# TECHNICAL AND INSTITUTIONAL ASPECTS OF INNOVATIONS: EVIDENCE FROM VERTISOL TECHNOLOGY DEVELOPMENT AND TRANSFER IN ETHIOPIA

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## 1. INTRODUCTION

Increased productivity was recognised as a considerable source of growth to which agricultural innovation made a decisive contribution. The green revolution which took place in the early 60´s can be cited as an example. The increase in productivity made a marked contribution to poverty reduction although various negative effects cropped up later as well.

Macro-economic studies conducted by Kendrick and Solow (1957) assigned a key role to innovation through technical progress as panacea for development. He considered technical progress as the third factor of production other than labor and capital. Kaldor (1957) moved further and explained technical progress in relation to accumulation and investment in the economy at a point in time. His explanation about growth in the economy was based on technical dynamism and hence named the production function as technical progress function.

Mainstream economics describes technical progress to be a conglomerate of three, but basically linked forms of economic activities (Walter 1977). These are the production of goods and services, adoption of new superior production processes, and utility. These characteristics correspond with the notions of product-processing and organizational innovations in their time path from first use to adoption or utility. Innovation, in general, can be considered as consisting of four cycles (processes). These are invention, reallocation, organization and marketing. The four processes of innovation are linked to agricultural development through research, extension and adoption processes.

Technical innovation in agriculture is closely tied up to supply of inputs, credit, processing, storage, transport, marketing etc. which call for an institutional innovation. Institutions are defined to be a set of formal and informal rules which constrain and govern the interaction of agents (Khan 1995). Institutional innovation is mainly available in the form of services. The services in agricultural innovation assume increasing importance from time to time and more complex technologies and markets with higher standards require greater division of labor. Typical to the services are: agricultural extension, financing, training, seed production and distribution, marketing and market promotion.

Looking back on to development of agriculture in the industrialized countries, it becomes clear that production, services and processing developed parallel to one another. When one of these functional services outstrips the others, a disequilibrium will be established and the other balances induce to catch up until a new balance is restored. Such a diseqilibrium brings about added operating costs (transaction costs) in a chain from producer to consumer. This point clearly emphasises the need for institutional innovation. The role of institutional innovation has been discussed in the literature from the point of view of the New Institutional Economics (NIE). The aim of the NIE is to assess the existence, development and use of institutions and to identify economically and socially viable institutions with high economic performance. This paper attempts to discuss the relationship and synergy between institutional and technical innovations and the importance of institutions in the transfer of technical innovation in Ethiopia by way of case study from the vertisol technology of smallholders' farming.

## 2. METHODOLOGY

For this case study, a total of 142 farmers, 72 farmers from Gimbichu sub-district and 70 from Tullubollo sub-district were sampled. Out of the 72 farmers selected from Gimbichu area, 38 were designated as adopters and 34 as non-adopters while out of the 70 households drawn fro Tullubollo area, 47 were classified as adopters and the rest (23) as non-adopters. The sampled households were selected from peasant associations using a multi-stage sampling procedure. A total of 18 peasant associations were selected, 10 from Tullubollo and 8 from Gimbichu sub-districts. From each peasant association a certain proportion of farmers was drawn based on the size of the population in each peasant association. Sample households were selected at varying distances to the adjacent peasant associations. The idea was to have a fairly representative, random household sample for the analysis. The analysis was conducted using probit response model.

## 3. TECHNICAL AND INSTITUTIONAL INNOVATION IN VERTISOL

Innovations could be developed and transferred by various institutions. Universities and Research institutes are among the examples cited most frequently. Vertisols in general are agriculturally important soils in Ethiopia. The vertisol farming system has all over the country some common feature. Characteristically vertisols are sticky when wet and hard and crack when they are dry. While dry water intake rates are high in vertisols, and because of dip cracks, upon wetting, the intrinsically low hydraulic conductivity leads to severe surface waterlogging, runoff and erosion during the rainy season. Consequently, the actual vertisol productivity is far below its potential. The Joint Vertisol Project (JVP), a team of various disciplines and a consortium of various institutions in Ethiopia, has developed packages of Vertisol technology to redress waterlogging problem of the soil with ultimate goal of increasing production.

The technical package developed by a JVP includes, a Broad Bed Maker (BBM) plough developed by modifying the traditional plough-*Maresha*-and a technology for dry planting. Farmers are advised and encouraged to adopt the entire mix of technical package instead of step-wise adoption (Abiye and Frew 1993). The majority of these mixed inputs are perfect complements, and these technological components are recommended as a package since there would be no or little response to one component without the presence of the others. Our study reveals that the following technological components of Vertisol are more likely to be adopted simultaneously (jointly) than separately–BBM and choice of varieties, fertilizer use and choice of varieties, and choice of varieties and sowing date, in this case early season planting. Farmers, for instance, are knowledgeable, in that the use of improved seed without fertilizer use is minimal and hence they hardly grow improved wheat without fertilizer. Nevertheless, sub-optimal use of fertilizer and seed rate is unavoidable. At this juncture it is worth-considering to highlight the components of innovation in terms of intensity of use. The intensities for various inputs are compared between adopters of the recommended technology and the non-adopters (Table 1).

When we look closely at the individual factors in adoption decision, close to 70% of adopters used the recommended seed rate of 150 kg/ha, while only a few of the group (30%) considered to be the non-adopters follow the recommended date of sowing (dry planting) and seed rate. Both the adopter and non-adopter groups have used the improved variety. The difference is in terms of intensity of use. In Chefedonsa, in one part of the study area, almost the same level of improved variety was used by the non-adopters. More than 60% of the farmers have applied the recommended rate of fertilizer, although nearly all the farmers in the study area are applying fertilizer. There is a slight difference in the use of fertilizer observed between adopters and non-adopter groups (Table 1). This trend indicates that the use of fertilizer is a long time experience among the farmers in the survey region. The use of improved variety is relatively a short time experience as compared with fertilizer.

**Table 1. Average intensity of use of technology**

| Components | Adopters N=85 | Non-Adopters N=57 |
|---|---|---|
| Fertilizer use (kg/ha) | | |
| For wheat-Urea | 105 | 85 |
| For wheat-DAP | 110 | 105 |
| For Teff-DAP | 150 | 120 |
| For Teff-Urea | 102 | 100 |
| Improved seed -wheat (kg/ha) | 136 | 114 |
| Local wheat (kg/ha) | 123 | 130 |
| Improved teff (kg/ha) | 30 | 20 |
| Local teff (kg/ha) | 57 | 40 |
| Sowing date (Percentage of farmers) | | |
| wheat - end June-mid July | 85% | 60% |
| Teff - early July | 63% | 60% |
| Share of wheat area on total farmland (%) | | |
| Gimbichu(N=72) | 48% | 40% |
| Tullo Bollo(N=70) | 14% | 7% |
| Use of BBM | | |
| 1993 | 10 | |
| 1994 | 15 | |
| 1995 | 32 | |
| 1996 | 37 | |

**Source:** Calculated from own data.
**Note:** Multiple responses are possible.

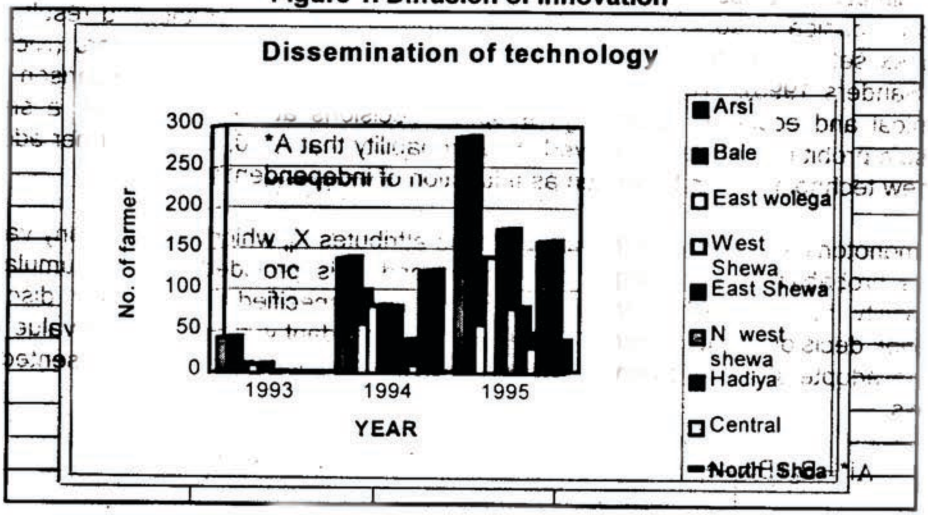
**Table 2. Access to extension and intensity**

| | Adopters | Non-adopters |
|---|---|---|
| Training in use of BBM | 75% | 11% |
| Credit for inputs (Birr) | 437 | 223 |
| Intensity of extension visit | | |
| Often | 80% | 60% |
| None | 20% | 40% |
| Source of improved seed | | |
| MOA | 50% | |
| Research centers | 16.5% | |
| Market | 9.2% | |
| Own | 2.5% | |
| Seed exchange | 15% | |

**Source:** Own survey.
**Note:** Multiple responses are possible.

Although the dissemination of BBM seems to have increased over time (Fig. 1), the percentage of land allocated under BBM varies from one area to another depending on the inputs used, and the amount of land available and the availability of support.

**Figure 1. Diffusion of Innovation**




Among the group of farmers, those already exposed to the BBM use, 96% of them confirmed that BBM helps to avoid drainage problem successfully and improves the yield substantially. It helped them to reduce the drudgery of labour.

Most of those farmers who appreciated the use of the BBM have received intensive training from the Ministry of Agriculture (MOA) or NGOs and research centers. Most of the farmers at Chefedonsa got the exposure and training from the Debrezeit research center located in the vicinity. Not less than 80% of adopters claim that BBM is highly applicable to their situation Some 9% claim that there is no visible difference between the BBM and manual BBF

## 4. INSTITUTIONAL INNOVATION AND TECHNOLOGY ADOPTION

In the foregoing analysis, the response pattern of farmers towards the vertisol technology for both groups of adopters and non-adopters was described and explained by the use of qualitative response variables. The response variables were further analysed along with other variables using an adoption model that takes into account the institutional, economic and technical variables and farmers' perceptions.

The use of response model requires the assumption of utility maximization. The decision to adopt is derived from better physical yield, profitability, and risk avoidance. In turn, profitability and riskiness of a component are a function of elements of the agro-climatic and socio-economic, and institutional environment. The observed adoption choice of agricultural technology is hypothesized to be the end result of a complex set of inter-technology preference comparisons made by farmers (Nichola and Sanders 1996). To model the effect of technology preference comparison and technical and economic factors on adoption decisions at the initial level, a single decision probit model was employed. The probability that $A^*>0$, i.e. the farmer adopts the new technology, can be written as a function of independent variables.

The monotonic translation of the values of the attributes $X_i$, which may take any value, into a probability which ranges between 0 and 1 is provided by the cumulative probability function. When the functional form is specified as a binary discrete adoption decision model, where $A_i$ is the limited dependent variable taking a value of 1 for the adopters and 0 otherwise, it is known as a probit model and presented as follows;

$$Ai^* = B_0 + BX_i + e_i$$

$A_i$=1 if $A^*_i$ >0, and 0 otherwise (Gujarati 1978)

where $A^*_i$, is a limited dependent variable and latent variable and cannot be observed. We instead observe the dummy variable $A_i$. X is a vector of socio-economic and demographic characteristics of the farm household, and the technology perception of the farmer; B is a vector of parameters to be estimated and $e_i$ is an error term. The error term $e_i$ is assumed to be independently (normally) distributed with zero mean and constant variance. When $A_i$ >0, the farmer is observed to adopt the technology. This model permits the investigation of the decision of whether or not to adopt.

Taking into account the above assumptions, the independent variables included in the empirical probit model consist of socio-economic characteristics of the farmer and institutional factors. These are: age of the household (AGE); number of oxen (NUMOXEN), number of animals (NOANML) as proxy variable for wealth, average distance from the main road in hours (AVRDISTN); land area allocated for teff in hectares (TEFARA), harvesting of wheat in kg (HARVWHT), on-farm trial attended (ATNDONFA) as dummy, land allocated to improved wheat in hectares (WHEATARA), amount of nutrients used from urea source in kg (UREAWHT), amount of nutrients used from DAP source (DAPWHT), amount of credit used in the past agricultural season in Birr (CREDIT), number of household members above 15 years of age (MEMAB15) and family size (FAMLYSIZ). Farmers' subjective assessment or perception of technology are included in this study and these are: yield of wheat (YILDWHT), seed size of wheat (SEDSZWHT), food quality (FODQUWHT)-dummy, frost tolerance of wheat (FRTOLWHT) and marketability (MKTWHT). These subjective preferences indirectly induce adoption to allocate more land under improved variety and then stimulate or retard the use of BBM technology. In each case the subjective perception variables were represented as dichotomous variables that take on the value of 1 if the farmer believes that the improved technology has the indicated attribute, and the value zero otherwise.

**Table 3. Probit Model Results**

| Variable | Estimated coefficients | Elasticity at means |
|---|---|---|
| MEMAB15 | 0.0048<br>(1.190) | 0.145 |
| FAMLYSIZ | 0.0363<br>(0.266) | 0.015 |
| TEFAREA | -0.180<br>(2.978)* | -0.659 |
| AVEDISTN | -0.015<br>(-1.947)*** | -0.0779 |
| YILDWHT | -1.2650<br>(-2.720)** | - |
| FROTWHT | 0.477<br>(1.51) | - |
| FODQUWHT | -0.079<br>(-0.203) | - |
| MKTWHT | 0.867<br>(2.003)** | - |
| NOANML | -0.0777<br>(-3.273)* | -0.453 |
| UREAWHT | -0.00210<br>(-0.149) | -0.0119 |
| NOXEN | 0.0004<br>(0.398)*** | 0.0196 |
| CREDIT | 0.0078<br>(2.4068)** | 0.4732 |
| CONSTANT | -0.641<br>(-1.2572) | |

LOG-LIKELIHOOD FUNCTION = -50.706
LOG-LIKELIHOOD(0) = -95.648
LIKELIHOOD RATIO TEST = 89.8843 with 12 D.F.
MADDALA R-SQUARE = 0.4690
CRAGG-UHLER R-SQUARE = 0.63376
MCFADDEN R-SQUARE = 0.46987

The numbers in brackets are asymptotic t values; one, two and three asterisks indicate that the coefficient is significant at 1, 5 and 10%, respectively.

Adoption analysis is carried out at two levels, namely, with the assumptions of supply restriction and without supply restriction. The first probit model without supply restriction was estimated using the conventional definition of adoption with 85 adopters (non-limit observations) and 55 non-adopters (limit observations). The results from the probit model revealed that adoption decision is significantly related to Teff area, distance, yield and marketability of wheat, number of livestock owned, number of animals and the credit variables (Table 2). Contrary to expectation, the Teff farm has negative sign and is significant at 10%. This is probably because the allocation of more area to teff means the reduction of land allocated to wheat and eventually to BBM technology. Teff area has got the highest impact on the probability of adoption decision. A 10% increase in the land size allocated to teff crop is expected to result in a decrease in the probability of the decision to adopt by about 7%. Teff has no drainage problem and is a less risky crop compared with wheat. Therefore, a competition exists between teff production and other cereals in terms of land allocation.

The number of livestock owned significantly and strongly affects the adoption decision of the technology. Livestock ownership, as is the case in many empirical studies, is considered as accumulated wealth, a source of liquid cash and security against crop failure and other misfortunes. Contrary to expectation, however, in this model, the coefficient turned out to be negative. A 10% increase in the livestock unit is expected to reduce the probability of adoption of the vertisol technology by 4.5%. This is probably due to the competition between the livestock and crop production. Distance from the main road, representing the time taken to reach the nearest market resulted in a negative coefficient, confirming that marketing facility is an integral part of technology adoption decision. Credit is also another positive significant variable that influenced the adoption decision of the farmer. Credit has the elasticity value of 0.47 which suggests that a 10% increase in credit use, increases the probability of adoption decision of the farmer by 5.2%. The number of family members above the age of 15 is positively related to the adoption decision, indicating that farmers' adoption decision is also influenced by the availability of agricultural labor force.

It is important also to note that farmers are consumers of the products of agricultural innovations, and it is believed that their subjective preferences for characteristics of new agricultural technologies affect adoption decision. Some of the desirable characteristics considered in this case are yield, desirable grain colour, food quality, straw quality, marketability, frost tolerance and resistance to waterlogging and they were found out to have significantly affected the adoption decision. We may note that a variety preferred for its yield might not be preferred for marketability. Farmers in Gimbichu, for instance, prefer ET-13 or Cokrit bread wheat varieties to Buhe or Foka durum wheat varieties. On the contrary, farmers in Tullubollo prefer Foka, Kilinto and Buhe durum wheat varieties to other bread wheat varieties for various reasons (Buhe for its good grain color). Considering such factors would definitely enhance the speed of adoption. Contrary to our expectation, the coefficient for yield perception was negative. This might be due to the effect of other traits of the technology which might have dominated coefficients. Some of these results indicated clearly that institutional variables (e.g., credit, market) play an important role in the process of technology development and show a strong linkage that should be established between technical and institutional innovation to speed up the adoption of innovation. The institutions such as banking, seed companies and producers of the technology should interact among themselves and avail the services to their clients efficiently.

The findings of this study in general show that the promotion of agricultural development through technical progress goes far beyond technical innovation into institutional innovation. It is unthinkable to talk of agricultural development in general and rural development in particular without considering linkages and balances between the development of various institutional support systems (banks, seed distribution companies, fertilizer distributors and farmers' organisations).

## 5. CONCLUSIONS

Much effort has been exerted on disseminating the vertisol technology to a wider adoption by the smallholders in the highlands of Ethiopia. In general, the on-farm testing and evaluation of the technologies with farmers' participation proved to have increasingly influenced the process of technology adoption.

Yet, much more effort is required, in terms of institutional innovation, for wider adoption of the packages of the vertisol technology. If agriculture is to develop and innovation promoted, not only should technical innovation at research stations be kept in mind, but efficient institutional innovation which stimulate balanced service system must be established. Such typical agricultural service system includes demand-oriented research and extension, financial and marketing services, and input delivery mechanism. Despite differences in content, all services must involve a close relationship and intense interactions between the institution and the client (mostly farmer groups) e.g., seed suppliers, fertilizer suppliers, BBM suppliers, Banks, traders, farmers' associations or cooperatives, NGOs, research centers, local administration and other relevant bodies.

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