The Effect of Social Capital on Technology Adoption: Evidence from Rural Tanzania

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Abstract: This paper develops and tests a model of technology adoption which predicts that the probability of adoption is increasing in household-level human capital and land endowments and village-level adoption patterns and social capital. The results of implementing the model with data from the plateau zone of Tanzania suggest that the probability of adoption of improved fertilizer is increasing in land endowments, the cumulative proportion of adopters, the presence of tribally-based social affiliations, and the village distance from a local market. When adoption patterns are omitted from the implementation of the model, it is shown that the probability of adoption remains increasing in land endowments and ethnic affiliations, and is also positively associated with consultative norms, the adoption of improved seeds, the availability of credit and extension services, and the average number of years that households have resided in the village. The results are robust with different sub-samples of the available data and after testing for multicollinearity, omitted variables, and simultaneity, where indices of ethnic fractionalization and land inequality are used as exogenous instruments. Overall, these results support the finding that tribally-based social affiliations act as a form of social capital in the adoption decision and provide an economic justification, during the design of extension programs, for investments in social assessments in order to analyze characteristics of local social structures.

I. Introduction[1]

> *"What are human investments? Can they be distinguished from consumption? Is it at all feasible to identify and measure them? What do they contribute to income? Granted that they seem amorphous compared to brick and mortar, and hard to get at compared to the investment accounts of corporations, they assuredly are not a fragment; they are rather like the contents of Pandora's box, full of difficulties and hope." Theodore Schultz (1961), in his address to the American Economic Association on human capital.*

Almost 40 years after the establishment of the concept of human capital in the corpus of economics, the concept of social capital is now taking hold. Based on noted theoretical and empirical work in other social sciences (Coleman 1990, Putnam 1993), many leading scholars in economics (Becker 1996) and development economics (Dasgupta 1998, Collier 1998) are welcoming this concept that "a dense network of social connections, even though developed for noneconomic purposes, will enhance both political and economic efficiency" (Arrow 1998). Others are more guarded: Solow (1995), while acknowledging the appeal of this idea, has called for more rigorous measurement and additional empirical evidence.

Like human capital, social capital is a concept with much appeal and promise, but full of definitional and operational ambiguities. The concept challenges economic researchers to develop models in which social structures affect economic decisions through specific mechanisms; and to develop measures of social structures which can be used to test such models with standard estimation techniques.[2]

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2 Two recent examples. DiPasquale and Glaeser (1998) develop a model of investment of public goods with social capital and find evidence that, because of lack of mobility, homeowners are more likely to invest in volunteering, getting involved in local governments, and joining local organizations. Rao (1998) presents a model of expenditures on festivals in rural India and finds evidence that festivals build village-level social capital and that households who spend more money on festivals receive private economic and social returns.

The diffusion of innovations among agricultural households is an ideal topic for developing and testing an economic model which incorporates characteristics of the social structure. First, a substantial body of economic literature exists on information diffusion and technology adoption among neighboring households in rural villages. This literature suggests that there are large spillovers in the diffusion of more complex agricultural technologies: households tend to observe, ask questions of, and imitate the adoption patterns of their neighbors.

However, this economics literature has not yet detailed how social structures within these villages may affect diffusion and adoption. This is despite the fact that a substantial body of quantitative and qualitative evidence from rural sociologists, dating back to the 1950s, suggests that these social structures critically affect the adoption decision (Rogers 1995).

The adoption of fertilizer in rural Tanzania is in turn an excellent specific candidate for testing such an economic model. Nkonya, Schroeder and Norman (1997) examine the factors affecting adoption of improved maize seed and fertilizer in northern Tanzania. They find that farm size and human capital positively affect adoption, and that farmers tend to adopt fertilizer after the adoption of improved seeds. Why the delay? A background report for the study explains that:

> "Adoption of chemical fertilizer is far less than adoption of [improved seeds]. This may be explained by the stepwise adoption of technologies, i.e. farmers decide to adopt seed technology first since it is easier to practice and would adopt fertilizer later. Seed technologies are normally adopted spontaneously while fertilizer needs good knowledge before farmers decide to use it" (Nkonya *et. al.* 1998).

Is the availability of this 'good knowledge' affected by the local social structure? Such a conclusion would be consistent with two other recent studies. Detray (1995), using data from field work among households and farmers' associations in two regions in Tanzania, finds evidence to support the hypothesis that member-controlled participatory associations have a significant positive effect on farmers' market orientation. Narayan and Pritchett (1997), in their study on poverty and social capital in rural Tanzania, construct an 'index of social capital' based on the quantity and quality of local organizations in 87 villages and present evidence of a statistically-significant relationship between their index and household expenditure per capita.[3]

If it can be shown with economic theory and econometric analysis that characteristics of the social structure in rural Tanzania affect information sharing and the diffusion of innovations among agricultural households, this would be a good example of a type of social capital at work--of "an element of the social structure that affects relations

[3] Among the many possible mechanisms that they suggest may be at work is the diffusion of information: they find that households in villages with high levels of their social capital index have greater use of modern agricultural inputs. They do not, however, test for the existence of this mechanism with a formal model of technology adoption nor with a complete set of data that includes other important determinants of adoption, including household-level land endowments and village-level adoption patterns.

among people and is an input of a production function" (Schiff 1992). Additionally, it would have policy implications for the introduction of new technologies in poor communities in the developing world--for example, via group-based extension services.

In this paper, I develop a model in which the acquisition of information and the adoption of new technology are increasing in two household-level characteristics--land holdings and human capital--and two village-level characteristics--the cumulative proportion of adopters and social capital. The model is tested using household data from three recent household surveys in rural Tanzania, which include information on fertilizer adoption, selected household- and village-level characteristics, and the characteristics of local civic associations.

The paper proceeds as follows. Section II reviews current economic and non-economic research on information diffusion and technology adoption among agricultural households. Section III presents a model of technology adoption that incorporates village-wide social capital among neighboring agricultural households. Section IV presents the proposed econometric estimation and the available data, and section V summarizes the results from random-effects probit estimation and from supporting empirical evidence. Section VI concludes with policy implications for the design and implementation of extension services in Africa.

II. The Literature on Information Diffusion and Technology Adoption

The premise of the concept of social capital begins with the observation that recurring and patterned social interactions within a well-defined boundary form a local 'social structure'[4], and that the characteristics of this social structure will affect many economic decisions of agents within that boundary. Specifically, the local social structure may affect economic decisions and outcomes through three main mechanisms: information sharing; the impact on transactions costs, and the reduction of collective action dilemmas.[5] The adoption of improved technologies among agricultural households provides an ideal test of the first of these three mechanisms: that social structures affect economic decisions and outcomes through information sharing among agents.

A. Social Structures and Information Sharing.

Technology adoption can dramatically improve the well-being of agricultural households, but many questions about the determinants of adoption remain unanswered (Besley and Case 1993). In a review of early empirical and case study evidence on technology adoption, Feder, Just, and Zilberman (1985) suggest that some adoption outcomes that can not be explained with traditional models or by standard household data may be the result of differing social, cultural and institutional environments. This conforms to the conclusions of myriad studies in rural sociology: "The heart of the diffusion process consists of interpersonal network exchanges … between those individuals who have already adopted an innovation and those who are then influenced to do so" (Rogers 1995).

Economic research on technology adoption in rural areas has only partially addressed the issue of how interpersonal network exchanges affect adoption. Much of this research (Feder and Slade 1984; Case 1992; Besley and Case 1994; Foster and Rosenzweig 1995; Pomp and Berger 1995) does address how non-adopters learn from adopters. These and similar studies build their modeling or empirical estimation on a very likely assumption: that neighboring agricultural households are, *de facto*, members of a social structure who exchange information about improved agricultural practices.

However, none of these studies models or tests how social structures, which vary from village to village, may affect adoption. Yet much economic and non-economic research suggests that the characteristics of social structures are critical determinants of the way that information is diffused among households. In a review of diverse research on diffusion--much of which was conducted by rural sociologists among agricultural households--Rogers (1995) concludes that: "The heart of the diffusion process consists of interpersonal network exchanges … between those individuals who have already adopted an innovation and those who are then influenced to do so".

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[4] A social structure can be defined as "recurrent and patterned interactions between agents that are maintained through sanctions" (Swedberg 1994).

[5] General discussions and additional examples of how local social structures are associated with information diffusion, transactions costs and collective action are found in Esman and Uphoff (1984), Nugent (1993), Dasgupta (1997), Woolcock (1998), Collier (1998), and Isham (1999), among others.

Specifically, Rogers (1995) cites three characteristics of social structures that promote more rapid diffusion of innovations. First, village homogeneity, the degree to which two or more individuals who interact are similar in certain attributes, promotes more information sharing. When individuals share common attributes and beliefs, communication between them is more likely to be effective. For example, Munshi and Myaux (1998) find evidence that information diffused among households with similar religious affiliations helps to explain the adoption of improved contraception methods in Matlab, Bangladesh.

Second, leadership heterogeneity, the degree to which leaders within a social structure differ in certain attributes, also accelerates the diffusion of innovations. For example, when leaders have different professions or higher socioeconomic status than other members of a social structure, this can provide an information link between two different sets of agents. Such links are critical in information sharing about innovations across groups (Granovetter 1973).

Third, social norms that favor change can promote consultative decision-making and lead to more rapid diffusion of innovations. In villages with more traditional norms, innovators are viewed with suspicion and mistrust. By contrast, in villages with social norms that encourage collective decision-making, innovators are rapidly to share their new ideas and influence the opinions of others. Innovations were more rapidly accepted in villages in Brazil with norms that encouraged more participatory decision-making (Herzog *et. al.* 1968, as cited in Rogers 1995).

B. Social Structures and Information Sharing in Rural Tanzania.

What is the current state of local social structures in rural Tanzania? This sub-section focuses on the specific characteristics--village homogeneity, leadership heterogeneity, and decision-making norms--that may play a role in information sharing and the diffusion of innovations.

Tanzania experienced a unique social upheaval in the 1970s, when the *Ujamaa* program of forced 'villagization' was implemented across the rural countryside. Under this ambitious attempt at a new form of African socialism, households that had been self-organized along ethnic lines or around small marketplaces were forced into government-administered villages, and many indigenous social and economic organizations were forcibly disbanded (Putterman 1994).

As a development plan, *Ujamaa* was a failure. But into this decade, it has left a legacy of local social systems that are unique in Africa: local organizations, networks and norms that were shaped by forced migration and government intervention less than twenty-five years ago. Traditional social structures (as in other parts of Africa) were significantly altered. For example, the government tried to curtailed independent organizations and to create a new hierarchical structure within villages built around the ruling party, Chama cha Mapinduzi (CCM) (Tripp 1992).

What effect did *Ujamaa* have on the current state of local social structures? First, most Tanzanian villages still foster active social organizations. These associations--which include women's groups, burial societies, youth groups, and local political groups--combine social activities with economic and political activities. Most villagers join such groups for 'emotional support, encouragement, and a sense of belonging', but they also offer some economic assistance: burial societies, for example, help people cope emotionally and financially with death (Narayan 1997). Notably, many of these associations are still tribally based, preserving a critical part of the pre-*Ujamaa* social structure.

Religious-based groups (Christian and Muslim-based groups) and economic cooperatives (farmers cooperatives, primary societies, dairy groups and credit associations), which have different purposes than social organizations, also are prominent in most villages. Members report that religious groups provide spiritual guidance and offer a place to pray; and that economic groups are specifically created to increase agricultural production and to pool local savings (Narayan 1997). While the activities in the groups are not primarily social interactions, the activities in these groups undoubtedly shape local social norms and networks. Like social organizations, many of these are still tribally based.

The long-term nature of the leadership structure within local social structures was more significantly affected by the villagization process. Under *Ujamaa*, the decision structures were government-approved 'Village Councils': among other tasks, they oversaw communal village activities (Quinn 1995). Most villages now have an influential governing structure that is composed of chosen representatives. Notably, there is evidence that this structure affects the flow of information from elsewhere. Non-governmental and local governmental authorities (who might, for example, be promoting extension services to diffuse improved agricultural practices) must work under the tacit rule that they can not contact and work with villagers without the knowledge and permission of local leaders (Nagpal 1994).

Finally, how can one assess whether local social norms in the villages favor or hinder change? One set of evidence comes from decision-making norms within local organizations. Some organizations--for example, party-affiliated and religious groups--are characterized by centralized decision-making and low levels of member involvement. Others--for example, local women's groups--have maintained participatory norms which have led to higher member satisfaction (Tripp 1992). Recent case study evidence from the Morogoro and Kilimanjaro regions suggests that member-controlled participatory groups can change farmers' market orientation, and that networks of these groups can play an important role in removing local institutional obstacles to development (Detray 1996).

As discussed in the next section, the data that are available from the recent Social Capital and Poverty Survey (SCPS) in Tanzania permit testing whether these three characteristics of social structures--village homogeneity, leadership heterogeneity, and decision-making norms--have promoted more rapid diffusion of innovations among agricultural households.

III. A Model of Adoption of a New Technology with Social Capital

The model developed in this paper relaxes the assumption that interpersonal network exchanges are the same across all villages. The model, an extension of Feder and Slade (1984), includes village-wide elements of the social structure as an input into the accumulation of knowledge by each household, knowledge which affects the adoption decision.

A. The Model of Feder and Slade (1984)

Consider a village of M farmers. An improved agricultural input has recently been introduced in the village (for example, by a trader in a local market or by an extension agent). Each farmer, endowed with a given quantity of land, must decide how many resources to allocate to the acquisition of new knowledge about improved agricultural practices and how much (if any) of the improved input to use.

Each farmer's stock of knowledge in period *t* is defined as[6]:

(1) $K_t = K_{t-1} + A_t + I_t$,

where K_{t-1} is the carried-over stock from the previous period, A_t is private 'actively acquired' information, and I_t is public 'passively acquired' information.

The private information requires monetary resources (or time) to obtain: for example, by a visit to a local agricultural office or participation in an extension class. Its cost is:

(2) $C_t = C(A_t)$,

where $C' > 0$, $C'' > 0$, and $C(0) = 0$.

The public information, by contrast, is available to all farmers without cost: "The farmer gains [this] information passively by listening to discussions among other farmers or observing incidentally the practices followed by neighbors" (Feder and Slade 1984).

How do elements of each farmer's stock of knowledge affect agricultural production? Some elements affect overall productivity: for example, visits to an extension office or discussions with a neighboring farmer produce general information about better crop spacing. Other elements affect productivity of the new input: the same visits and discussions produce input-specific information about using the improved agricultural input.

Accordingly, agricultural production is a function of both the general and input-specific impacts of knowledge. Let each farmer's agricultural output Y_t depend on a positive stock of knowledge, a positive endowment of land (L), and a non-negative amount of the improved input (N_t) as follows:[7]

(3) $Y_t = g(K_t)\, F(L, h(K_t)\, N_t)$.

The general impact of knowledge on productivity is represented by the knowledge function g(.). Assume that $g' > 0$, $g'' < 0$, and that g(.) converges to an upper limit (g^*) as cumulative knowledge increases to an upper limit (K^1):

(4) $g' > 0$ if $K \leq K^1$; $g(K) < g^*$ if $K \leq K^1$;

$g' = 0$ if $K \geq K^1$; $g(K) = g^*$ if $K \geq K^1$.

[6] For notational simplicity, the index for each farmer is subsumed in this and all subsequent equations for the theoretical model.

[7] This model does not consider labor or other traditional inputs. These can be integrated into a more fully specified production function, but doing so does not affect the fundamental results on knowledge and technology adoption.

The input-specific impact of knowledge on productivity is represented by the knowledge function h(.). Assume that $h' > 0$, $h'' < 0$, and that h(.) converges to an upper limit (h^*) as cumulative knowledge increases to an upper limit (K^2):

(5) $h' > 0$ if $K \leq K^2$; $h(K) < h^*$ if $K \leq K^2$;
$h' = 0$ if $K \geq K^2$; $h(K) = h^*$ if $K \geq K^2$.

K^1 and K^2 represent the amounts of knowledge beyond which additional increments of information have no effect on productivity through g(.) and h(.), respectively. The value $\max(K^1, K^2)$ represents the 'saturation level of information' beyond which additional information has no effect on productivity.

Let the production function F(.) be concave in its inputs. Assume also that $F(.,0) > 0$ and $F_L(.,0) = F_0^* > 0$ (and is finite), so that farmers who use none of the improved input can still produce an output.

Assuming constant returns to scale in F(.),

(6) $y_t = g(K_t)\, f(h(K_t)\, n_t)$,

where y_t is output per acre and n_t is the amount of the improved input per acre. From the assumption for F(.), $f' > 0$, $f'' < 0$, $f(0) > 0$, and $f'(0) = f'_0 > 0$ (and is finite).

The per-period profit for the farmer is:

(7) $\Pi_t = L\,[g(K_t)\, f(h(K_t)\, n_t) - pn_t] - C(A_t)$,

where p is the price of N_t and output price is unity. The farmer's myopic[8] objective is to maximize (7) subject to (1) and $n_t \geq 0$, $A_t \geq 0$.

B. Extension of the Model.

The set-up of this model is extended here in two ways. First, human capital affects the general and input-specific impact of knowledge.[9] Second, the quantity of passively acquired information available to all farmers is affected by the cumulative proportion of adopters in the village and by village-wide social capital.

To introduce human capital into the model, let the impact of knowledge be dependent on each farmer's level of human capital. First, the general impact of knowledge on productivity is now represented by the productivity function $g = g(V, K_t)$, where V is each farmer's stock of human capital. Assume that overall productivity is increasing in both human capital and knowledge (so that $g_v, g_k > 0$, $g_{vv}, g_{kk} < 0$, and $g_{vk} > 0$).

Let g(.) converge to an upper limit ($g^*|_V$) as cumulative knowledge increases to an upper limit (K^1):[10]

(4)* $g_k > 0$ if $K \leq K^1$; $g(V,K) < g^*|_V$ if $K \leq K^1$;
$g_k = 0$ if $K \geq K^1$; $g(V,K) = g^*|_V$ if $K \geq K^1$.

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[8] Feder and Slade note that, alternatively, the farmer's objective can be formulated as the discounted stream of net profits; this would add another term to the short-term operating profit but would not change the overall results about the determinants of adoption.

[9] Feder and Slade (1984) propose the addition of human capital to their model without detailing the necessary assumptions and subsequent implications.

[10] The upper limit $g^*|_V$ is increasing in the level of human capital: with the stock K^1, farmers with more human capital will achieve higher levels of productivity.

Let the input-specific impact of knowledge on productivity now be represented by the knowledge function $h = h(V, K_t)$ which is also increasing in both human capital and knowledge (so that $h_v, h_k > 0$, $h_{vv}, h_{kk} < 0$, and $h_{vk} > 0$). Let h(.) converge to an upper limit ($h^*|_V$) as cumulative knowledge increases to an upper limit (K^1):

(5)* $h_k > 0$ if $K \leq K^2$; $h(V,K) < h^*|_V$ if $K \leq K^2$;
$h_k = 0$ if $K \geq K^2$; $h(V,K) = h^*|_V$ if $K \geq K^2$.

What do (4)* and (5)* imply? *Ceteris paribus*, farmers with higher levels of human capital will be more productive--because of both the general and input-specific impacts of knowledge--than farmers with lower levels of human capital.

To introduce the cumulative proportion of adopters and social capital into the model, let public information in each period be increasing in the village-wide adoption pattern and social capital. Let I_t be defined as:

(8) $I_t = I(M_t, S)$,

where M_t is the cumulative proportion of adopters in the village at the beginning of period *t* and S is village-level social capital. Assume that $I_m, I_s > 0$, $I_{mm}, I_{ss} < 0$, and $I_{ms} > 0$.

What does (8) imply? *Ceteris paribus*, a representative farmer will acquire more knowledge in a village with many neighbors who have adopted. This kind of learning externality is at the heart of the research of Besley and Case (1994), Rosenzweig and Foster (1995), and Pomp and Berger (1995). Controlling for the cumulative proportion of adopters, the farmer will also acquire more knowledge with more interpersonal network exchanges among these neighbors, as measured by specific elements of the village social structure. This possibility is not specifically considered by these researchers.

With these two modifications, per acre output and per period profit are, respectively:

(6)* $y_t = g(V,K_t)\, f(h(V,K_t)\, n_t)$;

(7)* $\Pi_t = L\,[g(V,K_t)\, f(h(V,K_t)\, n_t) - pn_t] - C(A_t)$.

Under this extended set-up, the maximization of profits will now be affected by human capital, the cumulative proportion of adopters and social capital.

Based on these extensions, the farmer's myopic objective is to maximize (7)* subject to (1), (8) and non-negativity of the choice variables ($A_t \geq 0$, $n_t \geq 0$). Solving this Kuhn-Tucker problem yields the following propositions about the determinants of knowledge accumulation and adoption at the household level[11]:

Proposition 1: Farmers with greater land endowments will obtain more private information and adopt more rapidly.

Proposition 2: Farmers with more human capital will obtain more private information and adopt more rapidly.

Proposition 3: Farmers with neighbors that adopt will have higher levels of cumulative information and adopt more rapidly.

[11] The proofs of these propositions are detailed in Isham (1999).

Proposition 4: Farmers in villages with higher levels of social capital will have higher levels of cumulative information and adopt more rapidly.

The results from these four propositions can be summarized as follows. *Ceteris paribus*, farmers with higher levels of land and higher levels of human capital will obtain more private information; *ceteris paribus*, farmers in villages with more adopters among neighboring farmers and with higher levels of social capital have more cumulative information. Both of these increases of information will lead to a more rapid adoption of the new technology.

IV. Econometric Modeling and the Data

The estimation procedure for formally testing this model must be appropriate for analyzing clustered binary response data, since the available data is a binary choice between adoption and non-adoption; the households are randomly selected from a set of villages *qua* sampling clusters; and the model predicts that adoption will depend on between-cluster and within-cluster covariates.[12]

Begin by letting K_{ij}* be a latent random variable for household i in village j which is some measure of the household's stock of knowledge about improved agricultural practices in a given year t.[13] Assume that K_{ij}* is a linear function of a set of non-stochastic household-level independent variables and an error term. These household-level covariates include (as predicted by propositions 1 and 2) human capital (H_{ij}) and land holdings (L_{ij}) as well as a vector of other household-level variables (X^h_{ij}) which could affect the accumulation of knowledge (including household demographics and agricultural practices).

Let K_{ij}* also be a function of a village-level fixed effect (W_j) which affects all households within village j, so that:

$$(9) \qquad K_{ij}^* = \beta_0 + H_{ij}\beta_1 + L_{ij}\beta_2 + X^h_{ij}\beta_3 + W_j + \mu_{ij},$$

$$i = 1 \ldots m_j,\ j = 1 \ldots n^*$$

where μ_{ij} is iid ~ N(0,1).[14]

Let the fixed effect W_j be a linear function of non-stochastic village-level independent variables and an error term. These covariates include (as predicted by

[12] A set of up-to-date methods for analyzing clustered binary response data is reviewed by Pendergast *et. al.* (1996). They define *between-cluster* covariates as variables in which the value can change from cluster to cluster but is the same for all members of the cluster; and *within-cluster* covariates as variables where the value can vary among members of the same cluster.

[13] An alternative choice of the latent variable (following Case 1992) is as the expected profit using improved fertilizer (conditional on the expected profit using other inputs).

[14] Households are indexed from 1 to m_j since, as described in the next subsection, the number of households surveyed per village varies from 10 to 15.

propositions 3 and 4) the cumulative proportion of adopters (P_j) and social capital (S_j) as well as a vector of other village-level variables ($X^v{}_j$) which could affect the accumulation of knowledge (including agricultural resources and village wealth and migration).[15] Accordingly,

(10) $W_j = \alpha_0 + P_j\alpha_1 + S_j\alpha_2 + X^v{}_j\alpha_3 + \varepsilon_j,$

$j = 1 \ldots n^*,$

where ε_j is iid ~ $N(0,\sigma_\varepsilon^2)$.

Combining (13) and (14) yields:

(11) $K_{ij}^* = \beta_0 + \alpha_0 + H_{ij}\beta_1 + L_{ij}\beta_2 + P_j\alpha_1 + S_j\alpha_2 + X^h{}_{ij}\beta_3 + X^v{}_j\alpha_3 + \mu_{ij} + \varepsilon_j,$

$i = 1 \ldots m_j, j = 1 \ldots n^*.$

Assuming that the process (ε_j) is independent of the process (μ_{ij}), (11) has the structure of a random effects model (Greene 1993).

Unfortunately, K_{ij}^*, some measure of the total amount of knowledge about improved agricultural practices of each household, is not observed. Instead, only the adoption decision about improved fertilizer of each farmer is observed.

Let $F_{ij} = 1$ if the measure of knowledge exceeds a certain amount K^f and the improved fertilizer is adopted, and let $F_{ij} = 0$ if the measure is less than K^f and the improved fertilizer is not adopted:

(12) $$F_{ij} = \begin{bmatrix} 1 \; if \; K_{ij}^* > K^f \\ 0 \; if \; K_{ij}^* \le K^f \end{bmatrix}.$$

Probit estimation is often appropriate for estimating models with a such a binary dependent variable.[16] The generalized estimating equation (GEE) approach of Liang and Zeger (1986), (adjusted for possible heterogeneity with Huber-adjusted standard errors) is used here to estimate (11); it produces consistent and asymptotically normal estimates for random-effects probit models. Propositions 1 - 4 of the model predict that β_1, β_2, α_1 and α_2 in (11) will be positive.

Formal estimation of (11) requires data on fertilizer adoption (F_{ij}), human capital (H_{ij}), land holdings (L_{ij}), cumulative proportion of adopters (P_j), social capital (S_j) as well as other possible household-level ($X_{ij}{}^h$) and village- level regressors ($X_j{}^v$). Three household surveys that were recently conducted in rural Tanzania can be merged with the for a complete set of these data.

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[15] As in Pomp and Berger (1995), the variable 'cumulative proportion of adopters' is lagged in time, as follows: in period t, P_j is the proportion of adopters in village j at the end of period t-1.

[16] Logit estimation is also generally appropriate for analyzing binary response data, and under standard assumptions about the error term, there is no a priori reason to prefer probit estimation over logit estimation (Greene 1993).

First, the National Sample Census of Agriculture (NSCA) was conducted in two consecutive agricultural seasons (1993-94 and 1994-95) among two different sets of households in 540 villages. It contains detailed household information on the use of fertilizer, land holdings, human capital, and other household demographics.[17]

Second, the Human Resource Development Survey (HRDS)[18], was conducted in 1993 in another set of households in 100 of the 540 villages covered by the NSCA. In addition to collecting standard household data on family demographics and household expenditures, it contains data on household expenditures and the ethnic and religious composition of each village.

Third, the Social Capital and Poverty Survey (SCPS) conducted in 1995, was a stratified random sample of households in 87 villages across all 20 rural regions of Tanzania. In addition to collecting a limited amount of household data on family demographics, household expenditures and some agricultural practices and characteristics (but not on land holdings), this survey was designed to collect detailed information about local social structures. This was the first household-level survey which integrated the collection of household data on the causes and consequences of economic decisions (compatible with the World Bank's Living Standards Measurement Study (LSMS)) and data on local social structures.[19] To measure local social structures, the strategy of this survey was to focus on self-reported household activity in local organizations. This included social organizations as well as religious and economic groups.[20]

Which households and villages covered by the NSCA, the HRDS and the SCPS can be used to implement the model? First, since the model concerns technology adoption among farmers, the Tanzanian agro-ecological zones which rely primarily on fishing or

[17] More detailed descriptions of these data sets and the variables presented in this chapter, including information on how the variables were created, are presented in Appendix B.

[18] The licensing agreement to use these data requires the inclusion of the following statement: "These data come from a nationally representative survey of 5,000 households in Tanzania. This survey was a joint effort undertaken by the Department of Economics of the University of Dar es Salaam, the Government of Tanzania, and the World Bank, and was funded by the World Bank, the Government of Japan, and the British Overseas Development Agency."

[19] Since its implementation in 1995, there have been three other such surveys conducted in Bolivia, Burkina Faso and Indonesia (World Bank 1998).

[20] A wide range of survey questions in the SCPS was designed to gather data on many different characteristics of the social structure which could affect many different economic outcomes. Using these data, the research strategy of Narayan and Pritchett (1997) was to aggregate weighted means of many variables created from survey questions into a single 'index of social capital', and then to test whether this index was associated with indicators of well-being. While this strategy proved successful in suggesting the relative importance of elements of the social structure for changes in well-being, it does not give clear evidence as to how selected characteristics of the social structure affect specific outcomes, evidence which could generate important policy conclusions for the design and implementation of local development projects. For example, using similar survey data from rural Indonesia, Grootaert (1999) finds that membership in internally heterogeneous organizations provides benefits to individual households in terms of access to credit and pooled savings, but that the highest participation in local collective action--for example, building schools and maintaining roads--comes from members of more homogenous organizations.

herding are excluded.[21] Second, since predicted determinants of adoption include land holdings, human capital, the cumulative proportion of adopters, and social capital, the households must be chosen from the 1994-95 season of the NSCA among the 87 villages surveyed by the SCPS in 1995.[22]

When these three data sets are merged following these guidelines, this permits testing the model with all 511 households from the 1994-95 season of the NSCA located in all 40 villages from the SCPS data that are in farming zones--the central plateau, the southern and western plains, and the northern highlands.[23]

For these 511 households, means and standard deviations of the household- and village-level variables used in the analysis are presented in Table 1.[24] The dependent variable is 'fertilizer adoption', a dichotomous variable which indicates whether households report using some inorganic (chemical) fertilizer in the 1994-95 season. Twenty-two percent of the households in the sample reported that they used this technology.

[21] These are the eastern coastal zones and the central arid and semi-arid zones. Only eight households in these zones report using improved fertilizer.

[22] Notably, a small number of the SCPS households were supposed to have been chosen from households covered by the NSCA in the 1993-94 season. It would have been desirable to merge these data sets at the household level to extend the estimation of the model: for example, to test whether a household's own activities in local organizations, controlling for land endowments and other characteristics, affects adoption. Unfortunately, testing the model this way proved to be infeasible: many of the households with the same survey codes seem to have been incorrectly identified, further restricting the usable sample size (less villages and less households per village), and no data was available of previous adoption levels in the 1992-93 season.

[23] Two other villages in the northern highlands that met these criteria were eliminated from the sample because they were incompletely surveyed, with a total of only six and eight households respectively. All other villages in the sample have from 10 to 15 surveyed households.

[24] The pairwise correlations of these variables are presented in Table B4 of the appendix of Isham (1999).

Table 1: Selected Summary Statistics in Rural Tanzania				
Variable description		Data source	Summary statistics	Variable label
Dependent variable	Fertilizer adoption	NSCA (94-5)	0.22	Fij
			(0.42)	
Predicted	Years of education	NSCA (94-5)	4.53	Hij
determinants			(2.80)	
of adoption	Land	NSCA (94-5)	3.79	Lij
			(1.24)	
	Cumulative adoption	NSCA (93-4)	0.26	Pj
			(0.37)	
	Tribal affiliations	SCPS	0.23	Sj
			(0.16)	
	Leadership heterogeneity	SCPS	0.30	Sj
			(0.15)	
	Consultative norms	SCPS	0.65	Sj
			(0.21)	
Other	Female	NSCA (94-5)	0.15	Xhij
possible			(0.36)	
determinants	Age	NSCA (94-5)	46.3	Xhij
of adoption			(15.4)	
	Improved seeds	NSCA (94-5)	0.27	Xhij
			(0.44)	
	Credit availability	NSCA (93-4)	0.08	Xvj
			(0.16)	
	Extension activity	NSCA (93-4)	0.23	Xvj
			(0.28)	
	Distance from market	HRDS	1.67	Xvj
			(2.03)	
	Years in village	SCPS	18.6	Xvj
			(2.5)	
	Plateau region	All	0.58	Xvj
			(0.49)	
	Plains region	All	0.28	Xvj
			(0.45)	
	Highlands region	All	0.14	Xvj
			(0.35)	

The three independent variables that that are used to test propositions 1 to 3 of the model are: 'Years of education', the years of education of the head of the household;

‘land’, the log of hectares of cultivated land[25]; and ‘cumulative adoption’, the village share of fertilizer adopters in the 1993-94 season[26]. It is notable that 26 percent of the households surveyed in these villages in the previous season--more than in the current season--report that they used this technology. An explanation of this difference that is consistent with the model developed in the previous section (and the estimation procedure) is that the decrease in overall adoption is associated with an unobserved village-level shock: for example, annual precipitation or a price shock.

Based on the discussion in the section on the role of homogeneity, leadership heterogeneity, and decision-making norms in information sharing and the diffusion of innovations, three independent variables that are used to test propositions 4 of the model: ‘ethnic affiliations’; ‘leadership heterogeneity’ and ‘consultative norms’. ‘Ethnic affiliations’ is the village share of households which report that their local organizations include only members of the same clan (as opposed to different tribes or anyone in the village). This includes characteristics of social organizations as well as religious and economic groups.[27] ‘Leadership heterogeneity’ is the village share of households which report that their local organizations are characterized by leaders with different livelihoods than of other village members. ‘Consultative norms’ is the village share of households which report that members vote and discuss decisions within their local organizations.

The variables that are used to measure other household- and village-level characteristics that could effect the adoption decision are. ‘age’, the age of the household head; ‘age squared’ the square of the age of the household head; ‘female’, a dummy variables for female headed-households; and ‘improved seeds’, a dummy variable for households that reports using this technology. The village-level variables are: ‘credit availability’, the village-level mean of households that reported using credit in the 1993-94 season; ‘extension activity’, the village-level mean of households that reported that they were visited by an extension agent in the 1993-94 season; ‘distance from market’, the village-level median of household’s reported distance from the closest market ; and ‘years in village’, the average number of years that households have lived in the village.[28]

Finally, the implementation of the model must account for different ecological conditions (for example, soil quality and rainfall patterns) among the agroecological zones

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[25] This is the same measure of land used by Feder and Slade (1984). Using the logarithmic transformation imposes a decreasing effect of land holdings on the probability of adoption, as discussed in the robustness tests in the next section.

[26] This is the same measure of village-wide adoption used in Pomp and Berger (1995).

[27] In the job market paper with the preliminary version of the material in this dissertation (Isham 1999), only social organizations were used in creating these measures. Feedback from many seminar participants was to aggregate the characteristics of all social, religious and economic groups, in particular since religious groups play a large role in the social lives of Tanzanians. This was the same research strategy of Narayan and Pritchett (1997).

[28] The choice of including measures of these characteristics as regressors in the basic model (as well as other measures of other characteristics in the robustness checks in the next section) is based on literature reviews of the determinants of adoption (Feder, Just and Zilberman 1985, Besley and Case 1993) and recent specific research on Tanzania (Nkonya, Schroeder and Norman 1997).

in Tanzania. Fertilizer adoption was highest in the 1994-95 season in the highlands, and lowest in the plains. Additionally, from the mean of 'cumulative adoption', adoption in the 1993-94 season was significantly higher in the plains and highlands. Other differences of note are that land use is higher in the plateau, there are almost twice the amount of female headed households in the plains, the standard deviation of 'ethnic affiliations' is much higher in the plateau region, improved seeds are adopted more frequently in the highlands, and credit availability and extension activity are relatively low in the highland and plateau, respectively.[29]

Because of these differences, dummy variables for the agro-ecological zones--'plateau zone', 'plains zone', and 'highlands zone'--are also incorporated into the preliminary implementation of the model. Then the appropriateness of imposing equality--across the zones--of the coefficients on the other regressors is tested.

V. Empirical Results

This section presents the results from implementing the model with pooled data across all the agro-ecological zones and in the plateau zone. The research procedure is to first implement the model by pooling across all three zones and to test for the equality of the coefficients between the zones; to re-estimate the model within the plateau zone[30]; to present summaries of the marginal effects of changes of the independent variables; and then to test the general robustness of the main results.

A. Implementing the Model with Pooled Data

As discussed in the previous section (and shown in Appendix Table C1 of Isham (1999)), there are significant differences in the means and standard deviations of 'fertilizer adoption' and some of the independent variables in the model across the three agro-ecological zones. This raises the possibility of 'false pooling': that the model would be misspecified by pooling together households from these different zones.

This was confirmed by conducting Wald Tests (the equivalent of Chow tests in OLS estimates) of the equality of the coefficients across these zones All of these tests soundly reject the null hypothesis that these coefficients are equal. For example, even the test of equality of the coefficients on only the first four regressors between only the plateau and plains zones can be easily rejected. The χ^2 test statistic is 33.2, where the critical value for $\chi^2(95)$ with five degrees of freedom (four regressors and a constant) is 11.1.[31] This implies that it is incorrect to impose equality of the coefficients across the three agro-ecological zones.[32]

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[29] See Appendix table C1 in Isham (1999) for the means and standard deviations of the household- and village-level variables used in this analysis by each of these three agro-ecological zones.

[30] The estimation of the model with these data is then tested for robustness in the next section of this chapter.

[31] As discussed in the next sub-section, a full Wald test of the equality of all coefficients across all three zones can not be implemented.

[32] In the first draft of this paper, quality of the coefficients was imposed across all three agro-ecological zones.

Given this results, the model is estimated here with data from the plateau zone, which has the most households (297) and villages (23) of the entire sample of 511 households and 40 villages. The model can not be fully estimated in the other zones because of the use of village-level regressors and the small number of available villages (11 and 6, respectively). The advantage of estimating the model within one zone is that it allows one to test for the household- and village-level determinants of adoption among farmers who face similar agro-ecological conditions. The disadvantage is that the overall sample size is further reduced.

B. Implementing the Model with Data from the Plateau Zone

In this sub-section, the model is estimated with data from the plateau zone, and the magnitudes of changes in the independent variables are presented.

1. Implementing the Base Model

Table 2 lists the results from testing the model in the plateau zone. The three specifications (each using the third estimation method) list the full set of covariates with

Table 2: Model Implementation with Data from the Plateau Region

Years of education	-0.002	-0.006	-0.007
	(0.064)	(0.063)	(0.061)
Land	0.28 *	0.29 *	0.30 **
	(0.16)	(0.15)	(0.14)
Cumulative adoption	2.99 ***	3.10 ***	3.22 ***
	(0.38)	(0.34)	(0.40)
Tribal affiliations	1.66 *	-	-
	(0.88)		
Leadership heterogeneity	-	0.61	-
		(1.40)	
Consultative norms	-	0.00	-0.40
		0.00	(0.85)
Female	0.036	0.065	0.036
	(0.313)	(0.252)	(0.296)
Age	0.072	0.068	0.067
	(0.062)	(0.061)	(0.059)
Age squared	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)
Improved seeds	0.62 *	0.58	0.58
	(0.38)	(0.38)	(0.39)
Credit availability	0.57	0.46	0.54
	(0.67)	(0.84)	(0.71)
Extension activity	0.28	0.14	0.10
	(0.25)	(0.25)	(0.28)
Distance from market	0.12 **	0.20 ***	0.20 ***
	(0.06)	(0.05)	(0.04)
Years in village	0.20	0.13	0.14
	(0.13)	(0.12)	(0.13)

'ethnic affiliations', 'leadership heterogeneity', and 'consultative norms' for the respective tests of proposition 4.

First, in all three cases, proposition 1 can be rejected. These results do not support the conclusion, as of many studies on adoption, that human capital is a large and significant determinant of the adoption of fertilizer. (This can also be rejected, as shown in Appendix Table 3 of Isham (1999), when 'literacy', a dummy variable for the achievement of literacy in reading and writing, is used as an alternative human capital measure).

Second, in all three cases, propositions 2 and 3 can be not be rejected (using the 10 percent level of significance). Greater land holdings and high adoption patterns in the previous period are positive and significant determinants of adoption. (The same conclusions on these propositions can be reached, as shown in Appendix Tables 4 and 5 respectively of Isham (1999), when a linear term for land and dummy variables for previous adoption levels are used as an alternative measures).[33]

Third, only in the case of 'ethnic affiliations' does a measure of the local social structure seem to be a positive and significant determinant of adoption. (The p-value is 0.06.) Neither 'leadership heterogeneity' nor 'consultative norms' are positive and significant.

These specifications in Table 5, henceforth the 'base model,' capture the central positive finding of this section of the paper: that the empirical results from the implementation of the model conform to the three of the four propositions of the model. The probability of adoption of improved fertilizer is increasing in land holdings, cumulative adoption patterns, and tribally-based social affiliations.

2. The Magnitudes of Changes in the Independent Variables

What are the magnitudes of the effect of the independent variables on the probability of adoption? Table 3 presents marginal effects, evaluated at alternative points in the distribution, for each of the variables associated with propositions 1 - 4.[34] Among the last three (significant) regressors, the marginal effect of a percentage increase of land endowments (since the indicator is the log of household land) is lowest when evaluated at its minimum value (1 hectare) and increasing over the rest of the range.

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[33] As shown by the full results in Appendix Table 5 in Isham (1999), the implementation of the model with the alternative adoption variables does seem to suggest that 'credit availability' and 'extension activity' are positive and significant determinants of adoption. The sensitivity of the results to the inclusion of any independent variable representing adoption in the previous period is discussed in the next section.

[34] These are calculated as $\left.\frac{\partial \Phi(Xb)}{\partial X_i}\right|_{X_d}$, where X_i is the regressor associated with each of the propositions and X_{id} denotes that the expression is evaluated at different points of the distribution: the minimum, 25th percentile, median, mean, 7[th] percentile, and maximum. The values for method 1 (which are simpler to calculate) are used since the coefficients are virtually identical across all three estimation methods.

Table 3: Marginal Effects at Alternative Points - Regressors for Propositions 1 - 4						
Point	Minimum	25th Percentile	Median	Mean	75th Percentile	Maximum
Years of education	-0.00018	-0.00018	-0.00018	-0.00018	-0.00018	-0.00018
Land	0.017	0.055	0.068	0.067	0.080	0.099
Cumulative adoption	0.29	0.29	0.29	0.42	1.19	0.50
Tribal affiliations	0.28	0.36	0.40	0.43	0.47	0.64

'Cumulative adoption' has its highest marginal effect at the 75th percentile. This corresponds to much of the adoption literature (as summarized by Rogers 1995), which in many settings documents an 'S-shaped diffusion curve', where the influence of previous adopters is very low in the initial periods of diffusion, grows rapidly, and then tapers off.[35] The marginal effect of 'ethnic affiliations' is increasing over its range. This suggests that, in terms of the marginal probability of adoption, there is an increasing benefit to having a more homogenous social structures.

Finally, Table 7 presents calculations of the relative magnitudes of the changes in the probability of adoption associated with these effects. The first column presents the range of each of the regressors from the 25th percentile to the 75th percentile; the second column presents the mean of the marginal effects over this range. The third column, the product of these two terms, is an estimate of the change in probability of using improved fertilizer based on an exogenous change of the regressor from the 25th percentile to the 75th percentile. Measured this way, 'cumulative adoption' has the largest effect on the probability of adoption, followed by 'ethnic affiliations' and 'land'. Since the distributions of these variables are quite different (in particular, 'cumulative adoption' is bunched at its minimum and maximum), these comparisons need to be viewed with caution. They do show, however, that the change in probability of adoption associated with the social capital variable is of the same general magnitude as that of land.

[35] Note that the distribution of 'cumulative adoption' in the sample is also unbalanced: fifty-seven percent of the households are in villages where there was no adoption among households sampled in the previous period; thirty percent are in villages where there was partial adoption; and the remaining thirteen percent are in villages where there was complete adoption. Appendix Table C5 in Isham (1999) presents the implementation of the model where 'any adoption' (= 1 if 0 < 'cumulative adoption < 1) and 'complete adoption' (= 1 if 'cumulative adoption' = 1) replace 'cumulative adoption'.

Table 4: Estimated Magnitudes of Changes of Probability of Adoption				
	Range (25th to 75th percentiles)	Mean of marginal effect over range	Change of probability	
Years of education	6	0.000	-0.001	
Land	1.65	0.06767	0.112	
Cumulative adoption	0.53	0.591	0.313	
Tribal affiliations	0.3	0.410	0.123	

This section has presented the estimation procedure and the data that are used to implement the model and the basic results of the implementation. The next section attempts to verify the robustness of the central finding that the empirical results conform to the three of the four predictions of the model

3. Checking the Robustness of the Implementation of the Model

This sub-section checks for the robustness of the implementation of the model by addressing the possibilities of false pooling within the plateau zone, the endogeneity of 'cumulative adoption', and omitted variable bias. A three stage least-squares procedure is then implemented, accounting for the endogeneity of 'cumulative adoption' and the social capital variables.

a. The Consequences of Removing Selected Villages from the Sample

With 23 villages and at least five village-level variables, a set of households located in one village can easily bias the results on selected village-level variables. The results in Table 2 are very susceptible to false pooling even within the plateau zone.

To test for this form of false pooling, 23 re-estimations were conducted of each of the results in the three columns in Table 1, where one of the 23 villages is omitted in turn from the estimation. Overall, these re-estimations show that the significance levels on 'ethnic affiliations' decrease when 19 of the villages are excluded from the sample and increase when four of the villages are excluded from the sample. Based on these results (which can be confirmed by inspection of the corresponding partial scatter plot), villages 6, 8, 17 and 21 seem to have the largest influences on the magnitudes and significance levels of 'ethnic affiliations' in the full sample. Appendix Table C6 in Isham (1999) presents the re-estimation of the full model, excluding these four villages. The results are similar to those in Table 2: the probability of adoption of improved fertilizer is increasing in land holdings, cumulative adoption patterns, and tribally-based social affiliations.

b. Omitting Cumulative Adoption from the Base Model

In the implementation of the model so far, it is important to note that 'cumulative adoption', the share of adopters in the previous period, is endogenously determined.[36] If selected village-level effects have large effects on adoption, they would have increased adoption levels in the years prior to the implementation of the NSCA survey. Without household-level panel data, it is not possible to untangle the magnitudes of these village-level effects in the years prior to the implementation of the survey.

Two empirical procedures are used to test the model in light of the endogeneity of this variable. First (in this subsection), 'cumulative adoption' is just omitted from the list of regressors: this permits testing which other village-level regressors are positively associated with adoption in this year. Second (in the next section), 'cumulative adoption' is included in three-stage least squares estimation, where the set of instruments include determinants of 'cumulative adoption' which are exogenous to the structural equation.

Table 5 lists the results from testing the model in the plateau zone without 'cumulative adoption' and with 'ethnic affiliations', 'leadership heterogeneity', and 'consultative norms' respectively. In all three cases, 'improved seeds' is positively associated with adoption (using the 10 percent level of significance). 'Land' is positively associated with adoption in two of the specifications. (The p-value of 'land' in the first column is 0.15).

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[36] I thank numerous seminar participants for this observation.

Table 5: Model Implementation without Cumulative Adoption						
	Method 3		Method3		Method 3	
Years of education	0.012		0.009		0.016	
	(0.041)		(0.031)		(0.041)	
Land	0.19		0.20	*	0.26	**
	(0.13)		(0.12)		(0.12)	
Tribal affiliations	4.91	**	-		0.00	
	(2.18)				0.00	
Leadership heterogeneity	-		2.97		-	
			(1.98)			
Consultative norms	-		-		3.77	**
					(1.74)	
Female	0.03		0.02		-0.04	
	(0.22)		(0.16)		(0.22)	
Age	0.053		0.044		0.052	
	(0.035)		(0.033)		(0.033)	
Age squared	-0.001	*	-0.001		-0.001	*
	(0.000)		(0.000)		(0.000)	
Improved seeds	0.93	**	0.60	*	0.82	**
	(0.47)		(0.32)		(0.41)	
Credit availability	4.23	***	2.97	***	3.52	***
	(1.21)		(1.08)		(1.00)	
Extension activity	2.03	***	1.79	**	0.87	
	(0.70)		(0.71)		(0.65)	
Distance from market	-0.07		0.14	**	0.24	***
	(0.11)		(0.06)		(0.07)	

Among the village-level variables in Table 5, ‘ethnic affiliations’ and ‘consultative norms’ are positively and significantly associated with adoption in their respective specifications. In addition, ‘credit availability’ and ‘years in village’ are positively and significantly associated with adoption in all three specifications.

While ‘extension activity’ and ‘distance from market’ are significant in the second specification in Table 5, they alternate in significance depending on the inclusion of ‘ethnic affiliations’ and ‘consultative norms’. This important result is explained by multicollinearity. As shown in the second part of Appendix Table 2 of Isham (1999) (the correlations of all regressors within the plateau region), the pairwise correlation between ‘ethnic affiliations’ and ‘distance from market’ is 0.52; between ‘ethnic affiliations’ and ‘consultative norms’ is -0.54; between ‘consultative norms’ and ‘distance from market’ is -0.36; and between ‘consultative norms’ and ‘extension activity’ is 0.25.

It is very important to account for these pairwise correlations in the estimation process. First, as discussed above, both ‘ethnic affiliations’ and ‘consultative norms’ are measures of characteristics of social structures that are hypothesized to be positively associated with adoption. However, they are negatively correlated: more tribally-based groups tend to have less participatory decision making. In addition, each of these village-level characteristics changes with the distance from the local market (which may well affect the adoption decision through the availability of inputs): closer villagers have less tribally-based groups and have more participatory decision making. Finally, extension activity is higher in villages with more participatory decision making.

To try to identify the marginal effects of these correlated regressors, Table 6 includes both ‘ethnic affiliations’ and ‘consultative norms’ in two different specifications, which include and omit, respectively, ‘extension activity’ and ‘distance from market’. The conclusions from these specifications suggest that the two characteristics of the local social structure are positively associated with adoption, allowing for the possible effects of availability of extension services and proximity to a market.

Table 6: Model Implementation without Cumulative Adoption and with Two Social Capital Variables				
	Method 3		Method3	
Years of education	0.031		0.022	
	(0.050)		(0.044)	
Land	0.25	*	0.31	**
	(0.14)		(0.12)	
Tribal affiliations	6.46	**	5.22	***
	(2.51)		(1.07)	
Consultative norms	4.87	***	5.30	***
	(1.78)		(1.58)	
Female	0.02		-0.08	
	(0.26)		(0.23)	
Age	0.07		0.05	
	(0.04)		(0.03)	
Age squared	-0.001	*	-0.001	*
	(0.000)		(0.000)	
Improved seeds	1.022	**	0.833	*
	(0.491)		(0.448)	
Credit availability	2.76	***	2.38	***
	(0.73)		(0.73)	
Extension activity	1.42	**	-	
	(0.59)			
Distance from market	-0.07		-	
	(0.11)			
Years in village	0.50	***	0.43	***
	(0.14)		(0.10)	

These specifications in Table 6 capture the central positive finding of this section of the paper: that when 'cumulative adoption' is omitted from the base model, the probability of adoption of improved fertilizer is positively associated with land endowments, ethnic affiliations and consultative norms, the adoption of improved seeds, the availability of credit and extension services, and the average years of household.

c. Omitted Variables and Endogeneity

Two strategies are adopted in this sub-section to test for omitted variable bias and the endogeneity of the variables of interest. First, other possible determinants of adoption are added to the estimation of the base model without cumulative adoption. Second, a three stage least-squares procedure, with instruments for 'cumulative adoption', 'ethnic affiliations', and 'consultative norms', is implemented.

A set of other variables were tested as regressors in the implementation of the base model without cumulative adoption. Before re-estimating the full model, this allows one to test whether omitted variable bias (OMV) explains any of the variables that are positively and significantly associated with adoption in Table 5.[37]

The household-level variables that are tested here are: 'household size', the total number of reported household members; and 'household labor', the total number of adult farmers. The village-level variables are: 'per capita expenditure'; 'education of neighbors', the average of years of schooling of each farmer's neighbors, and 'land of neighbors' the average land holdings each farmer's neighbors; 'Gini coefficient', an index of inequality based on village-level expenditures; 'Land Gini coefficient', an index of inequality based on village-level land holdings; and 'Ethnic fractionalization', an index of the ethnic diversity in each village.[38]

Appendix Tables C6 - C13 in Isham (1999) show that the inclusion of each of these variables does not alter the conclusion that 'ethnic affiliations', 'consultative norms', 'credit availability', and years in village' are positively associated with adoption. (The same interaction between the two measures of the social structure, 'extension activity' and 'distance from market' is also present in all of these specifications.) The only included variable that is significant in any of these specifications is 'per capita expenditures', when included with 'ethnic affiliations': it also lowers the magnitude and significance level of 'improved seeds' in both specifications. This village-level regressor will be added to the re-estimation of the model in the final sub-section.

Overall, these results do not suggest that the inclusion of selected household- or village-level variables significantly alter the positive findings in Table 9.

The possibility of OMV bias is not totally eliminated by including tests of a set of other variables. In addition, as discussed above, at least one of the regressors in the full

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[37] The inclusion of these variables as potential regressors is based on reviews of the adoption literature (Feder *et al.* 1985 and Besley and Case 1993) as well as the suggestions of seminar participants.

[38] As discussed in Appendix B of Isham (1999), 'per capita expenditure', 'Gini coefficient', and 'ethnic fractionalization' are calculated for these villages from the HRDS.

model--'cumulative adoption'--is endogenously determined. Finally, 'ethnic affiliations', and 'consultative norms' may themselves be endogenous. For example, it is conceivable that early adoption by a set of neighbors could lead to more communication--and more consultations--within local organizations.

Three stage least-squares estimation is a potential solution to eliminating these possible sources of bias. The challenge is to find suitable instruments for the variables of interest.

For 'cumulative adoption,', the instruments are 'adoption in 1990', the share of households in the SCPS survey that recalled using agro-chemical fertilizer in 1990; and 'land in 1993', the village-level share of land endowments from the 1993-94 NSCA.

For 'ethnic organizations', the instruments are 'ethnic fractionalization', 'religious fractionalization', a similar variable of religious diversity, and 'land Gini coefficient'.[39]

For 'consultative norms', the instruments are 'participation', the village-level mean of participatory local organizations, 'religious fractionalization', and 'land Gini coefficient'.

These instruments explain these potentially endogenous variables quite well. The respective R-squared statistics when these instruments are included in the first stage of the estimation procedure and when they are excluded (in an OLS model) are: 0.629 and 0.456 for 'cumulative adoption'; 0.436 and 0.375 for 'ethnic affiliations'; and 0.487 and 0.216 for 'consultative norms'.

The results of the three-stage least squares procedure (and the comparable linear probability models) with all 23 villages in the plateau region, are presented in Table 7. Among the variables of interest, 'cumulative adoption' and 'ethnic affiliations' are both positive and significant determinants of adoption, while 'consultative norms' is not. This seems to support the first central finding of this dissertation: that tribally-based social affiliations are the single characteristic of the local social structure that acts as a form of social capital in the adoption decision, controlling for previous adoption patterns.

[39] La Ferrara (1998) uses the SCPS survey to show that ethnic fractionalization and income inequality are associated with more homogenous and less participatory groups.

Table 7: Model Implementation with Three-Stage Least Square				
	Linear probability		3SLS	
Years of education	0.0034		0.0045	
	(0.0057)		(0.0059)	
Land	0.023	*	0.012	
	(0.013)		(0.015)	
Cumulative adoption	0.79	***	0.80	***
	(0.06)		(0.10)	
Tribal affiliations	0.30	***	0.61	***
	(0.10)		(0.16)	
Consultative norms	0.22	*	0.31	
	(0.12)		(0.23)	
Female	-0.019		-0.030	
	(0.046)		(0.046)	
Age	0.009	*	0.010	*
	(0.005)		(0.005)	
Age squared	-0.00010	**	-0.00011	**
	(0.00005)		(0.00005)	
Improved seeds	0.050		0.049	
	(0.041)		(0.043)	
Credit availability	0.23	**	0.20	*
	(0.09)		(0.11)	
Extension activity	-0.001		0.005	
	(0.063)		(0.065)	
Distance from market	0.034	***	0.023	**
	(0.007)		(0.011)	
Years in village	0.021	***	0.026	***
	(0.007)		(0.007)	
Expenditure per capita	0.00066	*	0.00063	*
	(0.00038)		(0.00038)	

Based on the discussion in the previous section, is this result robust to sample selection bias? Appendix Table 15 in Isham (1999) presents the re-estimation of the three-stage least squares procedure (and the comparable linear probability models), excluding the same four villages which have the largest influences on the magnitudes and significance levels of 'ethnic affiliations' in the full sample. The results are similar to those in Table 7 and also support the finding that tribally-based social affiliations act as a form of social capital in the adoption decision.

To summarize, this section has tested the model of technology adoption developed in the previous section. Since Wald tests for the equality of the coefficients between the zones were easily rejected, the model was estimated within the plateau zone. The empirical results conforms to three of the four propositions of the model: the probability of adoption of improved fertilizer is increasing in land holdings, cumulative adoption patterns, and tribally-based social affiliations. When 'cumulative adoption' is omitted from the base model, the probability of adoption of improved fertilizer is positively associated with land endowments, ethnic affiliations and consultative norms, the adoption of improved seeds, the availability of credit and extension services, and the average years that households have resided in the village, and that this result was robust to the possibility of omitted variable bias. Finally, the results from the full implementation of the model were robust to the possibility of sample-selection bias and the endogeneity of previous adoption patterns and the indicators of tribally-based social affiliations.

VI: Policy Relevance

This section explores the policy conclusions that emerge from the central findings presented in this paper.

A. The Design and Effectiveness of Local Extension Programs

Since the late 1970s, the primary policy tool for sharing information about new agricultural technologies in developing countries has been the training and visit (T&V) system of extension (Birkhaeuser, Evenson and Feder 1991). This system is built around scheduled meetings between extension agents and 'contact' farmers, on the assumption that these farmers will then share the information about new technologies with other farmers in their villages. Since farmers have traditionally organized themselves into local organizations, T&V programs in Tanzania (and in most of Africa) are now organized around local organizations in order to diffuse information more rapidly.

A recent study of 676 farmers in seven Kenyan districts (with agro-ecological conditions that are similar to neighboring Tanzania) shows how information is diffused from extension agents to individual farmers through groups and informal farmer networks. While 25 percent of the sample farmers in the survey attributed their awareness of improved practices to extension workers, 39 percent attributed their awareness to neighbors and other farmers; 73 percent of the sample farmers who had received any extension advice (about one-third of all farmers in the sample) reported discussing the advice with other farmers (Bindlish and Evenson 1993). The study also found that other farmers had a larger direct role in the diffusion of simpler improved practices such as spacing and timely planting, which were adopted by 72 percent of the sample farmers; where as extension workers had a larger direct role in the diffusion of more complex technologies such as plant protection chemicals, which were adopted by 10 percent of the sample farmers. This study does not consider whether characteristics of local social structures play a role in the diffusion of such complex technologies.

Another recent study on the effectiveness of extension programs worldwide (Purcell and Anderson 1997) reached the policy conclusion that designers of extension programs need to place great emphasis on pre-project analysis and project preparation in order to identify and assess farmer circumstances, including formal and informal institutional constraints. The authors concluded that 'rapid rural appraisal techniques', which use group animation and exercises to facilitate information sharing and analysis among different villagers (World Bank 1996), are often necessary during this process to analyze the constraints of technical knowledge among the targeted farmers.[40]

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[40] Purcell and Anderson (1997) also recommend that project design include the following steps: consider the needs of all socioeconomic groups, including women in farm households, and prioritize target groups; define the scale, type and intensity of face-to-face services in particular areas according to local needs and resources and the capacity of local groups; develop a needs-based staff training program that focuses not only on technology but also on interacting with farmer groups in order to maximize their participation in problem definition and their support of the extension process; and incorporate traditional mass media and modern information technology as appropriate.

B. Policy Implications for Local Extension Programs

In light of these results on the design and effectiveness of local extension programs, what are the policy implications of the research presented in this dissertation for extension programs in Tanzania--and in the rest of Africa? First, extension services do play a role in the diffusion of fertilizer adoption. As discussed in Chapter IV, the probability of adoption of improved fertilizer is positively associated with extension services, among other village-level variables, when 'cumulative adoption' is omitted from the econometric model. Villages with more extension activity do have higher levels of adoption. Given the public good nature of information about improved agricultural technologies (Birkhaeuser *et al.* 1991), this justifies public support of extension services.

Second, previous adoption patterns are a critical determinant of adoption. As discussed in the previous section, households are more likely to adopt fertilizer if they live in villages with many other adopters. As documented elsewhere (Besley and Case 1994; Foster and Rosenzweig 1995; and Pomp and Berger 1995), previous adoption patterns yield positive externalities for household-level agricultural production. This justifies the specific use of T&V extension systems: farmers in Tanzania do seem to share information about new technologies with other farmers in their villages.

Finally, as suggested in the discussion of the implications of the theoretical model, the empirical results in this paper provide evidence that levels of social capital also yield positive externalities for household-level agricultural production. Specifically, controlling for other household- and village-level characteristics, households are more likely to adopt fertilizer if they live in villages with tribally-based social affiliations. As shown in Tables 3 and 4, the change in probability of adoption associated with this social capital variable is of the same general magnitude as that of land. These results suggest, in agreement with much research in rural sociology (Rogers 1995), that villages with tribally-based social affiliations are more likely to diffuse new information successfully.[41]

Building on the policy conclusions of Purcell and Anderson (1997), these results provide an economic justification, during the design of extension programs, for investments in 'social assessments' in order to analyze characteristics of local social structures. Social assessments are "systematic investigations of the social processes and factors that affect development impact and results"(World Bank 1996). Since the early 1990s, they have been used in a wide range of development initiatives to identify key local stakeholders; to assure that social differences are taken into account in the design of development projects; and to assure that social differences do not limit service delivery (McPhail and Jacobs 1995a). Social assessments are relatively inexpensive: the average cost of social assessments in 42 reviewed development projects was less than $100,000 (McPhail and Jacobs 1995b).

Accordingly, using social assessment in the design of extension programs in Africa (which averaged $28 million at the World Bank) is likely to be a cost-effective way to identify villages within a target region that are tribally homogenous or tribally diverse. Social assessments by government officials, representatives of NGOs, and staff of donor

[41] Easterly and Levine (1997) present more general evidence that ethnic fractionalization is associated with poor development outcomes.

agencies may also help to identify how other characteristics of villages impede the flow of information among different sets of households. For example, in villages with high levels of inequality and norms that discourage social contacts between the rich and the poor, these norms would hinder the flow of public information about agricultural practices from the rich to the poor. Overall, this information can provide information on which villages will, *ceteris paribus*, have higher expected returns to group-based extension programs.

However, such information does not provide a *prima facie* justification to avoid investing in extension programs in communities with high ethnic fragmentation. Many poor communities with the most urgent need for improved agricultural techniques may be ethnically diverse. This is particularly true in Tanzania, where (as discussed in Section II), government policy has played a large role in shaping local social structures.

Thus, if national policy dictates that investments in extension should be targeted to the poorest villages, the allocation of investment resources for extension programs may need to be adjusted to take into account the characteristics of local social structures. Possible adjustments include investments in the strengthening of local organizations (for example, through direct training about new agricultural techniques); and in more direct follow-up with individual farmers to counteract likely patchwork patterns of adoption in ethnically diverse areas.

Like all potential investments within a development project, the expected costs and benefits of such investments should be compared to the expected costs and benefits of others: for example, in project infrastructure.[42] At least, conducting social assessments can provide development practitioners with more complete information to guide their potential investments in extension programs.

[42] For an extension of these points, see Isham (2000).

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