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# Simulating Strategy Options for Enhancing HYV-Maize Technology Adoption in Oromia, Ethiopia

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**Abstract**

*Using a sample selection induced bivariate probit model fitted to data collected from small scale, resource poor farmers in Western Oromia (Jimma, Ilu-Ababaor, Estern and Western Welega zones), I define and simulate different strategy (Pure and Mixed) scenarios. The scenarios provide the extent to which the adoption of maize technology package (HYV-seeds, fertilizers and planting methods) among currently non-adopter maize growers could be increased with the use of different strategies. Among the scenarios evaluated, I find a strategy that emphasizes information approach, as a pure strategy, or when integrated with education and/or the agent approaches-in a mixed strategy, significantly influential (effective).*

Key Words: Technology, Adoption, and Maize

## I. INTRODUCTION

Several studies attempted to evaluate the adoption of improved technologies in Ethiopia. Customarily all of the studies test and thereby list some farmer and institution specific factors that affect the adoption decision of farmers' positively or otherwise. While the identification of these factors by itself is a challenging academic exercise, using any of them in practical agricultural development exercises, however, depends to a large extent on their ability to attract the attention of development practitioners and policy makers in effect. If these factors are to be of practical importance, development practitioners and policy makers need to be informed about the likelihood of the effectiveness of the alternative strategies that could use these factors. None of the studies conducted so far provide this information. This paper attempts to fill this caveat.

Resource poor, small-scale farmers produce more than 90 percent of cereals, pulses and oilseeds in Ethiopia. Next to Teff, cultivation of Maize supports the livelihood of a significant proportion of these farmers as a source of employment and income. Maize is also one of the three main (Teff, Maize, and Wheat) staple food crops in the country.

At a mean annual growth rate of 1.62 percent, the area under maize cultivation doubled from 0.75 million hectares in 1961 to 1.5 million hectares in 1998. Now it covers 23 percent of the total cultivated area and ranks as the second most widely cultivated cereal crop in the country. With annual output of more than 2.3 million metric tones, the production of maize currently accounts for nearly 33 percent of the total cereal output in the country (CSA, 1998).

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Maize and other cereal farms in the country are generally constrained by low labor productivity and lack of productivity augmenting inputs such as high yielding variety seeds and fertilizers (Belete, et al, 1991). Poor extensions services, shortage of traction power (Seyoum et al, 1998) and declining fertility of farmlands (Omiti et al, 1999) are also among the main problems. One feasible alternative through which the livelihood of these farmers could be improved is by adopting HYV seeds, Picket (1991). However, high yielding improved maize variety seeds cannot be purchased or sold in competitive markets in Ethiopia. Yet with institutionally rationed supply of seeds, extension advise and both free market and government based supply of complementary packages such as fertilizers and pesticides, the number of small scale farmers adopting HYV maize technology in Ethiopia is rapidly growing.

Based on the premise that achieving substantial productivity increase requires giving farmers appropriate extension messages and complementary institutional arrangements (Howard *et al*, 1999), different agricultural extension programs that strive to achieve this end have been implemented over the past two and half decades. All the programs have involved the distribution of modern inputs such as fertilizers, improved seeds and related technology packages. However, the scale and organization of institutional arrangements, the approach, and emphasis were different from program to program.

This study was originally initiated in 1998 to identify some key institutions and household related determinants of these small-scale farmer's decisions to adopt a maize technology package (High Yielding Variety-HYV, Fertilizers, and planting methods) was initiated in 1998. A reference sample was taken from the Western major maize-growing belt of Ethiopia. Besides, identifying and providing descriptions of factors that influence farmers' preferences to adopt or not adopt the HYV maize technology package, some key factors were also tested and implications for policy and further research were drawn. This paper presents some of the important determinants identified in the study, defines alternative strategy scenarios to enhance the adoption of the package by currently non-adopter farmers and presents results of the simulation derived from two different models.

## II. MODEL SPECIFICATION AND ESTIMATION

In an environment where crop insurance is not available and farmers are highly resource poor, for several reasons, farmers may consider trying or adopting a new technology package as both a costly and risky business. Besides this, weather related uncertainty of the production environment, the insecurity of land contracts and weak extension advice often act against these farmer's decision to accept a technology package. HYV maize technology has an additional feature. Because HYV maize seeds are not available in the free market, not all farmers who would wish to adopt get access to the technology. All these combined, even if a farmer starts to use the technology at a particular time, the possibility that the farmer remains an adopter of the technology is difficult to ascertain. For instance, a farmer cultivating a few rows of HYV seeds and using fertilizers at the time of the survey could decide to later reject the technology just because she was at a trial stage.

In this study, therefore, I take into account the minimum economical area of land (0.5 ha) recommended by the department of agriculture and the use of recommended agronomic practices (row planting) and complementary input that comes as package with the improved seeds. Accordingly, an adopter farmer ($Y_i$) is one who is cultivating the HYV maize seeds, on at least 0.5 hectares of land, in rows, and has applied fertilizer that comes as a package. The response ($Y_i$), recorded as 1, if the status of the farmer conforms to the definition above, and 0 otherwise, is discrete (mutually exclusive and exhaustive).
The explanatory variables include farmer specific demographic factors ($X_{1i}$), socio-economic variables ($X_{2i}$), labor arrangement ($X_{3i}$), and institutional services[2] and accessibility factors ($X_{4i}$). These variables are believed to influence farmer's movement on the ladder of learning, and ultimately, the critical decision to accept or reject the technology. In order to capture the influence of a set of these non-stochastic exogenous variables on the farmer's decision to adopt the package, we need to observe threshold limit beyond which the farmer comes forward to accept the technology. Take this threshold (latent variable) as $Y^*_{i.}$ and using a utility maximization approach, define the random utility of a farmer i- who availed access to the package as a member of the farming community- as:

$$Y^*_i \quad = \quad \begin{cases} U_{i1}(X_i) = \beta_1 X_i + \varepsilon_{i1} & \text{for adoption, and} \\ U_{i0}(Xi) = \beta_0 X_i + \varepsilon_{i0} & \text{for non-adoption.} \end{cases}$$

Based on Amemiya (1981) and the specification by Nkmaleu and Adesina (2000), the utility maximizing farmer i will adopt the technology package only if the random utility $U_{i1}$ surpasses $U_{i0}$. That is, when $Y^*_i > 0$. The probability P, of being an adopter is thus,

$$\begin{aligned} E(Y_i{=}1|X_i) \quad = \quad P_i(Y_i^*>0) \quad &= \quad P(U_{i1}>U_{i0}) \\ &= \quad P(\beta_i X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0}) \\ &= \quad P(\varepsilon_{i0} - \varepsilon_{i1} < \beta_i X_i - \beta_0 X_i) \\ &= \quad P(\varepsilon_i < \beta_i X_i) \end{aligned}$$

Assuming that $\varepsilon_i$ is symmetrical and normal in distribution, and following Green (2000) and Aldrich and Nelson (1984), the standard Probit function could be fitted to estimate the parameters $\beta_i$ by the method of maximum likelihood as

$$F(x) = \Phi(\beta \, 'X_i)$$

Where, $X_i$ is a vector of supply and demand setting factors, $(X'_{1i}, X'_{2i}, X'_{3i}, X'_{4i})'$ listed above under which a farmer operates and makes her choice of the technology. $\beta$ is an unknown parameter vector to be estimated, and $\Phi$ is the cumulative distribution function (CDF) for the vector of random error, $\varepsilon_i$.

However, given the fact that the supply of the HYV seeds is rationed, not all farmers who wish to adopt get the chance to do so. It depends first on whether the farmer decides to apply or not apply to avail the rationed package. Then some farmers who applied to avail

[2] The importance of these services lie on their role to create awareness by the farmer about the existence of the technology package, develop right perceptions, set farmers' interest to try the technology for testing it under their own management practices. This also involves the willingness to change an established tradition of maize farming practices.

the package may not be picked because of criterion set by the rationing procedure. Not all those picked may also come forward to try the package and make the adoption decision. Therefore, the estimates of the parameters in the simple observable binary response variable $Y_i$ =1 for adoption and 0, otherwise may suffer from a sample selection bias. In order to take care of the sample selection bias, I estimate the Probit model conditional on another binary response variable Z*, which takes a value 1 if the farmer applied and 0, otherwise; and is itself a function of set of exogenous variables, $W_i$ with parameters $_i$ and a random error term □$_i$. Following Heckman's approach, therefore, the model is estimated as:

E($Y_i$ |$X_i$ , Sample selection) = E($Y_i$ |$X_i$ , Z* = 1)

= E($Y_i$ |$X_i$ , $_i$□$W_i$+ □$_i$ >0)

= $\beta_i X_i$ + E($_i$ |□$_i$ >-$_i$□$W_i$ )

= $\beta_i X_i$ + (□□□□□) (□[-$_i$□$W_i$ )/(1-□(-$_i$□$W_i$ ])

= $\beta_i X_i$ + (□□□□) [□($_i$□$W_i$ )/(□(-$_i$□$W_i$ )]

Given the nature of the data we can't observe □□. Thus, normalizing it to 1, we get the final model:

$$= \Phi(\beta' X_i + (\rho\sigma_\varepsilon)\lambda_i)$$

Significant ρ in the above model necessitates a bivariate probit model. After estimating the model by the method of maximum likelihood, differentiating p with respect to each element of $X_i$ yields f□(□$X_i$,)$_i$, where f is the standard normal density function. This gives the relative effects of each of the explanatory variables (marginal effects) evaluated at the mean. Using exogenous variables that have significant impact on the farmer's decision to accept the package, I define several strategy options. Each strategy is designed to alter specific characteristics of the currently non-adopter farmer (Section four provides the details). Let be the strategy defined on one of the exogenous variable(s), $X_{i1}$. Then, keeping other ($X_{ij}$) characteristics of the non adopter farmer and that of adopter farmers constant, the effect of using this specific scenario in enhancing the likelihood of adoption of the package on the currently non-adopter farmer i is obtained as:

$$P_{1i} = \Phi(\beta_1'(X_{1i} + \Delta X_{1i})(\beta' Z_i)$$

Where, $Z_i$= $X_{ij}$ for all other J variables different from $X_{i1}$ and is the particular strategy under consideration targeting those farmers for whom $P_i$ 0.05 or $Y_i$=0. The difference, $P_{1i}$-$P_i$ shows the increment in the likelihood of the adoption of the technology by farmer i attributed to the strategy. As the chosen strategy targets only the currently non-adopter farmers, the result differs from inferences that could be made based on the marginal effects computed for all farmers in the sample. Finally, the effects of each of the alternative strategies to enhance the probability of adoption of the package among the target farmers were compared using a simple mean test.

## III. RESULTS

### 3.1) KEY DETERMINANT FACTORS

Results from the MLE Probit with sample selection model fitted are presented in Table 1. The results indicate that institutional services, particularly, intensity of agricultural extension contacts, diversity of information channels, and physical accessibility to service centers play significant role in enhancing the adoption of the maize technology package among small scale farmers.

**Table 1: Maximum Likelihood Estimates of the Coefficients of the Variables in the Probit Model, (Western Oromia, Ethiopia).**

| Variables | Coefficients | Partial Effects |
|---|---|---|
| Age (in years) | -0.994E-03(0.6926E-02) | -0.167E-03(0.1165E-02) |
| Level of education (school years) | 0.0467(0.0266)* | 0.0078(0.0045)** |
| Resistance to change (Index) | -1.3194 (0.5475)*** | -0.2222(0.0934)*** |
| Extension intensity (Number of contacts) | 0.0720 (0.0229) | 0.0112(0.0039)**** |
| Information diversity (Index) | 0.4109 (0.0937)*** | 0.0692(0.0156)*** |
| Physical access (D) | -0.5054(0.1383) *** | -0.0851(0.0233)*** |
| Total farm size (ha) | 0.0990(0.0525)** | 0.01670.0087)*** |
| Livestock (TLU) | 0.0704(0.0251)*** | 0.0118(0.0041)*** |
| Labor force | 0.0884(0.0388)** | 0.0148(0.0066)** |
| Seasonal (SPHL) labor hiring (D) | 0.4426(0.1724)*** | 0.0745(0.0287)*** |
| Early adoption of fertilizers (D) | 0.6018(0.1823)*** | 0.1014(0.0284)*** |
| Dependency ratio | 0.0046(0.0791) | 0.785E-03(0.0133) |
| Regional dummy | -0.8220(0.1617)*** | -0.1384(0.0273)*** |
| Maize farm land tenure (D) | -0.0929(0.1687) | -0.0156(0.0284) |
| Relative area share of maize (%) | 0.0206(0.0392) | 0.0035(0.0066) |
| Constant (α) | -0.6363(0.4557) | -0.1071(0.0771) |
| -2 Log likelihood Ratio | 229.04*** | |
| Model χ2 | 164.05*** | |
| Degrees of freedom | 15 | |
| Percent correct prediction | 78.6 | |
| N | 700 | |

Figures in parenthesizes are standard errors. ***, **, * Denote significance at P<0.01, P<0.05, and P<0.10, respectively. Forty-eight observations were excluded due to missing observations on one or more of the exogenous variables. D = Dummy

In summary, the results in the above table depict the following.

1) **Institutional services:** All significant and with the a priori expected signs
   (i) An increase in the intensity of extension services and diversity of information sources (observation of demonstration plots, on or off-farm training, listening to agricultural education program broadcasts) will increase the likelihood of adoption of improved maize technology package.
   (ii) Physical inaccessibility (distance to development centers and primary product markets) had a negative impact. This proves the

negative impact of infrastructure related problems on technology adoption.

**2) Socio-Economic Variables:**

(i) Inference on the coefficients of the socio-economic factors reveals the probability of adopting HYV maize technology package as an increasing function of the resource endowment base, especially the farm size (hectares) and the livestock units maintained by the farm households.

(ii) A reflection of to what extent farmer's interest for maintaining an already established tradition of farming could impede change, the index of resistance variable has a negative and significant coefficient.

(iii) In line with the theoretical expectation and the findings of Abay and Assefa (1996), Asfaw, et. al (1997) and Mulugeta (1993), the higher the level of education the higher the likelihood of the farmer to adopt the maize technology package.

**3) Market experiences and regional differences**

(i) Farmers that had the experience of hiring seasonal or permanent labor are more likely to adopt HYV maize than those that did not employ hired labor.

(ii) Farmers who applied chemical fertilizers to other crop fields prior to their decision to use HVY maize seeds have a significantly higher likelihood to adopt the HYV maize.

(iii) Significant variations exist in the likelihood of adoption among farmers in different regions.

By making use of the key factors identified I defined and simulated several scenarios that could be used to enhance the adoption of the package by farmers who are currently non-adopters either as a Pure Strategy (PS) or a Mixed Strategy (MS) option.

## 3.2) STRATEGY OPTIONS

According to the CSA (1998), there were 3, 363, 980 households cultivating about 3, 149, 730 hectares of land under temporary crops in Oromia. Maize accounts for 577,450 hectares or about 33 percent of the area. Based on the sample, about 104, 763 households (16.9 percent) of these maize cultivating small farms have not yet adopted the package. To enable these non-adopter farmers to join their peers and shift up the overall productivity frontier, it requires a concerted effort. In light of this, identification of key strategy approaches is important. Therefore, questions about which of the variables are more important, and what strategy options could be considered for furthering adoption of the technology among those farmers that still use low yielding varieties need to be addressed.

In this session I identify some possible strategy options that could be pursued. To this end, I use the marginal effects of the variables in the model to gauge the order of importance of the key factors on the likelihood of adoption of the HYV maize technology package by all farmers. Accordingly, information diversity, the ability to employ hired labor, farm size, and level of education, followed by family labor force, total livestock units, and intensity of extension services lie in descending order of their positive roles. Physical in-accessibility to the development centers followed by the index of resistance to changes however had influential counter impacts.

To enhance the adoption of the package by the currently non-adopter farmers some or all of these characteristics of the farm households could be targeted. While the effects of some of these variables could be observed in the short run, others may seem difficult to alter directly or their effects may take a longer time horizon to bring the desired change. As a result, the importance of each of these factors may vary from the point of view of their effectiveness in achieving the desired goal. Defined and presented in Table 2 below are some simulated possible strategy alternatives and their comparative status in enhancing the likelihood of adoption among the remaining 17 percent of the maize cultivating small farms.

**i) THE PURE STRATEGY (PS) APPROACHES:**

a) The Agent Approach (PS-I): This is a strategy defined to increase the intensity of extension services among currently non-adopter farmers. It involves providing one additional on-farm contact between the extension agent and the non-adopter farmer over the current average two rounds of on-farm contacts. Simulation of the effect of making such a provision using parameters of the model shows that this effort alone would enhance the likelihood of the currently non-adopter farmers to adopt the package on average by five to six percent.

b) The Information Approach (PS-II): This is an approach in which an effort to increase the diversity of information sources currently in use by one unit of the index is to be made. This could be, for instance, either of enabling a farmer to visit one more additional demonstration plot or other farmer's maize field over an above the current average of three visits. Alternatively it could also be an access to radio agricultural extension education program or additional day of on farm training or attending a field day. The results from Table 2 show that such an approach would increase the likelihood of a currently non-adopter farmer to adopt the package on average by 35 to 45 percent.

c) The Education Approach (PS-III): As a key to the adoption of the package or related technologies and their further intensive use, this approach is defined to improve the literacy levels of farmers through primary education for both adopter and non-adopter farmers. Under this option, I consider the provision of three additional years of schooling for all farmers who have not completed primary schools and literacy campaign or adult education program for illiterate farmers (whether currently adopter or non-adopter). Simulation of the effect of the use of this approach indicates that the likelihood of adoption would increase on average by three percent. Comparatively this approach seems least effective. Partly it might be because the approach targets both adopter and non-adopter farmers. However, it is important to note that educating farmers has other spill over effects that would contribute to the overall development of the rural sector.

d) The Livestock Approach (PS-IV): This approach is defined to involve the provision of livestock unit to the target non-adopter farmer(s). This could be, for example, enabling the farmer to buy oxen, a cow or other livestock units and/or a combination of them. Besides directly increasing the availability of the traction power, this approach could supplement the food supply and income position of the household. Credit service could be provided to extend this option. With a six percent mean likelihood of enhancing the adoption, this approach is as effective as the agent approach and has more direct impact than the education approach.

**Table 2: Alternative strategy scenarios and their effects in enhancing the mean likelihood of adoption of the package among currently non- adopter farmers in western Oromia.**

| Strategy Options | Increases in the mean likelihood of Adoption (Model-1) | Increases in the mean likelihood of Adoption (Model-3) |
|---|---|---|
| **A) Pure Strategies( PS)** | | |
| PS-I: Agent approach | 0.0606(0.2423) | 0.0577(0.2354) |
| PS-II: Information approach[3] | 0.4545(0.3556) | 0.3462(0.3004) |
| PS-III: Education approach | 0.0303(0.1741) | 0.0192(0.1387) |
| PS-IV: Livestock approach | 0.0606(0.2423) | 0.0577(0.2354) |
| **B) Mixed Strategies (MS)** | | |
| MS-V (I and II) | 0.5152(0.5075) | 0.3654(0.4862) |
| MS-VI (I and III) | 0.0703(0.1741) | 0.0385(0.1942) |
| MS-VII (I and IV) | 0.1212(0.3314) | 0.1346(0.3446) |
| MS-VIII (II and III) | 0.4242(0.5019) | 0.3077(0.4660) |
| MS- X (II and IV) | 0.5152(0.5075) | 0.3654(0.4862) |
| MS-XI (III and IV) | 0.0703(0.2141) | 0.0577(0.2354) |
| MS-XII( I, II and III) | 0.5152(0.5075) | 0.3654(0.4862) |
| MS-XIII (I, II and IV) | 0.5455(0.3706) | 0.4231(0.3969) |
| MS-XIV (II, III, IV) | 0.5152(0.5075) | 0.3462(0.4804) |
| MS-XV (I, III and IV) | 0.0909(0.2919) | 0.1346(0.3446) |
| MS-XVI (I, II and IV) | 0.5758(0.5059) | 0.4423(0.5015) |

Figures in parenthesizes are standard errors. The probability estimates are based on the pure (PS) and mixed (MS) strategies defined in this section. They were computed only for currently non-adopter farmers

Overall, among the pure strategy options, the information approach has a significantly higher likelihood of enhancing the adoption of the package among currently non-adopter farmers. This livestock and the agent approach follow this. The education approach has the least impact. Given the current features, providing farmers with additional traction

[3] The values in the information approach row in column II can be taken as follows: All other the same, on the average the likelihood of adoption of the package by a currently non-adopter farmer would increase by 45 percent if this particular approach is followed.

power or related complements and an additional contact with the extension agent are equally effective.

As an exhaustible list of pure strategies three other possible pure strategy scenarios could also be pursued. These include (i) Land market approach, (ii) Accessibility approach, and (iii) Labor market approach. The land market approach could involve legalizing the informal land markets that are currently at work so that farmers could get opportunities to trade in (lease or mortgage) their land and labor resources. This would enable farmers to enter into formally defined secure tenure arrangements and have free mobility of their scarce resource. I did not pursue simulating the pure or mixed strategy effects of this approach because the coefficient of the dummy variable on Maize land tenure (in the informal land market) is not significant. The Accessibility Approach could involve establishing additional development centers in a relatively remote rural areas and construction of feeder roads to help farmers get easy access to the nearby market centers. This approach requires us to define the exact locations of the development center(s), the length of available feeder roads, and related infrastructure and services. Given the data set, this is not possible. Also, the Labor Market Approach is not considered for two reasons. First it is highly tied to the land market conditions and second for many reasons, it is an exogenous option to policy makers.

**ii) THE MIXED STRATEGY (MS) APPROACHES:**

Mixed strategies are approaches that involve the integration of any two or more pure strategy alternatives defined earlier. For instance, by supplementing increased extension intensity with diversified information (MS-V) or with the livestock approach (MS-VII), it is possible to define two different mixed strategy scenarios. Alternatively, the education approach defined for expanding primary education or literacy campaign could be integrated with the information approach (MS-VI). With a further intensified effort, a scenario that integrates three or more approaches could also be defined. A typical example is a case in which the agent, the information and the education approaches (MS-XII) are integrated. All the four approaches could also be mixed as in MS- XVI.

The importance of mixed strategies of this different nature lies with the fact that each of the elements of the strategies may vary from farmer to farmer. For instance, some farmers cite lack of adequate information as a reason for non-adoption. Others indicate shortage of draft animal for land preparation, problem of land tenure and their inability to process the application due to their illiteracy. Thus strategies in which several approaches are integrated may be necessary to deal with these problems. Table 2 also provides estimates of the changes in the mean likelihood of adoption resulting from each of the possible mixed strategy approaches.

Evident from the table, possible mixed strategy options using strategies MS-V, MS-X, MS-XII and MS-XIV enhance the likelihood of adoption among the currently non-adopter farmers by 48-50 percent. The first two of these four strategies were defined to integrate the agent approach with the information approaches (MS-V) and the information approach with the livestock approach (MS-X). The last two combine three different alternatives. Mixed strategy MS-VII in which the information and education approach were combined ranked the second best alternative among the class of these paired strategy options. In MS-XIII, the information, the agent and the livestock approaches were combined. With a 54 percent likelihood of enhancing the probability of adoption, this strategy produced one of the highest impacts. Integration of all the four pure strategies in MS-XVI enhances the likelihood by 57 percent. But comparison of this effect at mean levels with that of MS-XIII shows no significant differences between the two at $p<0.05$. Evaluation of other outcomes in a similar fashion also depicts no significant differences between the effects of MS-VII and MS-XV, MS-XI and MS-XV, and PS-I and PS-III.

Based on the above comparison, a careful assessment of the alternatives reveals that most options that could be pursued by integrating two or more of other options with the information approach stand consistently effective. To effectively enhance the adoption of the technology package among the currently non-adopter farmers, therefore, some options may not be worth pursuing. The results in the table show the use of information approach alone or its integration with few other options, as the most attractive alternative.

Apart from these differential impacts that these alternatives could generate, important variations between each option in terms of cost effectiveness and regional (agro-ecological) differences could exist. For example, the impact of enabling a farmer to visit another farmer's field in the information approach, my not be as attractive as it is in areas where there are many adopters compared with areas where many farmers have not yet adopted the technology package. Already available infrastructure and related facilities could lead to differences in the impact of each of the scenarios. Further research for evaluating the significance of such differences could be helpful in ranking the strategies.

## V. CONCLUSION AND IMPLICATIONS

This study sheds light on some technical and socio-economic factors that determine the adoption of HYV maize technology package in the Western maize belt of Oromia, Ethiopia. The study finds that with improved economic access, the likelihood of adoption of the HYV maize package significantly increases. Factors especially related to institutional services play key roles in enhancing HYV maize technology adoption. Physical inaccessibility to development centers and primary product markets negatively constrain the likelihood of HYV maize technology adoption. Despite the low level of educational achievements observed in the area, the study shows that educated farmers have higher propensity to grow HYV seeds than illiterate farmers. Farmer's experiences in using a complementary input such as fertilizers, significantly contributes to a higher likelihood of adoption of the package.

A sound agricultural development strategy aimed at improving the livelihood the farmers and economic growth of the region requires wider dissemination and adoption of such improved technology that would raise the productivity and income level of these small-scale farms. To this end (i) designing strategies that would make use of stronger institutional approaches such as further intensification of the extension contacts, and diversified information sources, (ii) improving farmers' resource positions, such as traction power, and expanding training (formal or informal) opportunities, (iii) raising education levels, making development centers accessible, (iv) labor market development and (v) the use of strategies that emphasize the information approach or its integration with education and/or the agent approaches are critical.

In this endeavor knowing the cost effectiveness of the strategy options will remain pertinent for the department of agriculture. Comparison of the net welfare effects of whether it is advantageous to pursue a given strategy option, say the agent or information approach, that has the highest likelihood of bringing the desired changes with other less effective (but less costly) approaches- such as the livestock, or any other option before taking the action is very important. Based on the SG-2000 program experiences, integration of the agent and information approaches on average costs about 837 Ethiopian Birr per farmer willing to adopt the package (Howard, 1999). At this rate bringing about 17 percent of the currently non-adopter maize cultivating farms through using this approach would cost the Oromia Agriculture department more than 87 million Birr. This could also vary depending up on the time horizon over which it will be implemented.

Many social changes are generally the consequences of strategies pursued to enhance economic progress. In this regard, although the effectiveness of some of the alternatives such as the agent approach could be more attractive in the short run than the long run, other approaches like the education and information approaches, though presumably costly, need to be emphasized. This is because they also have positive externalities in the long run. Increased human and physical capital accumulation will enhance choices and this will make it easier for farmers to overcome biases of any sort. Moreover, the accumulation of human capital will inevitably lead to the introduction of ideas that make it more difficult to sustain production practices on the lower bound of the technical and allocation efficiency frontier.

The livestock approach that could make use of credit services for enabling the non-adopter to purchase an additional draft animal is less costly. But whether sticking to the less costly and yet less effective strategy is optimal needs a thorough and detailed analysis. Given the meager financial resources and weak economic position of the farmers and a multitude of competing agricultural development goals that should be taken as their priorities, decision-makers need to be informed about these differences. Despite the attempt to present a class of alternative strategy scenarios, the present study did not provide detailed and exhaustive list of strategies and their cost effectiveness. I hope that these questions be seriously considered by future research efforts in the same or related areas.

In conclusion, it is important to note that besides the adoption of improved technologies, enhanced productivity gains, higher human and physical capital accumulation, and further improvements in the livelihood of millions of farmers in region who cultivate maze or other crops at large depends on the ability of the concerned authorities in the region to have a vision and will to use these strategies and the resources at hand in an integrated way.

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