other advanced management decision tools. This paper makes an attempt to fill this research gap based on the empirical results from the Ethiopian wheat breeding research programme.

II

OBJECTIVES AND SCOPE

Crop breeding research programmes have indeed played a significant role in enhancing agricultural productivity and in triggering the overall process of economic development in most developing countries including Ethiopia. But, much of the successes were confined to the geographic areas endowed with favourable biophysical and socio-economic conditions. Paralleling such a regional bias of crop

* Post-Doctoral Scientist, International Water Management Institute, Colombo, Sri Lanka and Professor, Institute of Rural Development, University of Goettingen, Goettingen, Germany, respectively.

breeding programmes, there has also been group bias in terms of the distribution of their economic impacts. As a result, the lion's share of the benefits generated by these programmes were appropriated by well-to-do farmers and other privileged social groups. In order to counter these problems associated with the conventional crop breeding research approaches, alternative institutional and organisational approaches have been recommended to improve and broaden the benefits of crop breeding research programmes. The overall objective of the paper is to evaluate some of these approaches and their effects based on data pertaining to Ethiopia. Specifically, the paper aims to evaluate the economic efficiency and effectiveness of three alternative but not mutually exclusive wheat breeding research-cum-extension strategies using Dynamic Research Evaluation for Management (DREAM) model (Alston *et al.*, 1995). The hypothesis is that for a given budget, different institutional or organisational models of a crop breeding research programme would have different levels of economic efficiency and effectiveness. From here on, the paper is organised into five sections. Section III describes the three wheat breeding research/extension strategies in Ethiopia including the delineation of target regions. Section IV outlines the methodological framework of the study based on DREAM model. Section V discusses the data requirements and empirical basis; where-as the following section presents the results and analysis. Finally, the paper concludes with the presentation of major conclusions and their policy implications.

III

ALTERNATIVE WHEAT BREEDING RESEARCH APPROACHES FOR ETHIOPIA

Ethiopia, like many developing countries of Asia and Africa, is faced with three different, but not mutually exclusive, strategic choices regarding wheat improvement research and extension organisation. These choices are (a) direct use of a wheat variety developed elsewhere, (b) re-design wheat genotypes from elsewhere to fit own specific circumstances, and (c) draw on the available stock of scientific knowledge to create own wheat varieties. In the past, the main emphasis of the Ethiopian Wheat Breeding Research Programme (EWBRP) was on screening imported materials for local adaptation as well as on selecting, multiplying, and releasing promising new lines. More recently, however, the emphasis has shifted to hybridisation for incorporating the specific characteristics lacking in the introduced materials. The selection of activities from introduced segregating populations have also been intensified in recent years.

From the view point of this study, three wheat breeding research programme options were identified for comparison based on the prevailing EWBRP operations and the experience gathered from the wheat breeding research project implemented in Ethiopia during 1996-2001.¹ These are:

- 1) Variety Screening Programme (VSP), which represents the situation in which the EWBRP relies completely on the outputs of International Agricultural Research Centers (IARCs) notably International Maize and Wheat

Improvement Center (CIMMYT) and other National Agricultural Research Systems (NARS) without any effort to modify the genetic materials so obtained.

- 2) Adaptive Breeding Programme (ABP), which involves in addition to evaluating imported germplasm crossing and selection activities, and
- 3) Comprehensive and Participatory Breeding Programme (C&PBP), which encompasses (a) exploitation of alien disease resistance genes in *Aegilops species*, (b) inoculation and disease assessment at seedling stages, (c) resistance testing of segregating population in green house and field conditions, and (d) on-farm parallel testing of the resulting wheat lines. The programme represents the case of the bread wheat breeding research project mentioned above (Solomon, 2001; Ayele, 2002).

The choice among these alternative options is conditioned by many factors including the possibility and magnitude of wheat variety *spill-in*, size of the wheat sector, the nature of the biophysical environment, resource costs and time lags, economies of scale and scope in research (Evenson and Binswanger, 1978; Brennan, 1991).

Technology *spill-in or spill-over* is an important concept in agricultural research literature. Two paths of arguments prevail concerning this concept. The first line of argument is that *spill-in or over* of biological technologies is limited by environmental specificity and therefore, there is strong case for a country to increase resources allocated to agricultural research. The second line of argument posits that research *spill-in* in the form of direct technology transfer can substitute for local research and hence many research programmes could significantly increase the efficiency of resource use by reducing the scale of their operations and focusing on the screening of varieties developed elsewhere (Maredia and Byerlee, 2000).

CIMMYT classifies the wheat growing environments in eastern Africa highlands into six Mega Environments (ME) based on latitude, moisture and temperature regime (Heisey and Lantican, 2000; Maredia and Byerlee, 2000). Ethiopia is generally categorised under ME2 and the broad breeding objective set for this environment is resistance to wheat rusts, *Septoria spp*, *Fusarium spp*, lodging and sprouting. This wheat-growing environment is too broad and need to be fine-tuned for effective breeding strategy. For this reason, the wheat growing zones of Ethiopia were roughly differentiated into eight target production and consumption zones based on historical data on wheat production and consumption and past wheat breeding research intensity (Gebre Mariam *et al.*, 1991; CSA, 2000; Regassa, 2002). The eight regions were classified into four major regional groups based on the actual and potential wheat production, the wheat breeding research intensity² and geographic proximity of the regions (Table 1).

TABLE 1. TARGET REGIONS AND REGION GROUPS IN ETHIOPIA

No.	Region group	Characteristics		Regions/Zones
		Per cent of actual wheat area relative to potential	Breeding research intensity	
(1)	(2)	(3)	(4)	(5)
1.	Highly favourable regions with high wheat breeding research intensity	76.0	63.8	Arsi and Bale
2.	Highly favourable with medium wheat research intensity	68.1	6.7	Shewa
3.	Favourable with medium wheat research intensity	134.2	13.0	Gojam and Gonder
4.	Potentially favourable regions with current least wheat research intensity	17.6	2.6	Southern Ethiopia, Wollega-Illubabor-Jimma, Wollo-Tigray and Hararghe

IV

METHODOLOGICAL AND CONCEPTUAL FRAMEWORK

Several methods can be used to analyse different approaches to wheat breeding research in public programmes (Alston *et al.*, 1995; Brennan, 19881; 1989 a, b). For this study, the DREAM model provides the methodological basis. While, Alston *et al.* (1995) have elaborated the theoretical and conceptual basis of the DREAM programme, Wood and Batix (2001) have presented the structure and logic of the latest DREAM interface.

(i) *The Conceptual Bases of the Dream Model*

The model is based on economic surplus measurement approach. The basic commodity market model of research benefits is shown in Figure 1 to elucidate the mechanics of research induced consumer and producer surplus measurement. S_0 represents the supply function before a research-induced technical change and D represents the demand function. The intersection of S_0 and D at a results in the initial price and quantity P_0 and Q_0 . Given that the demand function remains constant, the original market equilibrium a (P_0 , Q_0) is transferred by the effect of technological change to b (P_1 , Q_1). This is shown by a parallel shift of supply function down (vertical) in the price direction to S_1 . This research-induced supply shift leads to an increase in production and consumption to Q_1 (by $\Delta Q = Q_1 - Q_0$) and reduces price to P_1 (by $\Delta P = P_0 - P_1$). Consumers are better off because they consume more of the commodity (Q_1) at a lower price (P_1). The area P_0abP_1 represents this gain. The net welfare effect on producers may be positive or negative depending on the magnitude of k ($= P_0 - d$), which is the shift down of supply due to a cost saving induced by research relative to P_0 .³ The proportion of supply shift relative to the initial equilibrium price, P_0 , denoted by capital letter K , is equal to k/P_0 or $(P_0 - d)/P_0$. The magnitude of K depends on the supply and demand elasticities and the nature of the

research induced supply shift.⁴ Thus supply shift affects producers through reductions in marginal cost and market price. In the case drawn in Figure 1, with a linear supply curve shifting in parallel, producers necessarily benefit by an amount equal to area $P_1bI_1-P_0aI_0$. The net welfare effect or total economic surplus is equal to I_0abI_1 . The size of the market, as indexed by the initial quantity Q_0 , as well as the size of the research-induced savings in the unit cost of production, K , is critical factors in estimating the economic benefits from research.

Quantity/Year

Figure 1. Supply and Demand Model of Research Benefits

Source: Adapted from Alston *et al.* (2000).

The basic economic surplus approach depicted in Figure 1 above assumes a single market in a closed economy, i.e., at a given market level the suppliers, and the demanders of the commodity are aggregated together without provisions for (1) the possibilities of regional or socio-economic differentiation within a country and (2) the effects of world market prices. However, the model can be extended to measure the economic effects of research induced technical changes for other relevant market settings or assumptions.

(ii) *Specification and Parameterisation of the DREAM Model*

The model begins with supply and demand specification and initial parameterisation of the without research scenario within a region as follows:

$$Q_{i,t} = \alpha_{i,t} + \beta_i PP_{i,t}$$

$$C_{i,t} = \gamma_{it} + \delta_i PC_{i,t}$$

where Q , C , PP and PC are production and consumption quantities, and producers and consumers prices differentiated by regions and years, respectively. The parameters of the supply and demand equations are defined by beginning with initial

($t=0$) values of production and consumption quantities (Q_0 and C_0), producer price (PP_0), elasticity of supply (ε_0) and elasticity of demand ($\eta_0 < 0$) for each of the regions. Given these initial parameters, the model determines slope and intercept of supply and demand equations for the initial year as follows:

$$\beta_{i0} = \frac{\varepsilon_{i0} Q_{i,0}}{PP_{i,0}}; \alpha_{i0} = (1 - \varepsilon_{i0}) Q_{i,0}; \delta_{i0} = \frac{\eta_{i0} C_{i,0}}{PC_{i,0}} \text{ and } \gamma_{i0} = (1 - \eta_{i0}) C_{i,0}$$

The slopes are assumed to be constant for all time periods; however, the intercepts may grow over time to reflect the underlying growth in supply or demand due to factors other than research. The model simulates exponential exogenous growth in supply and demand that is expected to occur regardless of research.

$$\alpha_{it} = \alpha_{it-1} + \pi_i^q Q_{i,t}$$

$$\gamma_{it} = \gamma_{it-1} + \pi_i^c C_{i,t}$$

where π^c is the growth rate of demand and π^q is the growth rate of supply.

The expected research induced supply shift is estimated using probability of research success, P , a cost saving per unit of output equal to C per cent of the initial price, PP_0 , which is denoted by k/P_0 in Figure 1, and a ceiling adoption rate (A^{\max} per cent) in a region. Given these parameters, the supply function shifts down in the price direction, eventually by amount per unit equal to:

$$K^{\max} = P_i * C_i * A_i^{\max} * PP_{i,0} \geq 0$$

Figure 1 depicts the basic static model for research evaluation. However, evaluations of the economic effects of research involve procedures to account for the timing of streams of benefits and costs, which is a function of the research and adoption lag structures. Thus there is an often lengthy time lag between the initial investment in research, the eventual adoption of research results, and the flow of research benefits.

The actual supply shift in any particular year is some fraction of the eventual maximum supply shift, K_{\max} , defined above and is governed by the temporal dynamics of adoption and depreciation-cum-obsolescence factors assumed to be *Trapezoidal* or *Sigmoid* form in the DREAM model. The adoption process is a modifier that translates potential research effects, K^{\max} , into actual effects over time, K_t . Different research programmes will generate technologies that have different adoption paths in different locations.

The trapezoidal adoption pattern is depicted in the Figure 2. The relevant parameters of this adoption pattern include research and development time lag (λ_R), maximum adoption (A^{\max}), adoption lag (λ_A), time lag at maximum adoption (λ_M) and time lag for abandoning (λ_D).

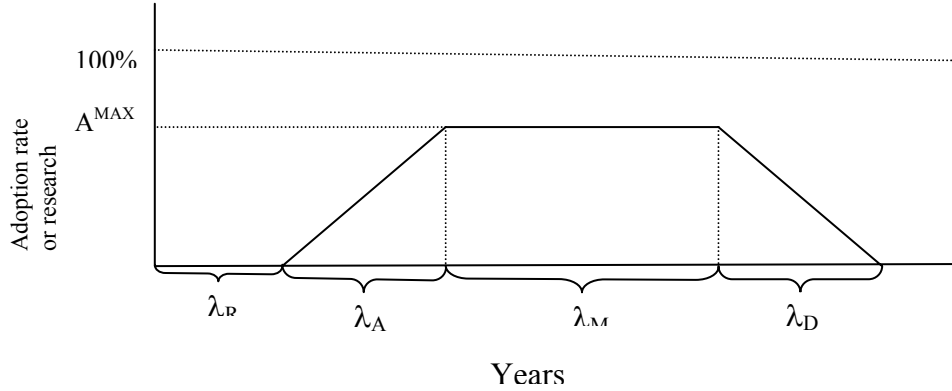


Figure 2. Trapezoidal Adoption Pattern

An alternative adoption response is an S-shaped (logistic) curve that involves a similar number of parameters. The logistic curve can be specified as

$$A_t = \frac{A^{\text{MAX}}}{1 + e^{-(\alpha + \beta t)}}$$

where A^{MAX} is the maximum adoption rate or a ceiling adoption rate as defined above, A_t is the actual adoption rate t years after the release of the new technology, and α and β are parameters that define the path of the adoption rate that asymptotically approaches the maximum. The β parameter captures the influence of biophysical, socio-economic, socio-cultural, support services (e.g., extension and credit provisions) and technology-specific characteristics on the incidence or intensity of adoption.

Assuming a Trapezoidal shape for the adoption curve the supply shift (in price direction) can be defined as follows:

$$K_{i,t} = 0 \quad (\text{for } 0 \leq t \leq \lambda_R)$$

$$K_{i,t} = \frac{K_i^{\text{max}}(t - \lambda_R)}{\lambda_A} \quad (\text{for } \lambda_R < t \leq \lambda_R + \lambda_A)$$

$$K_{i,t} = K_i^{\text{max}} \quad (\text{for } \lambda_R + \lambda_A < t \leq \lambda_R + \lambda_A + \lambda_M)$$

$$K_{i,t} = K_i^{\text{max}} \left(\frac{\lambda_R + \lambda_A + \lambda_M + \lambda_D - t}{\lambda_D} \right) \quad (\text{for } \lambda_R + \lambda_A + \lambda_M < t \leq \lambda_R + \lambda_A + \lambda_M + \lambda_D)$$

$$K_{i,t} = 0 \quad (\text{for } t > \lambda_R + \lambda_A + \lambda_M + \lambda_D)$$

In the case of *Sigmoid* adoption pattern all other parameters are as discussed above but we need data on the period from initial adoption to attain 50 per cent of maximum adoption ($0.5A^{\max}$) in years. In sum, ceteris paribus, the adoption process represented by trapezoidal functional form is faster than that represented by sigmoid functional form.

(iii) *Summary Indicators of Research Benefits*

The model generates time series of prices and quantities in addition to economic surplus measures for each region. For all of the scenarios to be considered, there is an overall quantity clearing rule to the effect that the sum of quantities demanded in each year equals the sum of quantities supplied (i.e., $Q_t = C_t$) with corresponding market clearing prices under free trade.

$$P_t = \frac{(\gamma_t - \alpha_t)}{\beta - \delta}, \text{ without research scenario market clearing prices}$$

$$P_t^R = \frac{(\gamma_t - \alpha_t^R)}{\beta - \delta}, \text{ with research scenario market clearing prices}$$

where, P_t^R and α_t^R are with research price and slopes respectively.

To aggregate the series of economic surplus measures generated for each year and region into summary indicators, we need to determine the discount rate r . If there is no data on the costs related to the generation and dissemination of the resulting technology, the model calculates only the gross present values of research benefits (GPVRB) over the relevant planning horizon (n) for consumers and producers as follows.

$$\sum_{t=0}^n \frac{\Delta PS_t}{(1+r)^t} \text{ (GPVRB to producers), and } \sum_{t=0}^n \frac{\Delta CS_t}{(1+r)^t} \text{ (GPVRB to consumers).}$$

where, ΔPS_t and ΔCS_t are the undiscounted producers' and consumers' surplus as illustrated in Figure 1. However, if costs can be determined, the model generates other indicators such as internal rate of return (IRR), benefit-cost ratio (B/C) and net present value (NPV).

$$NPV = \left[\sum_{t=0}^n \Delta PS_t / (1+r)^t + \sum_{t=0}^n \Delta CS_t / (1+r)^t \right] - \left[\sum_{t=0}^n C_t / (1+r)^t \right]$$

$$B / C = \frac{\left(\sum_{t=0}^n \Delta PS_t / (1+r)^t \right) + \left(\sum_{t=0}^n \Delta CS_t / (1+r)^t \right)}{\sum_{t=0}^n C_t / (1+r)^t}$$

where, C_t is the sum of annual costs of technology development, extension and other relevant costs, and ΔPS_t , and ΔCS_t are as defined above. IRR is the discount rate r , which drives the NPV to 0.

V

THE DATA

(i) Elasticity and Exogenous Supply and Demand Estimates

Price elasticities of wheat demand and supply for Ethiopia were obtained from published sources and approximation using economic theory. Rosegrant *et al.*, (2000, p. 160) reported wheat income elasticity of demand of 0.5 for sub-Saharan Africa. Economic theory suggests that own price elasticity of demand, income elasticity of demand, and the relevant cross elasticity of demand all sum to zero. Moreover, for normal goods and highly aggregated commodities, Alston (1995, p. 321) reports that the own price elasticity of demand is usually a negative number that is slightly larger in absolute value than the income elasticity. In the present case the own price elasticity of wheat demand for Ethiopia is assumed to be -0.5. Rosegrant *et al.* (2000) also report exogenous demand growth rate of 5.6 per cent per annum for the period 1990-97 in sub-Saharan Africa and this figure is applicable also to Ethiopia.

Supply elasticities of agricultural products depend on many factors such as the time frame, supply elasticities of factors used to produce a commodity and ease of factor substitutability. Most published elasticities of supply for agricultural products fall between 0.1 and 1.0 and long-run elasticities for most individual agricultural products are greater than 1. As an approximate starting point, an elasticity of 1 is used in this analysis. Despite the prevalence of intensive cropping systems in the highlands of Ethiopia the supply function for wheat may not be so inelastic mainly because of ease of factor substitutability. Following Alston *et al.* (1995), the exogenous growth in wheat supply that is expected to occur regardless of whether the breeding research programme of interest is undertaken was estimated. However, except for Arsi Bale, the estimated growth rates were not statistically significant (Table 2).

TABLE 2. WHEAT PRICES AND SUPPLY GROWTH RATES ACROSS REGIONS IN ETHIOPIA

No.	Region	Price in USD per tonne	Exogenous growth in supply (per cent)
(1)	(2)	(3)	(4)
1.	Wollo-Tigray	215.9	-1.67 ^{ns}
2.	Arsi-Bale	169.2	3.21*
3.	Haraghe	180.0	0.07 ^{ns}
4.	Gojam-Gonder	176.4	-0.06 ^{ns}
5.	Shewa	194.3	-0.03 ^{ns}
6.	Wollega-Jimma-Illubabour	188.3	0.03 ^{ns}
7.	Southern Ethiopia	166.8	-0.05 ^{ns}
8.	Rural and urban consumers	194.3	N.A.

* Significant at 10 per cent, ns = statistically not significant, N.A.= not applicable.

(ii) *Research and Adoption Lag Distributions, and Probability of Research Success*

The assumptions regarding probabilities of breeding research success, and research and adoption lag structures are presented in Table 3. Wheat breeding research time lag (λ_R) depends on the structure of the breeding research programme. Information regarding EWBRP structure was solicited from various published and unpublished sources.⁵ The pace of adoption of a new wheat variety ($\lambda_A + \lambda_M + \lambda_D$) depends on the support system, farmer/farm and varietal-specific adoption determinants.⁶ The functional form of adoption is determined by various factors such as the attributes of the individual adopters and the nature of the system in which the adoption process takes place. One of the system elements influencing the functional form of adoption is the nature of wheat breeding research programme itself. In the present case, varieties released from C&PBP are assumed to follow trapezoidal functional form or fast adoption process.⁷

TABLE 3. RESEARCH SUCCESS AND LAGS, AND ADOPTION PROFILES

Parameters* (1)	Symbol (2)	C&PBP (3)	ABP (4)	VSP (5)
Probability of research success (per cent)	P	75	90	42
Breeding research time lag (in years)	λ_R	6	13	7
Maximum Adoption (per cent)	A^{MAX}	20	20	20
Adoption lag (in years)	λ_A	5	7	8
Time lag at maximum adoption (in years)	λ_M	2	3	3
Time lag for abandoning (in years)	λ_D	3	5	4
Functional form of adoption		Linear	Logistic	Logistic

* The figures reported in the table are average for different regions of the country.

The varieties released from other breeding programme options are assumed to follow logistic functional form because of learning by doing is involved in their adoption process (i.e., farmer experimentation). The probability of success of the breeding research programme options are estimated by the percentage of total bread wheat varieties released so far that actually won commercial success in the respective regions.

(iii) *Estimation of Costs*

The other important issue in the analysis of the differential returns to alternative breeding programme options is the estimation and attribution of costs. The detailed breeding cost components include operational costs such as causal labour and other consumables, capital costs associated with the equipment used in all aspects of the wheat breeding programmes and general overhead costs. The general overhead costs refer to administrative overhead costs such as postage and telephone, library services, building maintenance, travel and general administration.

Capital costs: comprise depreciation and interest costs. Depreciation costs are calculated by allocating the decline in the value of the equipment over its service life as follows:

$$D_i = \frac{P_i - S_i}{n_i}$$

where, D_i = annual depreciation cost of a capital item i ,

P_i = initial price of capital item i ,

S_i = salvage value of a capital item i ,

n_i = total service life of a capital item i in years.

Specialised equipment is assumed to be used until it has no value as scrap. Interest costs, which measure the opportunity cost of the money tied up in capital equipment, were determined on the basis of the average value of the capital item and the annual interest rate as follows:

$$I_i = \left(\frac{P_i + S_i}{2} \right) r$$

where, I_i is the annual interest cost of capital item i ; P_i and S_i are as described above and r is the annual interest rate.

The other major cost categories are the general overhead cost and operational costs, which were determined from the EWBRP budget files for the last three years (i.e., 1999-2001) for Variety Screening and Adaptive Breeding Programme. While for Comprehensive and Participatory Breeding Programme/C&ABP) the figures were estimated from the documents of the case study project.

The total estimated costs of bread wheat breeding programme options are presented in Table 4. The costs for C&PBP seem to be lower than that of the other breeding investment options. This is because it was estimated for only two target regions of the country in which the case study project has been implemented, namely *Arsi-Bale* and *Shewa*. The costs for VSP option are significantly lower than that of ABP. The plausibility of VSP highly depends on the assumption that the required germplasm for the country will be made available by the IARCs or other NARSs at insignificant or no cost.

TABLE 4. A SUMMARY OF TOTAL WHEAT BREEDING RESEARCH COSTS IN BIRR IN ETHIOPIA

No. (1)	Category (2)	VSP (3)	ABP (4)	C&PBP (5)
1.	Capital costs	46,478	1,51,550	1,10,436
2.	Overhead costs	1,98,131	6,46,048	2,39,238
3.	Operational costs	2,69,772	8,79,650	1,91,724
4.	Total	5,14,381	16,77,248	5,41,398

1 USD=8.57 Birr.

Source: Regassa, 2002.

The next step is to allocate the above estimated costs to various growing regions or zones defined in the preceding sections and among years. The criterion used to allocate the costs among regions and years was the total number of plots managed within the respective regions and years. The number of wheat breeding trial plots (P)

handled in any given year by the respective breeding research programme options in each of the target regions are calculated as follows:

$$P = \sum_i^n T_i (L.S.R[NG + CH])$$

where: T = number of wheat breeding research trial types (i to n),

L = number of target regions in which the trials are tested,

S = number of sites within a target region,

R = number of replications per site,

NG = number of new genotypes tested and

CH = number of check varieties included in the trials for comparison.

VI

RESULTS AND DISCUSSION

(i) *Economic Returns to Wheat Breeding Research Organisational Options*

The alternative wheat breeding programme options discussed earlier constitute different scenarios with different research lag, probability of research success, adoption patterns, and costs. The results of the DREAM model that simulated the conditions of the three breeding research options are presented in the Table 5. On the aggregate, returns to wheat breeding research options are profitable as shown by NPV, B/C, and IRR. However, the aggregate figures distort the realities of specific regions in the country. The magnitude of economic returns to investment varies for the different wheat breeding research organisational models and for the target regions. C&PBP has the highest returns to investments made under the parameters assumed.

TABLE 5. AN EX-ANTE EVALUATION OF ALTERNATIVE BREEDING PROGRAMMES, ETHIOPIA

No. Regions		C & PBP			ABP			VSP		
		NPV*	B/C	IRR (per cent)	NPV	B/C	IRR (per cent)	NPV	B/C	IRR (per cent)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.	Shewa	2,077	3.71	32.9	674	1.4	15.0	1.0	1.2	14.8
2.	Arsi-Bale	445	1.14	15.1	1,676	1.3	15.2	13	1.5	18.1
3.	Gojam-Gonder	-	-	-	96	1.1	13.5	0.8	1.2	14.9
4.	Wollo-Tigray	-	-	-	1,085	6.4	26.5	8.8	10.8	48.6
5.	Wollega -Illubabour - Jimma	-	-	-	89	1.5	15.5	1.0	2.4	22.2
6.	Haraghe	-	-	-	-148	0.5	7.6	0.0	1.0	13.2
7.	Southern Ethiopia	-	-	-	-35	0.9	12.3	3.5	2.3	22.5
Average		4,012	2.03	23.2	5,943	1.7	16.7	55.0	2.2	22.5

* Figures for the NPV are all in thousands of Birr.

In *Hararghe* and Southern Ethiopia regions, the returns to ABP option were found to be economically unjustifiable. This indicates the need for institutional and organisational reform towards participatory and decentralised wheat breeding research style. Galt (1989), in his study of Nepalese crop breeding research

programme has made similar conclusion. He had shown that reorganisation of the breeding research towards decentralised, more targeted and participatory modes of operation would enhance breeding research efficiency by 20 per cent.

Returns to different wheat breeding research options were also calculated for each region group (Table 6). One can discern an interaction between region group and breeding strategy option. The highest returns were recorded for C&PRP in the highly favourable and medium wheat breeding research intensity region group followed by that of VSP in the favourable regions with least breeding research intensity. This reflects the past unbalanced commitment of the national wheat breeding research, the differential research spill-in potential and the heterogeneity in biophysical and socio-economic conditions of the regions or region groups. For instance, the level of returns in the highly favourable with high wheat breeding research intensity region group (i.e., Arsi and Bale) is highest for VSP indicating the high research spill-in potential of the region and the low investment costs required in this case. This means that genotypes developed at CIMMYT can be adapted to the Arsi-Bale region with relative ease. In their analysis of wheat breeding research at international scale (Maredia and Byrelee 2000, p. 14) concluded that given the possibility of technology spill-in, some of the less developed countries breeding research programs may be consolidated and focus on testing and adapting varieties or advanced lines developed at IARCs.

TABLE 6. RETURNS TO BREEDING PROGRAMME OPTIONS BY REGIONAL GROUPS

No. (1)	Region/ groups (2)	(per cent)		
		C&PBP (3)	ABB (4)	VSP (5)
1.	Highly favourable with medium wheat breeding research intensity	32.9	15.0	14.8
2.	Highly favourable with high wheat breeding research intensity	15.1	15.2	18.1
3.	Favourable with medium wheat research intensity	-	13.5	14.9
4.	Favourable with least wheat research intensity	-	16.9	27.4
	Average	23.2	16.7	22.5

Source: Regassa, 2002.

Similarly, the highest returns to VSP in the favourable with least wheat breeding research intensity region group indicates the fact that varieties developed for other regions are adaptable to these regions. In conclusion, if investments in wheat research are continued in the current fashion, regional disparity in breeding research benefits will prevail.

The ABP had significantly lower rates of return than the other two options. This is because even though the EWBRP runs its own crossing blocks, it was not in a position to come up with genotypes which are different in any meaningful way from those screened directly from CIMMYT. It is only recently that the programme started to re-organise its crossing blocks in order to cater for specific biophysical conditions of the country that may not be taken care by screening directly from CIMMYT materials. Examples of such activities include crossing blocks for high and low moisture stress tolerance. But, there are few, if any, new varieties developed yet from these activities during this study.

To know the sensitivity of the returns to variations in some market variables such as prices and price elasticities of wheat demand and supply, the DREAM model was iteratively re-run by varying the market variables within relevant range. The decline in wheat producer prices within the range of 5 to 20 per cent of the base price would not significantly affect the returns to the breeding programme options. This indicates that returns to wheat breeding research remain robust despite the downward fluctuations in wheat producer prices. The analysis of the sensitivity of the returns to varying elasticity assumptions again showed that the returns to the different wheat breeding research approaches remain within the acceptable range.

The sensitivity of returns to changes in technical parameters such as probability of research success, adoption lag distributions and the functional form of variety adoptions were also evaluated. There is visible variation in the sensitivity of the different breeding research options to the probability of research success assumption.⁸ The returns to C&PBP, which is expected to have higher probability of research success, remain acceptable even at 30 per cent research success rate because of its other merits such as reductions in research and adoption time lag distributions.

Similarly, VSP had acceptable rate of return under all success probability assumptions due to the significant cost saving as a result of relying on the supply of advanced or segregating wheat lines at no or insignificant cost from CIMMYT. However, for ABP to be profitable, its success probability rate must exceed 60 per cent in most of the regions.

Among the parameters related to adoption or adoption time lag distributions, the level of adoption ceiling (A^{MAX}) had significant effect on returns to wheat breeding research option (Table 7). Obviously, returns to wheat breeding research decreases as the adoption lag increases. Moreover, increases in years at maximum level of adoption and years to abandon increases (i.e., λ_M and λ_D) will enhance returns to all breeding programme options. These parameters indicate the durability of varieties once released for commercial production. The farmers in the major wheat areas of Ethiopia claim that wheat varieties lose their resistance to diseases within few years of introduction, on average within 4 years time (Regassa *et al.*, 1998). It was also observed that varieties released from ABP tend to stay in production for the extended years as compared to those developed from VSP. Therefore, research into durable disease resistance would have substantial economic implications.

TABLE 7. THE EFFECT OF CHANGES IN THE SUPPLY SHIFT MODIFYING ADOPTION PARAMETERS
(per cent)

Parameters (1)	Changes in values (2)	Changes in IRR		
		VSP (3)	ABP (4)	C&PBP (5)
Adoption lag (λ_A) in years	3 to 8	-2.5	-0.2	-3.0
Adoption ceiling (A^{MAX}) in per cent	20 to 60	14.8	8.8	18.2
Functional form (Trapezoid to Sigmoid)	-	-0.8	-0.4	-0.9
Year at maximum level of adoption (λ_M)	2 to 5	2.0	1.5	2.9
Years to abandon (λ_D)	2 to 5	1.2	1.0	1.5

(ii) *Welfare Effects of the Wheat Breeding Research Organisational Options*

The share of producers and consumers in the total GPVB is presented in Table 8. Given the assumed supply and demand elasticities and prices, consumers derive higher benefit from all of the wheat breeding programme options. However, the strict dichotomisation of producers and consumers may not be valid in Ethiopia since the farmers consume a substantial share of their total production and are actually producers-cum-consumers. Moreover, the entities included under producers and consumers categories depend on the level at which the benefit is measured in wheat marketing chain. In the present case, the wheat breeding research benefits were measured at farm level and producer surplus includes only quasi rents accruing to inputs used in wheat farming. The benefits accruing to off-farm activities (e.g., wheat marketing, distribution, and processing) were aggregated into consumers' surplus. However, in the study areas, rural people including members of farm families usually undertake these activities.

TABLE 8. RELATIVE SHARE OF CONSUMERS AND PRODUCERS IN TOTAL BENEFIT

		<i>(per cent)</i>	
No. (1)	Programme options (2)	Share of producers (3)	Share of consumers (4)
1.	Comprehensive and participatory breeding programme	32.9	67.1
2.	Adaptive breeding programme	32.5	67.5
3.	Variety screening programme	36.6	63.4

Source: Own computation.

The changes in elasticities have significant influence on the distribution of benefits. As the supply becomes inelastic, the producers will fare most from the total benefits generated (Table 9). On the contrary the consumers will get less and less share of the benefits. On the other hand, if supply becomes elastic the consumers will gain most from the total benefits generated.

TABLE 9. PRODUCERS AND CONSUMERS' SHARE OF THE BENEFITS UNDER VARYING SUPPLY AND DEMAND ELASTICITY

		Elasticity (1)	Producers share (per cent) (3)	Consumers share (per cent) (4)
Supply		0.2	71.3	28.7
		0.3	62.5	37.5
		0.4	55.6	44.4
		0.5	50.2	49.8
		0.6	45.8	54.2
		0.7	42.1	57.9
Demand		-0.2	15.9	84.1
		-0.3	22.2	77.8
		-0.4	27.8	72.2
		-0.5	32.5	67.5
		-0.6	36.6	63.4
		-0.7	40.3	59.7

Concerning the demand elasticities, as demand becomes inelastic consumers tend to get the better share of benefits generated. In fact, under all the plausible demand

elasticity assumptions (i.e., -0.2 to -0.7), the consumers get better share of the total benefits generated under all wheat breeding research programme options.

VII

CONCLUSIONS AND IMPLICATIONS

The level of economic returns to investment varies for the different wheat breeding research organisational models and for the target regions. In other words, one can discern an interaction between region or region group and breeding research strategy option, meaning that if investments in wheat research are continued in the current fashion, regional disparity in wheat breeding research benefits will prevail. This signals the need for institutional and organisational reform towards participatory and decentralised wheat breeding research style. Hence, different wheat breeding research and extension strategies need to be followed for different regions or region groups. In regions such as Arsi-Bale, where the spill in potential is high, screening and dissemination of advanced wheat lines from CIMMYT may suffice, while for other regions which have specific biophysical features that limits the direct utilisation or adaptation of introduced genetic materials, Comprehensive and Participatory Breeding Programme is the potential breeding strategy option. Regarding the welfare effects of the wheat breeding research, given the assumed supply and demand elasticities and prices, consumers derive a disproportionately higher benefit. This situation may partly explain the reason why most farmers in the study areas shy away from fully adopting the recommended technical production packages. This problem should be tackled through appropriate policy measures such as improving the marketing systems.

Received December 2002.

Revision accepted May 2004.

NOTES

1. This was a shuttle-breeding programme between the University of Goettingen and Ethiopian Agricultural Research Organisation with three interlinked activities. These were (1) development of basic wheat material, (2) development of bread wheat genotypes with adaptation to Ethiopian farming systems, and (3) socio-economic research activities. The operational style of the project was different from that of EWBRP. The main distinguishing features of the project were interdisciplinarity, participation of farmers and extension personnel at much earlier stage in the variety development process, shorter research time lag and its iterative and dynamic nature.

2. An index of wheat breeding research intensity (WBRI) for each target region has been calculated as follows:

$$WBRI = \frac{TNP}{PWA} \quad \text{where TNP is the total number of wheat breeding experimental plots handled from the start of the}$$

breeding work up to the final release of a variety for commercial use and PWA is the potential wheat production area in the respective target regions.

3. Economic theory indicates that the supply curve corresponds to the marginal cost curve of a firm as of minimum value of average variable cost curve.

4. The most common alternative supply shift assumptions made are linear parallel supply shift, linear in logarithms with proportional shift, and linear pivotal or proportional shifts. The measure of gross annual research benefits with proportional shift is roughly half the measure from a parallel shift assumption when all other elements of the analysis are the same.

5. See Ayele (2002) and Solomon (2001) for detailed description of the Ethiopian National Wheat Research Programme.
6. For wheat variety adoption patterns in different regions of Ethiopia see Bekele Hunde *et al.*, 2000; Tesfaye *et al.*, 2001; and Regassa and Mohammed, 2001.
7. This is because in this breeding programme option the farmers are integrated into breeding process at much earlier stage than usual allowing the readily articulation of the farmers' specific varietal demands. Hence, the risk of variety rejection and the time the farmers normally spend in experimenting with varieties (even though these varieties have passed the formal research and certification process) is minimised.
8. The probability of research success parameter (P), which measures the chance of coming up with a variety that can be taken up by the farmers, is varied between 18 per cent and 100 per cent to see the sensitivity of returns to breeding research investment.

REFERENCES

- Alston, J.M., C. Chan-kang, M.C. Marra, P.G. Pardey, and T.J. Wyatt (2000), *A Meta Analysis of Rates of Return to Agricultural Research and Development. Ex pede Herculem?*, International Food Policy Research Institute Research Report No. 113, Washington, D.C., U.S.A.
- Alston, J.M., G.W. Norton, and F.G. Pardey (1995), *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Cornell University Press, New York, U.S.A.
- Ayele Badebo (2002), "Breeding Bread Wheat with Multiple Resistance and High Yield for the Ethiopian Highlands: Broadening the Genetic Basis of Yellow Rust and Tan spot Resistance", Ph.D Thesis, Institute of Plant Pathology and Plant Protection, Georg-August University, Goettingen, pp. 105.
- Bekele Hunde, Kotu, H. Verkuijl, W. Mwangi and D. Tanner (2000), *Adoption of Improved Wheat Technologies in Adaba and Dodola Woredas of the Bale Highlands*, International Maize and Wheat Improvement Centre (CIMMYT) and Ethiopian Agricultural Research Organisation (EARO), Ethiopia, Mexico, D.F.
- Brennan, J.P. (1988), *An Economic Investigation of Wheat Research Programs*, Agricultural Economics Bulletin No. 35, Department of Agricultural Economics and Business Management, University of New England,
- Brennan, J.P. (1989 a), "An Analytical Model of Wheat Breeding Program", *Agricultural Systems*, Vol. 31, pp. 349-366.
- Brennan, J.P. (1989 b), "Economic Framework for Evaluating New Wheat Varieties", *Review of Marketing and Agricultural Economics*, Vol. 57, pp. 75-92.
- Brennan, J.P. (1991), *Economic Criteria for Establishing Plant Breeding Programs*, CIMMYT Economics Working Paper 92-01, Mexico, D.F.
- CSA (2000), *Area and Production for Major Crops, Agricultural Sample Survey 1999-2000*, Statistical Bulletin 227, Addis Ababa.
- Evenson, R.E. and H.P. Binswanger (1978), "Technology Transfer and Research Resource Allocation", in H.P. Binswanger, V.W. Ruttan *et al.* (Eds.) (1978), *Induced Innovation: Technology, Institutions and Development*, The Johns Hopkins University Press, Baltimore, U.S.A.
- Galt, D.L. (1989), *Joining FSR to Commodity Programme Breeding Efforts Earlier: Increasing Plant Breeding Efficiency in Nepal*, Overseas Development Institute, Agricultural Administration Unit Network Paper 8,
- Gebre-Mariam, Hailu, D.G. Tanner and Mengistu Hulluka (Eds.) (1991), *Wheat Research in Ethiopia: A Historical Perspective*, IAR/CIMMYT, Addis Ababa.
- Heisey, P.W. and M.A. Lantican (2000), *International Wheat Breeding Research in Eastern and Southern Africa 1966-1997*, CIMMYT ECONOMICS Working Paper 00-01, CIMMYT, Mexico, D.F.
- Maredia, M.K. and D. Byerlee (2000), "Efficiency of Research Investments in the Presence of International Spillovers: Wheat Research in Developing Countries", *Agricultural Economics*, Vol. 22, No. 1, pp. 1-16.
- Maurya, D.M., A. Bottrall, A. and J. Farrington (1988), "Improved Livelihoods, Genetic Diversity and Farmers' Participation: A Strategy for Rice Breeding in Rain fed Areas of India", *Experimental Agriculture*, Vol. 24, pp. 311-320.
- Namara, Regassa E., W. Mwangi, H. Vekuijl, M. Hassena and Z. Alemayehu (1998), *Farmers' Wheat Seed Sources and Seed Management in Chilalo Awraja, Ethiopia*, IAR and CIMMYT, Mexico, D.F.
- Namara, Regassa E. (2002), "Socioeconomics of Wheat Breeding Research in Ethiopia: Benefits and Challenges of Institutionalizing Participation and Systems Concepts", *Socio-economic Studies on Rural Development*, Vol. 128, Wissenschaftsverlag Vauk Kiel KG.
- Namara, Regassa E. and Mohammed Hasana (2001), "Factors Influencing Farmers' Awareness and Adoption of New Wheat Varieties in Chilalo Area of Southeastern Ethiopia", *Quarterly Journal of International Agriculture*, Vol. 40, No. 2.

- Rosegrant, M.W., M.S. Paisner, S. Miger and J. Witcover (2000), *Global Food Projections to 2000, Emerging Trends and Alternative Futures*, International Food Policy Research Institute, Washington, D.C., U.S.A.
- Salazar, R. (1992), "MASIPAG: Alternative Community Rice Breeding in the Philippines", *Appropriate Technology*, Vol. 18, pp. 20-21.
- Solomon, Assefa (2001), *Exploiting Alien Resistance Genes in Aegilops tauschii and their Utilisation for Development of Bread Wheat Genotypes with Multiple Resistance to Major Diseases*, CULVILLIER Verlag, Goettingen.
- Tesfaye, Zegeye, Girma Taye, D.G. Tanner, H. Verkuijl, Aklilu Agidie and W. Mwangi (2001), *Adoption of Improved Bread Wheat Varieties and Inorganic Fertiliser by Small Scale Farmers in Yelmana Densa and Farta Districts of North Western Ethiopia*, Ethiopian Agricultural Research Organisation (EARO) and International Maize and Wheat Improvement Centre (CIMMYT), Mexico, D.F.
- Wood, S. and W. Batix (2001), *Dynamic Research Evaluation for Management (DREAM), Version 3 Manual*, International Food Policy Research Institute, Washington, D.C., U.S.A.