CHAPTER 5

CONCEPTUAL FRAMEWORK: CHOICE OF A CROP MANAGEMENT TECHNOLOGY IN AN AGRICULTURAL HOUSEHOLD MODEL WITH SOCIAL CAPITAL

This chapter presents a theoretical framework for analysing the choice of a crop management technology by semi-subsistence households. The choice of crop management technology is analysed within an agricultural household framework that integrates production and consumption decisions to address the problem of missing or incomplete markets[1], a common feature in developing economies (Singh et al., 1986; Sadoulet and de Janvry, 1995; de Janvry et al., 1991). In these economies, markets may fail due to a variety of transaction costs, including high transportation costs, the opportunity cost of time involved in selling and buying, and risk associated with uncertain prices and the uncertain biophysical environment (de Janvry et al., 1991; Sadoulet and de Janvry, 1995). In the present study, market failures are assumed to be associated with transaction costs such as high transportation costs in the output markets (Mugisha and Ngambeki; 1994) and incomplete or missing input markets.

In Uganda, across much of the producing region, semi-subsistence households growing bananas have uneven access to markets. Some households participate as sellers, some as buyers only, and nearly a quarter do not participate at all (Edmeades et al., forthcoming). There is also minimal or no participation in the input markets (i.e. labour and organic fertilizers) for banana production, implying that the prices of these inputs are endogenous to the household (determined within the household) (de Janvry et al., 1991). Because virtual prices are determined by equating supply with demand, they depend on all factors that influence household decision making. As a consequence, production and consumption decisions cannot be separated (Strauss, 1986).

When some prices (whether in the output or input markets) faced by the household are endogenous, the profit maximization approach becomes inappropriate for analysing production decisions. Institutional weaknesses in developing economies contribute

[1] A market fails when the cost of a transaction through market exchange creates more disutility than the utility gain that it produces, such that no market transactions occur. Market failure is household-specific (de Janvry et al., 1991).

towards rendering information about new technologies imperfect, adding another source of non-separability of production and consumption to household decision making. Many of the theoretical approaches developed to predict seed and fertilizer adoption during the green revolution were based on profit maximization in the context of risk aversion. In the present study a utility maximization framework induced by market imperfections is assumed to be the objective underlying the household choice of a crop management technology.

Agricultural household framework, induced by market imperfections, has previously been applied to analyse the production behaviour of semi-subsistence households (e.g Edmeades, 2003). The novel insight in the present analysis is the extension of the basic agricultural household model to explicitly incorporate social capital in the modelling framework. Social capital may facilitate access to information about technologies (Isham, 2000; Narayan, 1997; Collliers, 1998) and others resources in form of bilateral transfers that could expand the household resource endowments, which, in turn, may influence production behaviour.

The improved banana production management technology consists of a package of several techniques for managing soil fertility, pest and disease constraints. The soil fertility management techniques include mulching and manure application. The pest and disease management techniques include corm paring, de-suckering, stumping and pseudo-stem management. More details on these techniques are given in Chapter 2. Although it is possible to implement the subcomponents individually, the full benefits of using the improved banana production management technology are achieved when all components are applied simultaneously. The implication of this is that when the subcomponents are many, the technology becomes complex and knowledge-intensive. Farmers may prefer to adopt the components sequentially so as to gain knowledge and/or accumulate capital that will enable them to adopt the whole package in the long run. Formal credit components could be incorporated in the technological package to reduce the expenditure constraint (see Chapter 3 for the review of the adoption literature). However, since participation in the formal credit market by rural households in Uganda is low (Edmeades et al., forthcoming), no attempt is made to model the role of formal credit markets in the choice of management practices by banana farmers.

As stated earlier, unlike the green revolution type technologies, the improved banana production management technology is farmer-made. This means that the management technology is not only knowledge-intensive but is also intensive in the use of local resources such as labour and land. Since banana farmers face some market constraints, informal mechanisms can serve as one of the means of overcoming market constraints. In the present study, the modelling approach emphasizes the mechanisms that allow the incorporation of social capital into the analysis of crop management technology.

Modelling the choice of crop management practices follows a number of steps. The goal is to analyse the effect of market constraints that exclude some households from participation and incorporate social capital into the modelling of crop management decisions. The present work diverges from the previous work related to the role of social capital in technology adoption (e.g Isham, 2000) in two significant ways. First, the optimal adoption decisions in the present analysis are derived from the agricultural household framework. This provides a basis for analysing the effect of market constraints on adoption decisions and the role of social capital in overcoming these constraints. Second, the modelling approach offers two explicit mechanisms (information and bilateral transfers) through which social capital may influence technology adoption.

The static risk-free model with stochastic production and incomplete markets is used to examine the effect of market constraints and illustrate how social capital may influence the production behaviour of agricultural households. The model also analyses the choice of a crop management technology under complete market conditions for the purposes of comparison. Next, uncertainty about the relevance of the technology is introduced to analyse the role of farmers' beliefs about the effects of the existing state of nature on biotic factors in technology adaptation.

5.1. Choice of a crop management technology under incomplete markets

In Uganda bananas are typically produced using family labour and organic fertilizers (used as mulch and manure). Organic fertilizers are mainly produced on the farm as by-products of other farm activities and there is virtually no market for the selling or purchasing of these inputs[2]. Consequently there is no market price for organic fertilizers. Similarly, reliance on family labour in production implies that leisure is valued by its marginal worth to the household rather than as an opportunity cost derived from a market wage rate. Because of this, production and consumption decisions are taken simultaneously (de Janvry et al., 1991), implying that production behaviour cannot be analysed without analysing the consumption side of the model. This section presents each side of the model in turn.

Based on Singh et al's (1986) formulation of the basic agricultural household model, the household derives utility from the consumption of bananas (x^B), other goods (x^G), and home time (h). For the sake of simplicity, it is assumed that other goods are purchased from the market and that home time is simply the time not spent on the production of household income. The household maximizes utility from the consumption of bananas, other goods and home time conditioned by a set of household characteristics (Ω_{HH}).

$$\max_{\psi} u\left[x^B, x^G, h \mid \Omega_{HH}\right] \tag{1}$$

Included in the vector of the household characteristics are factors that influence the marginal utilities of the consumption items and hence reflect the consumption preferences of the household.

On the production side, the household engages in banana production mainly for home consumption but a surplus may be sold on the market. Variable inputs, mainly labour (L) and organic fertilizers (F), are used to produce banana output (Q^B) on land pre-allocated to the crop ($\overline{A}$) for given farm characteristics (Ω_F) and the stock of knowledge (K). Banana output is assumed to be strictly increasing in variable inputs but at a decreasing rate for a given piece of land allocated to banana production ($\overline{A}$), a vector of exogenous farm characteristics (Ω_F) and the stock of knowledge (K_t).

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2 Household demand for this type of input is conditional on its own supply.

Bananas can be produced using two alternative management technologies: the improved management technology (f^I) and the traditional management technology (f^T). The improved management technology utilizes labour (L) to implement agronomic practices and techniques for maintaining high sanitation of the banana mat[3] and two types of external organic fertilizers (fertilizers in the form of mulch and manure application), as expressed in the vector (F). Use of the improved management technology increases the productivity of the land allocated to banana, which increases the amount of bananas available for household consumption and the surplus for sale. The yield effects of the improved technology are significantly superior to those of the traditional technology. The improved technology requires additional resources in the form of labour or cash income to hire labour. The farmer incurs some variable costs (in terms of time or money for hiring labour) in the gathering, transportation and application of the organic fertilizers. Banana output under the improved management technology (f^I) may be specified as follows:

$$q^I = f^I(A^I, L, F \mid \Omega_F, K_t) \qquad (2)$$

Following the model of Isham (2000) and Feder and Slade (1984), it is assumed that the stock of knowledge (K_t) evolves as a function of experience over years with the technology (τ), a set of diffusion parameters ($\mathbf{\Omega}_D$) and different forms of social capital (Ω_{SS}). Diffusion parameters include cumulative contact with the extension educators and the level of diffusion of the technology within the community. Some of the forms of social capital that are likely to influence information acquisition and hence knowledge accumulation are discussed in Chapter 3. The stock of knowledge can be expressed as: $K_t = k(\tau, \Omega_D, \Omega_{SS})$. Substituting for K_t in equation (2), and rewriting equation (2) gives:

$$q^I = \left(A^I, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})\right) \qquad (3)$$

[3] A banana mat is a collection of plants that are propagated from the same underground stem, which is commonly described by farmers as plants living as one family with a mother, a daughter and granddaughter.

The traditional management technology uses only labour (L) and land allocated to banana to produce banana output for a given set of farm characteristics (Ω_F). It is assumed that banana output under the traditional technology does not depend on the knowledge stock, since the technology has been available to the communities for many years and all farmers are assumed to have full information about it. Banana output under the traditional management technology is given by the following production function:

$$q^T = f^T\left(A^T, L \mid \Omega_F\right) \tag{4}$$

The two technologies compete for land allocated to banana production ($A^I + A^T = \bar{A}$). The household can choose to manage all its bananas with the improved management technology or with the traditional management technology. The household also has the option to allocate part of the banana area to the improved management technology and the remainder of the banana area to the traditional technology. The share of the banana area the farmer allocates to the improved management technology is represented by (δ) and ranges from 0 to 1. It is equal to 0 when no banana area is allocated to the improved technology (i.e. $A^I = 0$) and equals 1 when the entire banana area is allocated to the improved management technology (i.e. $A^I = \bar{A}$). Given a binding land constraint ($\bar{A}$), the total banana output obtained by the farmer is given by:

$$Q^B = f^I(A^I, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) + f^T(\bar{A} - A^I, L \mid \Omega_F) + \varepsilon_i \tag{5}$$

ε_i is a random variable assumed to be normally distributed with the mean at zero and constant variance. The inclusion of the random variable depicts the idea that banana production in any specific period is subject to variations associated with uncertain weather conditions. The specification of the stochastic structure adopted in equation (5) assumes that farmers are risk-neutral with respect to the banana management technologies but face exogenous risk factors associated with the uncertainty of weather conditions. Therefore the choice of the management technology is based on expected output. If we assume that the total banana area is equal to one ($\overline{A} = 1$), then $A^I = \delta$ and equation (5) can be rewritten as:

$$Q^B = f^I(\delta, L, F \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) + f^T(1-\delta, L \mid \Omega_F) + \varepsilon_i \qquad (6)$$

The household faces a number of constraints. The household has an initial endowment of income. In contrast to the standard consumer model assumed under perfect market conditions, in the presence of incomplete markets the income of the household is endogenous at the time of making decisions. The only income the household has at the time of making decisions is in the form of exogenous cash endowments (E). The formulation of the exogenous income in this model departs in some ways from the more typical formulation of the exogenous income in the literature. Here, the household's exogenous income (E) comes in the form of net transfers from private assets (I) or bilateral transfers from social networks (Ω_{SS}). The household may also receive income in the form of bilateral transfers such as gifts, free labour, remittances or informal credit from its social network of friends, relatives or membership in credit associations. This implies that controlling for the exogenous income from private assets, a representative farmer with social capital that can generate significant bilateral transfers will be able to overcome expenditure constraints and adopt a new technology. As discussed in Chapter 1, this possibility has not specifically been considered in the economic modelling of technology adoption. Under this extended set-up, the exogenous income can be expressed as a function of transfers from private assets (I) and social capital (Ω_{SS}) as: $E = e(I, \Omega_{SS})$.

The full income constraint is formulated as the market value of the marketed surplus $P^B(Q^B - x^B)$ plus exogenous income ($e(I, \Omega_{SS})$) and excludes the time endowment because its opportunity cost is endogenous. The household income is spent on purchasing other goods (x^G) consumed by the household at market prices (P^G).

$$P_i(Q^B - x^B) + e(I, \Omega_{SS}) - P^G x^G = 0 \qquad (7)$$

Both input and output markets for bananas are often incomplete or not readily available in rural areas. Market constraints on household production can be expressed as a function of exogenous characteristics (Ω_M) such as farm and market characteristics. The specific farm and market characteristics influence the magnitude of the transaction costs involved in market exchange and, through the shadow price, the household's choices. The fixed supply of organic fertilizer highlights the missing markets for these inputs and also defines the linkage between the choice of banana management technology and other farm activities, farm resources and household characteristics. The household cannot demand more fertilizer than it can supply from its own sources: $F^{DD} \leq F^{SS}$. This inequality reflects the fact that supply is fixed at the time of making decisions and that demand depends on supply[4]. Since organic fertilizers are produced as by-products of other activities on the farm, their supply depends on whether those activities are undertaken. Factors such as landholding and labour that influence those activities (i.e. the cultivation of annual crops) and/or livestock capital endowments will influence the costs of organic fertilizers to the household and, as a consequence, the choice of management techniques.

Imperfections in the labour market depicted by an explicit lack of wage labour imply that household participation in the labour market is conditional on the magnitude of the transaction costs involved. Some households may participate and others may not. Each household has an initial endowment of time it can allocate between banana production and leisure $T = L + h$. The production technology is a physical relationship defining the set of inputs used in banana production and generated output as specified in equation (6).

In summary, the household's maximization problem can be expressed as follows:

$$\max_{\psi} u\left[x^B, x^G, h \mid \Omega_{HH}\right]$$

$$\psi = (x^B, x^G, h, L, F, \delta)$$

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[4] Although organic fertilizers are produced as by-products of other farm activities, at the time of making the choice of the preferred banana management technology, the supply of organic fertilizers is fixed.

Subject to:

Full income constraint: $P^{B}(Q^{B}-x^{B})+e(I,\Omega_{SS})-P^{G}x^{G}=0$

Time constraint: $T=L+h$

Production technology: $G\left[f^{I}(\delta,F,L\,|\,\Omega_{F}k(\tau,\Omega_{D},\Omega_{SS})+f^{T}((1-\delta),L\,|\,\Omega_{F})+\varepsilon_{i}\right]$

Non-tradable constraint: $F^{SS}\geq F^{DD}$

Non-negativity restriction: $F\;,\delta,L\geq 0$

The first-order necessary conditions are derived based on the assumption that an interior solution will hold for some choices but not for others (corner solutions). For example, it is assumed that every household will consume bananas, other goods and leisure time, and hence an interior solution is expected on the consumption side. However, the utility derived from the use of the management technology may vary among households and the corner solution is possible for some households. Kuhn-Tucker conditions are used to derive optimal choices of crop management technology.

First-order condition

x^{B}: $$\frac{\partial U(.)}{\partial x^{B}}-oP^{B}=0 \tag{8}$$

x^{G}: $$\frac{\partial U(.)}{\partial x^{G}}-oP^{G}=0 \tag{9}$$

h: $$\frac{\partial U(.)}{\partial h}-\vartheta=0 \tag{10}$$

L: $$\varphi\frac{\partial G(.)}{\partial L}-\vartheta=0 \tag{11}$$

F: $$\varphi\frac{\partial G(.)}{\partial f^{I}}\frac{\partial f^{I}}{\partial F}-\iota\leq 0\,; \qquad F\geq 0 \tag{12}$$

δ: $$\varphi\left(\frac{\partial G(.)}{\partial f^{I}}\frac{\partial f^{I}}{\partial \delta}-\frac{\partial G(.)}{\partial f^{T}}\frac{\partial f^{T}}{\partial \delta}\right)\leq 0\,;\; \delta\geq 0 \tag{13}$$

o: $$P_{i}(Q^{B}-x^{B})+e(I,\Omega_{SS})-P^{G}x^{G}=0 \tag{14}$$

ϑ: $$T=L+h \tag{15}$$

ι: $$F^{SS}\geq F^{DD} \tag{16}$$

$$\varphi: \qquad G\left[f^{I}(\delta, F \mid \Omega_F k(\tau, \Omega_D, \Omega_{SS}) + f^{T}(1-\delta,); L \mid \Omega_F\right] \tag{17}$$

$o, \vartheta, \iota, \varphi$ are respective multipliers for the full income constraints, the time constraint, and non-tradable and production technology. Equations 10 and 11 reveal a possible solution regarding the choice of labour allocation by the household. Dividing equation (11) by equation (10) gives the marginal rate of substitution between work and leisure:

$$MRS_{L,h} = \frac{\partial G(.)}{\partial L} \Big/ \frac{\partial U(.)}{\partial h} = \frac{1}{\varphi} = w^{*} \tag{18}$$

The household equates the rate of technical substitution of labour used in banana production for leisure (given as a ratio of the physical marginal productivity of labour to the marginal utility of leisure) with the marginal valuation of labour, $(\frac{1}{\varphi})$ which is equal to the shadow price (w^{*}) of labour. The shadow price of labour depends on all the exogenous variables in the utility function as well as on production technology, the market wage rate (w) for unskilled labour and other market characteristics (Ω_M) that motivate the household to be self-sufficient in its labour supply. The shadow price is the opportunity cost of leisure forgone by transferring time to banana production and can be expressed as a function of market characteristics (Ω_M); household consumption characteristics (Ω_{HH}) that influence the marginal utility of leisure; the knowledge stock ($k(\tau, \Omega_D, \Omega_{SS})$; exogenous income ($e(I, \Omega_{ss})$); and farm characteristics (Ω_F) as follows:

$$w^{*} = w(w, \Omega_M, \Omega_{HH}, k(\tau, \Omega_D, \Omega_{SS}); e(I, \Omega_{SS}); \Omega_F) \tag{19}$$

The solution of the optimisation problem expressed in equations (12) and (13) consists of two related decisions: the decision regarding whether or not to use improved management technology and the decision regarding land allocation to the improved management technology, given that the optimal solution in equation (12) holds with equality. When the optimal solution in equation (12) holds with equality, then the input (F) will be used and the household will equate the marginal valuation of the input to production to its shadow price. However, if the optimal solution holds with inequality, the first order condition can also be expressed as follows:

$$\frac{\partial G(.)}{\partial f^I}\frac{\partial f^I}{\partial F} < \frac{\iota}{\varphi} = P^* \; ; \qquad F = 0 \tag{20}$$

In other words, the household will be unwilling to use the input (F) if its shadow price is greater than its marginal valuation (in terms of its marginal physical productivity). In this case, the observed demand of the input (F) will be censored at zero. The shadow price of the input (F) depends on the market characteristics that constrain transactions, household characteristics, farm characteristics that determine the supply and productivity of the input, knowledge parameters and all other factors that influence the productivity of the input in banana production.

$$P^* = F(\Omega_M, \Omega_{HH}, k(\tau, \Omega_D, \Omega_{SS}); e(I, \Omega_{SS}); \Omega_F) \tag{21}$$

The optimal solution in equation (13) is conditional on the optimal solution in equation (12), thus revealing the simultaneity of the two decisions. The optimal solution in (13) holds with inequality when the optimal solution in equation (12) also holds with inequality and no land is devoted to the improved management technology, implying that the expected gain from banana production when all land is used according to the traditional management technology exceeds the expected gain when some improved management technology is applied.

$$E\left((P^B f^T\right) > E\left(P^B f^I + P^B f^T) - P^* F\right) \tag{22}$$

Note that the shadow price "P^*" of the input (F) is now a parameter determined in the first adoption decision (discrete choice). It defines the linkage between the land share allocation to the improved management technology and the market characteristics. The price of banana (P^B) may be exogenous for households that participate in the market and endogenous for households that do not participate in the market, further linking the optimal utilization of land under the improved crop management technology to market characteristics and household consumption preferences.

When the improved management technology is applied, the conditions in (12) and (13) hold with equality and the optimal land share allocated to the improved management technology is determined by equating the marginal net benefit in both management technologies.

$$E\left(P^{B}(f^{I}-f^{T})-P^{*}\right)=0 \qquad (23)$$

Based on the first-order conditions, the following demand equations can be derived for the improved input (F) and land share allocation (δ) to the improved management technology:

$$F^{*}=F(P^{*},P^{B},w^{*}\,|\,\Omega_{F},k(\tau,\Omega_{D},\Omega_{SS}))$$
$$\delta^{*}\,|\,F>0=A(P^{*},P^{B},w^{*}\,|\,\Omega_{F},k(\tau,\Omega_{D},\Omega_{SS})) \qquad (24)$$

Substituting for the endogenous prices expressed in equations (19) and (21) gives the optimal decision as to whether or not to use the improved organic fertilizers and the conditional demand for the improved banana management technology (expressed as the land share allocated to the technology) reduced form. Demand for sanitation practices can be derived in a similar way.

$$F^{*}=F(,P^{B},w,\Omega_{HH},\Omega_{M},\Omega_{F},e(I,\Omega_{SS});k(\tau,\Omega_{D},\Omega_{SS}))$$
$$\delta^{*}\,|\,F>0=F(,P^{B},w,\Omega_{HH},\Omega_{M},\Omega_{F},e(I,\Omega_{SS});k(\tau,\Omega_{D},\Omega_{SS})) \qquad (25)$$

5.2. Choice of a crop management technology when markets are complete

In this section the model assumes complete markets for inputs and outputs. The purpose of reviewing this special case is to illustrate the biases that would occur in estimating crop management behaviour using profit maximization if producers were constrained by market imperfections.

The assumption of perfect market conditions implies that the markets for all goods exist, that all factor markets are functional and that they involve no transaction costs, risk or uncertainty that could potentially constrain market exchange. All prices, including that of banana (P^B), organic fertilizers (P^F) and the wage rate for labour (w), are exogenous to the household. The household does not have to worry about consumption when making production decisions since the household can now sell what it produces and purchase all it requires from the market at a price equal to the sale price if it produced the goods. The household production behaviour is modelled on that of a firm. The household makes production decisions to maximize revenue.

Since profit is the only income that results from household production choices, maximizing household revenue is equivalent to maximizing profits. The household problem is solved sequentially. Production decisions are taken to maximize profits and the profits earned are used to finance the household consumption demand. The household chooses a production management technology to maximize profits from banana subject to the land allocation constraint. Since profits depend on the banana output, factors such as farm characteristics and the knowledge stock, which influence the productivity of the land allocated to banana, indirectly influence the profitability of bananas. This means that social capital, through its influence on knowledge accumulation, still plays a role in production decisions even when markets for inputs and outputs are perfect.

$$\max \pi(P^B, P^F, w, Q^B \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}) = P^B Q^B - C(P^F, w, Q^B \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS})$$

Subject to

Land allocation constraint: $A^I \leq \overline{A} \quad \Rightarrow \delta \leq 1$

The demand for the improved management technology, expressed in the form of the demand for organic fertilizers and labour, can be derived from the maximization of the above constrained profit function. The following reduced form equations result:

Supply function for bananas: $Q^* = Q(P^B, P^F, w \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}))$

Demand for organic fertilizers: $F^* = F(P^B, P^F, w \mid \Omega_F, k(\tau, \Omega_D, \Omega_{SS}))$

Area share: $\delta^{*} = \delta(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS})$

Demand for labour: $L^{*} = L(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS}))$

Maximum profits $\pi^{*} = \pi(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS}))$

On the consumption side, the household maximizes utility specified in equation (1) subject to the budget constraint, which is the sum of the earned profits (π) and the exogenous income (E).

Utility function: $\max_{\psi} u\left[x^{B}, x^{G}, h \mid \Omega_{HH}\right]$

Subject to:

Full income constraint: $\pi^{*} + wT$

Time constraint: $T = L + h$

The maximization solution yields reduced demand equations for banana, other goods and home time. In the special case of perfect markets, the demand for improved management technology given by: $\delta^{*} = \delta(P^{B}, P^{F}, w \mid \Omega_{F}, k(\tau, \Omega_{D}, \Omega_{SS})$, is nested in the general agricultural household model, the difference being that, since all prices are exogenous, household consumption/worker characteristics are irrelevant in the technology demand equations. However, if these household characteristics are significant, then the use of a profit maximization approach as a framework for analysing adoption behaviour results in an omitted variable bias.

Adoption of the improved banana production management technology will depend on how the market prices of the organic fertilizers affect the profitability of banana production under the improved management technology. Since yield effects are superior under the improved management technology compared to the traditional management technology, a profit-maximizing producer would be expected to allocate all land to the improved management technology if it is profitable to do so or to the traditional management technology if traditional banana production is more profitable. Note that risk neutrality is assumed here. The case of partial adoption does not apply. However, this is not the case observed among banana producers, suggesting that profit maximization may not be the underlying objective of the observed adoption behaviour.

5.3. Choice of a crop management technology under technology relevance uncertainty

The role of uncertainty in technology adoption is well documented in the literature (Feder et al., 1985; Feder and Umali, 1993). There are various sources of uncertainty that can affect the adoption of new technologies, some of which concern the performance of the technology itself, such as yields (output) or price. Potential adopters may also be uncertain about the relevance or fit of the technology in their circumstances. Unlike performance uncertainty, where the decision maker does not know the production function of the new technology with certainty, under relevance uncertainty the decision maker knows with certainty that the new technology is superior to the old technology but does not know with certainty whether the technology is relevant to his/her circumstances. In other words, the uncertainty originates from variability in the state of nature rather than the production function of the technology. The present study focuses on the uncertainty about the relevance of the technology.

Assume that there are two states of nature, namely the occurrence of risk and non-occurrence. Also assume that this type of risk in banana production originates from the biotic and/or abiotic factors, including soil fertility deterioration, pests and diseases, which cause significant yield loss (Gold et al., 1999). Other sources of risk, such as weather variability and price variability, are assumed to be absent for the sake of simplicity and easy exposition[5]. Therefore it is assumed that when pests and diseases are absent and soils are good, banana yields are certain.

Denote as θ_1 the state of nature characterized by biotic and abiotic factors (absence of pests, diseases and soil fertility problems) and θ_2 the state of nature free of these biotic and abiotic factors. The farmer is uncertain about the occurrence of each state

[5] Even if the assumption of uncertainty as to the weather conditions is maintained as specified in section 5.2, it will not affect the results, since it has been assumed to affect banana output under both technologies equally.

of nature but has a belief (η) that the state of nature (θ_1) will prevail and $(1-\eta)$ belief that the state of nature will be θ_2 instead. The farmer's belief is based on his experience regarding the occurrence of each state of nature. If the farmer has no experience regarding the occurrence of these biotic/abiotic factors, he is certain that the state of nature will be θ_2.

Suppose that there are two management technologies for producing banana, namely the improved and the traditional management technologies. The two management technologies are as defined in section 5.1. The farmer is certain that the improved management technology (f^I) is superior to the traditional management technology (f^T) when the state of nature is θ_1. In other words, conditional on the occurrence of biotic factors, banana yields are higher under the improved management technology than under the traditional management technology. That is $(f^I - f^T) > 0 \mid \theta_1$; but the yield gain from the improved management technology is indeterminate under the state of nature (θ_2). The yield gains can be zero, given the fixed genetic yield potential of the crop. The expected net benefit from using the improved management technology is given by:

$$E(b) = P^B(\eta(f^I - f^T) + (1-\eta)(f^I - f^T) - M^*\delta \qquad (26)$$

where "b" represents the net benefit from the improved management technology and "M^*" is the vector of the shadow prices of the inputs (representing labour and organic fertilizers) used to implement the improved management technology. If we assume that there is a one-to-one correspondence between land allocated to the improved management technology and the amount of the improved input used, then "M^*" can also be interpreted as the per acre cost of the improved management technology. Suppose that the yield gain from the improved management technology in the absence of biotic and abiotic factors is zero[6] such that $(f^I - f^T) = 0 \mid \theta_2$; then the net benefit from the improved management technology may be expressed as:

[6] This assumption is considered realistic since the improved technology was recommended as mitigating the effects of the biotic and abiotic factors, and taking into account the fixed factor associated with the yield potential of the crop.

$$E(b) = P^{B}\eta(f^{I} - f^{T}) - M^{*}\delta \qquad (27)$$

The farmer's problem is to maximize the net benefit from the improved management technology. The farmer's maximization problem under this type of uncertainty is analysed in terms of the agricultural household framework. Hence the assumption of incomplete markets is maintained. The consumption and production structures are as specified for the case of incomplete markets under certainty, but the difference here is that under relevance uncertainty, stochastic production is not independent of technology. The problem facing the farmer is to choose the amount of the improved inputs, i.e. implicitly the land share allocated to the improved management technology, so as to maximize the expected net benefit of improved management technology.

A Kuhn-Tucker formulation of the maximization is used to derive the optimal decision to allocate a proportion of banana area to the improved management technology:

$$\delta^{*}: \qquad P^{B}\eta\frac{\partial E(b)}{\partial f^{I}}\frac{\partial f^{I}}{\partial \delta} - M^{*} \leq 0 \qquad \Rightarrow \qquad P^{B}\frac{\partial E(b)}{\partial f^{I}}\frac{\partial f^{I}}{\partial \delta} \geq \frac{M^{*}}{\eta} \qquad (28)$$

The optimal solution in equation (28) shows that for the improved management technology to be adopted under uncertain conditions with respect to the technology relevance to the farmer's local conditions, the expected benefit from the technology should be greater than or equal to its cost, weighted by the probability that biotic and /or abiotic factors (pests/diseases and soil fertility decline), are present.

The farmer's belief about the occurrence of the biotic/abiotic factors depends on the biotic and abiotic risk (Ω_R) in the community, household characteristics (Ω_{HH}), farm characteristics (Ω_F) and the stock of knowledge [$k(.)$], as follows:

$$\eta = \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS}) . \qquad (29)$$

From the optimal solution it can be seen that the decision and extent of adoption are a function of the exogenous factors expressed in equation (25) and the farmer's beliefs about the state of nature expressed in equation (29). Incorporating the farmer's belief in the adoption reduced-form equations yields the following reduced equations for the demand for the improved management technology in terms of discrete and continuous adoption decisions under incomplete markets with uncertainty.

$$F^* = F(P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS}); \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS}))$$

$$\delta^* | F^* > 0 = \delta(P^B, w, \Omega_{HH}, \Omega_M, \Omega_F, e(I, \Omega_{SS}); k(\tau, \Omega_D, \Omega_{SS}); \eta(\Omega_{HH}, \Omega_F, \Omega_R; k(\tau, \Omega_D, \Omega_{SS})) \qquad (30)$$

5.4. A summary of the household choice of a crop management technology

The foregoing sections presented a mathematical model illustrating the main factors that motivate households to use banana production management practices. In this section, the model is simplified into a schematic diagram to make it attractive to readers less interested in mathematical models. The adoption and use of banana management practices is conceptualised as the decision-making process portrayed in Figure 4.

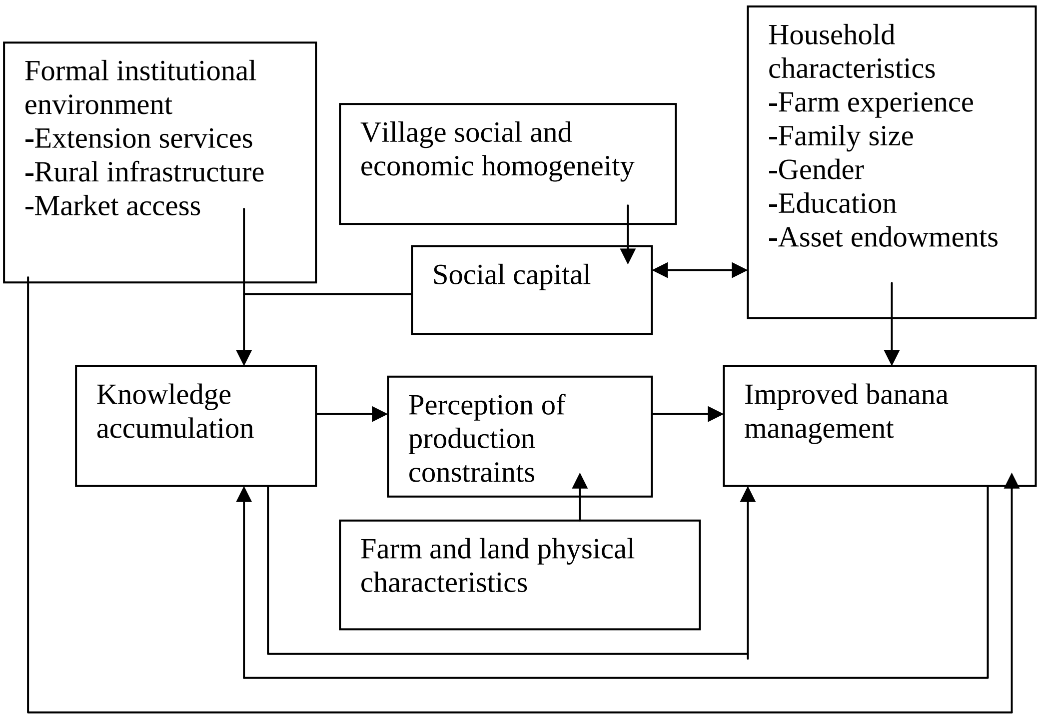

Figure 4. A socio-economic model of the decision-making process for the use of improved banana management practices

The model illustrates that the decision-making process regarding the use of banana management practices has three components: knowledge accumulation, perception formation and the use of banana management practices.

Perceptions may result from physical changes in the environment and/or information accumulation that creates awareness. On the other hand, knowledge accumulation depends on household characteristics and formal and informal information diffusion parameters. Formal diffusion mechanisms include extension and other information dissemination mechanisms. Experience with the technology and social capital constitute the informal mechanisms of information diffusion. Knowledge accumulation involves the acquisition of information about the problem as well as information on the management practices themselves. Hence it has a direct and indirect effect on the use of improved banana production management technology.

Once the problem is perceived and information is acquired, the decision maker decides whether or not to use the management practice and the extent to which it should be used. Although presented in linear form, the process may be non-linear. Perception of the problem may stimulate a search for more information and a decision to use the practice.

Variables cast on the right hand side of equation (30) are modelled to play separate roles in crop management decisions (Figure 4). Social capital influences households' decision to use the improved banana management practices indirectly by influencing knowledge accumulation and through its effect on household characteristics such as asset endowments. The improved banana management technology is resource-intensive and access to social resources such as bilateral transfers and information may influence its use.

The model also shows that social capital depends on factors that may influence the use of a technology directly or through other mechanisms, thus highlighting the complexity of the decision-making processes of agricultural households faced with imperfect market conditions. This means that ignoring the role of social capital may bias the direct effect of these factors on the use of banana management practices. While social capital indirectly influences a household's choice of banana management practices, it is also influenced by other household characteristics and community-level variables (Figure 4). Factors that influence household social capital were discussed in Chapter 4 and the topic will be further discussed in Chapter 8.

5.5. Concluding remarks

This chapter has demonstrated that social capital may influence the choice of a crop management technology through information acquisition and bilateral transfers. The choice of improved banana management practices is described within the framework of an agricultural household model with profit maximization and technology relevance uncertainties as special cases. Variables identified through different special cases and the general model are brought together in a summary and their interaction with the crop management decision-making process is illustrated using a schematic model.